*That Courage is not inconsistent with Caution**: Currency Hedging for Superannuation Funds

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* Epictetus, First century Stoic philosopher : The Discourses, Book ii, Chapter i.

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Abstract

Surveys of Australian superannuation funds verify that most international bond holdings, but not equity holdings, are hedged for currency risk. We compare the mean-variance efficiency of this practice with two alternative strategies: a conventional forward hedge; and a selective hedge triggered by the sign of the interest differential. These strategies produce optimal allocations which stochastically dominate the restricted portfolio according to Barrett-Donald (2003) tests. The advantages of alternative hedging strategies remain when the vector of sample mean returns is replaced by forecasts. Selective hedging works best for equities; conventional hedging for bonds. Adding unhedged bonds does not improve outcomes.

Keywords: currency hedging; superannuation; stochastic dominance

JEL Classifications: G11, G15, G23

I. Introduction

Over the past decade up to one fifth of Australian superannuation assets have been invested overseas, mainly as equities and fixed interest. Survey evidence shows that virtually all fixed interest holdings have been fully hedged against currency risk, but a large majority of equity holdings have been unhedged. By contrast, the theoretical and empirical literature on international finance has advocated controlling portfolio volatility by flexible approaches to currency hedging of both equities and bonds. This study evaluates the gains to loosening restrictions on currency hedging practices, assessing whether portfolios optimised over both hedged and unhedged asset classes would have produced significantly better outcomes for risk averse Australians holding superannuation assets. Specifically, we test whether adding hedged stocks and unhedged bonds to the choice set generates portfolios which stochastically dominate those derived under the default 'hedge-bonds-not-equities' restriction for the post-float period. Throughout the paper the analysis looks backward by using historical sample estimates of asset returns, and forwards using long-run return forecasts.

The paper contributes to the literature firstly by updating and extending the empirical evidence on currency hedging from the perspective of a balanced-fund Australian dollar (AUD) investor. In addition to the conventional rolling forward contract, we test a selective hedging rule in the spirit of Eaker and Grant (1990), Glen and Jorion (1993), and de Roon et. al. (2003), where hedge decisions depend on *ex ante* interest differentials. The selective hedging rule is more consistent with a random walk model of the exchange rate and has outperformed other strategies in earlier studies but has not, to our knowledge, been tested in the Australian case.

Secondly the analysis uses new tests for stochastic dominance (Barrett and Donald 2003) to compare the performance of the benchmark and alternative portfolios. Other more standard methods for testing diversification benefits, beginning with the work of Jobson and Korkie (1982), are based on unrestricted spanning conditions. Spanning tests are comprehensive but difficult to apply to the piece-wise linear frontiers emerging from the optimization process here. Further, the portfolio-by-portfolio comparison possible under stochastic dominance tests is a closer representation of the choices actually offered to members of Australian defined-contribution funds, who are typically limited to a few investment 'options'.

The main empirical results can be summarized as follows. The default hedge-bonds-not-stocks strategy used by many fund managers has not been optimal over the post-float period and is unlikely to be the best strategy in the future. A critical drawback is the exclusion of hedged equity classes. Results show that adding selectively hedged assets to the choice set would have significantly improved outcomes for investors on an *ex post* basis, with moderately risk averse investors gaining around 100 basis points each year. Selectively hedged equities also improved the forward-looking portfolios, but gains were smaller (at most 28 basis points) and equity hedging ratios lower. By contrast, excluding unhedged overseas fixed interest appears to have had no costs.

The remainder of the paper is set out in the following order. Section II reviews the international investment and hedging practice of Australian superannuation funds over the recent past. Section III briefly canvasses the theoretical and empirical studies related to currency hedging. Section IV describes the data, hedging rules and optimization set up. Portfolio allocations, efficient frontiers and certainty equivalent switching gains are outlined in Section V, and the Barrett-Donald tests for second degree stochastic dominance in Section VI. Section VII concludes.

II. International investment by Australian superannuation funds

One consequence of Australia's mandatory superannuation scheme has been a growth in offshore investment. This growth has two features: an increase in the proportion of superannuation funds invested overseas, and a rise in the number of Australians who have overseas assets in their portfolio. APRA (2003) reports that since 1995, the overseas assets share in total superannuation funds has expanded by 4 per cent to nearly 18 per cent. In addition, regulations mandating contributions from almost all employees, together with a prudential emphasis on diversification (APRA 2001), have ensured that the growth in total offshore investment has been accompanied by a widening *proportion* of the workforce holding internationally diversified portfolios. Unlike the United States, where many new defined contribution fund contributors are defaulted into cash or fixed interest options, Australian contributors usually default to 'balanced' investment options. Balanced funds typically incorporate cash, fixed interest, equities and property, and give 25-30 per cent weight to international assets (Battellino 2002). Hence we have a simultaneously wider and more intense focus on internationally diversified portfolios.

(i) Currency risk in internationally diversified portfolios

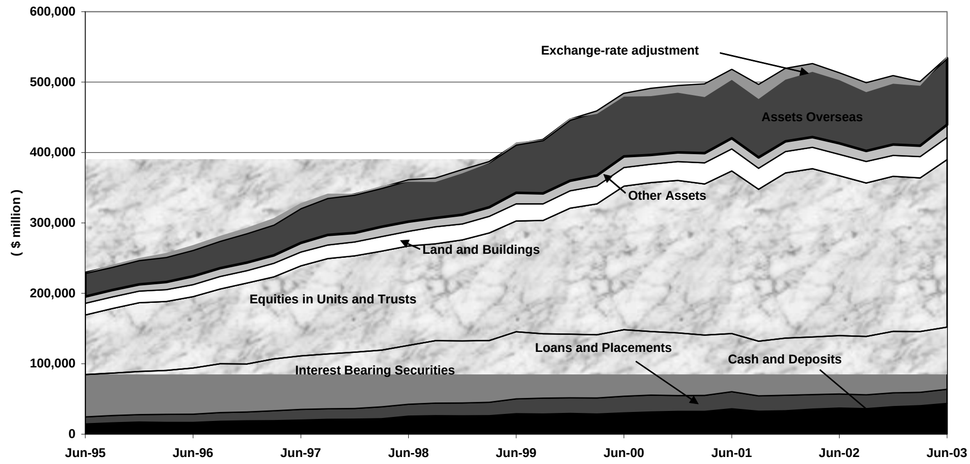
With the move to more international diversification comes greater concern about currency risk. Domestic investors plan to use their wealth to fund streams of real, AUD-denominated, consumption. It follows that the benefits of international diversification for any individual will depend on how his or her portfolio and consumption bundle interact with the path of the exchange rate. The contribution of the exchange rate to portfolio return and variance depends not only on the absolute size of the expected return and variance of the exchange rate, but also on the relative size of offshore allocations and the sign and size of covariance with the remainder of the portfolio.[1] In a portfolio with a low allocation to international assets, the net contribution of currency

[1] As offshore weighting increases, and as covariance between the exchange rate and other assets rises above zero, the exchange rate will add to portfolio variance. Consider an AUD investor holding US equity assets; the mean real return to the AUD/USD exchange rate over the post-float period was less than 50 basis points annualised, with a variance of 9 per cent. The local market variance of US equities over this period was nearly 16 per cent, so if underlying local market returns and the exchange rate were uncorrelated, the AUD return on US equities would be 25 per cent. However a negative covariance in this instance ensured that the net contribution of exchange rate volatility to the variance of the AUD return (17.5%) to US equities was less than 2 per cent.

risk to variance may be trivially small, but as offshore weightings increase, the potential impact of exchange rate risk grows.

An estimate of the contribution of currencies to the *level* of overseas assets in superannuation funds since 1995 is illustrated in **Figure 1**. Holding country weights fixed, and assuming a full exposure to exchange rate variation, the lighter shaded section of **Assets Overseas** measures the exchange rate contribution. A number of features are worth comment. Firstly, an unhedged position would have produced a net depreciation of 2.4 per cent over these eight years, via periods of strength (1995-1998) and weakness (1999-2002), suggesting both a long-term tendency to mean reversion and periods of serial correlation in the AUD. Such patterns are also noted by Cassie (2001), and Cashin and McDermott (2003). Secondly, total exchange rate exposure is possibly as large as, and more volatile than, some of the smaller asset classes so its role in portfolio performance is worth analyzing.

Figure 1: Estimated impact of exchange rate changes on superannuation funds 1995-2003.



Notes: Superannuation funds by asset class. Adjustment to Assets Overseas was based on allocations of 55% USD, 25% Euros (Deutschmarks), 10% Pounds and 10% Yen. These weights were used to derive a geometrically-weighted exchange rate index analogous to TWI, with June 1995=100, then to deflate the level of Assets Overseas. The calculations assume that all overseas assets are unhedged. Data sources: APRA Superannuation Trends, June 2003; Reserve Bank of Australia Bulletin Database, various.

(ii) Hedging currency risk

Investors control currency risk through various forms of hedging, most commonly short-dated forward foreign exchange contracts and cross-currency interest rate swaps (Muysken and Burt 2000 and Reserve Bank of Australia 2002). A forward exchange rate contract ties the one-period-ahead value of the foreign asset to the domestic-foreign interest differential via covered interest parity, so that the domestic investor receives a hedged return close to the local market return on the underlying asset plus the interest differential.

Whether a hedged or unhedged portfolio offers better return and risk characteristics depends on an array of empirical features. If the forward exchange rate is an unbiased predictor of the future spot rate, then expected *returns* for the two portfolios converge. There is, however, substantial empirical evidence against forward rate unbiasedness at least in the short run, and in that case returns may diverge. (See, among others, Engel 1996, Meredith and Chinn 1998, Wang and Jones 2002, and for Australia, Bhar, Chiarella and Pham 2003.) Portfolio *risk* depends on the size and sign of covariance relationships. Only if the covariances between the domestic and foreign assets and the exchange rate are positive will the volatility of the unhedged portfolio unambiguously exceed the hedged portfolio. So while it is reasonable to conclude that hedging will probably reduce portfolio risk without loss of return, the question ultimately depends on returns distributions and allocation weights.

Australian funds managers have almost universally hedged offshore fixed interest holdings, and maintained full currency exposure in equity holdings. An ABS survey of currency hedging by private sector investors reported that in 2001, 77 per cent of the value of aggregate foreign debt was hedged, compared with 12 per cent of the value of equities.[2] Furthermore, survey respondents confirmed that most hedging was designed to control the volatility of diversified fixed interest portfolios, whereas exposure of equity to currency risk was 'part of the rationale for the investment decision' (Reserve Bank 2002). Hence fixed interest portfolios have been typically marketed as 'conservative', and portfolios of international stocks as 'growth', with parallel approaches to currency risk.

In addition, surveys of fund managers' attitudes (VanEyk 2001, Dunstan 2001) remark on the fact that hedging international equities also creates a business or 'peer' risk. In particular, consider the conventional benchmark for international equity managers, the MSCI World Index

[2]Of the approximately 30 per cent of balanced funds invested internationally, the median equity holding is 24 per cent and bond share is 5 per cent (Battellino 2002).

(ex Australia) in Australian dollars. Currency hedging creates an asymmetric risk for managers tracking this (unhedged) benchmark, since *hedging* a depreciating AUD will be penalized, but *failing to hedge* an appreciation will not. And the reverse applies to bonds, since most fixed interest funds are benchmarked to the Citigroup World Government Bond Index[3] *hedged* into AUD.

It is safe to assume that in general, hedged bonds and unhedged equity represented the portfolio choice set of superannuation investors over the past two decades.

The default strategy of Australian fund managers is not necessarily at odds with the theoretical and empirical literature on currency risk hedging, but would amount to a knife-edge case. On one hand, the theoretically optimal default position is the 'world market portfolio partially hedged' (Solnik 1998). On the other hand, the empirical problem is to determine what this means with any precision. International theoretical and empirical evidence on currency hedging is briefly surveyed in the next section.

III. Literature review

By assuming that the stochastic properties of asset returns are clearly defined, finance theory sets out finely-tuned, optimal allocation solutions for internationally diversified investors. Attempts to apply these models empirically, however, are often clouded by parameter uncertainty. Much of the applied literature has therefore focussed on the problem of finding robust, rather than theoretically ideal, portfolio strategies, usually via some revision to the input vector of expected returns. In this section we briefly review the theory on optimal currency hedging as it has developed from Markowitz (1959) and Merton (1969, 1971), and summarize the problems of applying the models in the presence of parameter uncertainty.

[3] Previously the Salomon World Government Bond Index - hedged AUD.

(i) Currency hedging in the canonical portfolio allocation model

The canonical portfolio allocation model is due to Adler and Dumas (1983). Following their analysis and also Stulz (1994), consider an investor whose problem is to maximize expected utility with arguments nominal consumption, the price level and time, and where the absence of money illusion implies that utility is homogeneous of degree zero in consumption and prices. The controls are consumption (C) and the (Nx1) risky asset weights, $\mathbf{w}$. All values are expressed in terms of the home currency. The objective is:

$$\max E \int_t^T V(C, P, s) ds \tag{1}$$

All income is derived from asset returns. The investor can choose from $N(= n + L)$ risky and one risk-free asset, of which n are domestic and international stocks and L are nominal bank deposits or bills denominated in foreign currencies. The $(L + 1)$st asset is the risk-free asset in the (numeraire) home currency of the investor. Risky asset returns, $\frac{dY}{Y}$, are described by conventional geometric Brownian motion:

$$\frac{d\mathbf{Y}}{\mathbf{Y}} = \boldsymbol{\mu} dt + \boldsymbol{\sigma} d\mathbf{z} \tag{2}$$

where

$\boldsymbol{\mu}$ = Nx1 vector of nominal drift parameters (including capital gains and dividends)

$\boldsymbol{\sigma}$ = Nxm matrix of diffusion parameters

$d\mathbf{z}$ = is an m dimensional Brownian motion

The risk free asset is described by:

$$\frac{dB}{B} = rdt \tag{3}$$

The price index (which is assumed to perfectly represent the agent's consumption bundle) is also a stationary stochastic process:

$$\frac{dP}{P} = \pi dt + \sigma_\pi d\mathbf{z} \tag{4}$$

where π and $\boldsymbol{\sigma}_\pi$ are the drift and diffusion of the rate of inflation.

Combining these gives a nominal wealth process:

$$dW = [W(\mathbf{w}'(\boldsymbol{\mu} - \mathbf{r}) + r) - C]dt + W\mathbf{w}'\boldsymbol{\sigma} d\mathbf{z} \tag{5}$$

where $\mathbf{r}$ is an Nx1 vector.

Solving this problem for optimal allocation weights gives a portfolio comprised of the classical myopic and hedge components. (Refer to Appendix 1 for derivation.)

$$\mathbf{w} = \frac{1}{\lambda}(\boldsymbol{\sigma}\boldsymbol{\sigma}')^{-1}(\boldsymbol{\mu} - \mathbf{r}) + \left(1 - \frac{1}{\lambda}\right)(\boldsymbol{\sigma}\boldsymbol{\sigma}')^{-1}\boldsymbol{\sigma}\boldsymbol{\sigma}'_\pi \tag{6}$$

Note that $\boldsymbol{\sigma}\boldsymbol{\sigma}'$ is the (NxN) covariance matrix of risky asset returns and $\boldsymbol{\sigma}\boldsymbol{\sigma}'_\pi$ is the (Nx1) vector of covariances of the risky assets with the investor's inflation rate. When the investor has relative risk aversion $\lambda = 1$ (log utility) the optimal weights reduce to the myopic allocation, $\mathbf{w} = (\boldsymbol{\sigma}\boldsymbol{\sigma}')^{-1}(\boldsymbol{\mu} - \mathbf{r})$. By contrast, where $\lambda \to \infty$, the minimum variance portfolio is optimal, which in this set-up is the vector of regression coefficients of the rate of inflation on risky asset returns, $(\boldsymbol{\sigma}\boldsymbol{\sigma}')^{-1}\boldsymbol{\sigma}\boldsymbol{\sigma}'_\pi$. Between these extremes, investors hold a risk-tolerance-weighted combination of the myopic and inflation-hedge portfolios.

Under a full investment constraint, agents will also hold an allocation in their own risk-free bond such that the $N+1$ vector of weights is:

$$\begin{pmatrix} \mathbf{w} \\ \\ 1-\mathbf{1}'\mathbf{w} \end{pmatrix} = \frac{1}{\lambda} \begin{pmatrix} (\boldsymbol{\sigma}\boldsymbol{\sigma}')^{-1}(\boldsymbol{\mu}-\mathbf{r}) \\ \\ 1-\mathbf{1}'(\boldsymbol{\sigma}\boldsymbol{\sigma}')^{-1}(\boldsymbol{\mu}-\mathbf{r}) \end{pmatrix} + \left(1-\frac{1}{\lambda}\right) \begin{pmatrix} (\boldsymbol{\sigma}\boldsymbol{\sigma}')^{-1}\boldsymbol{\sigma}\boldsymbol{\sigma}'_{\pi} \\ \\ 1-\mathbf{1}'(\boldsymbol{\sigma}\boldsymbol{\sigma}')^{-1}\boldsymbol{\sigma}\boldsymbol{\sigma}'_{\pi} \end{pmatrix} \tag{7}$$

There are two components to the optimal currency hedge in (7). The first component is the set of long or short positions in foreign bills (the relevant L elements of vector $\mathbf{w}$), comprising part of the log portfolio, where the hedge ratio is defined as minus the weight of currency i to stock i. These are functions of the excess return to currency i, and covariance with all other risky assets. The second component are adjustments to the log portfolio designed to favour any assets offering inflation protection. Equation (7) shows that a zero/one approach to currency hedging is unlikely to be theoretically or empirically optimal. On the contrary, the optimal hedge is most probably not an extreme, and will vary with an agent's domicile and risk tolerance.

The portfolio in equation (7) clarifies the views of several authors. In Solnik's (1974) IAPM, domestic inflation is non-stochastic or is independent of $\boldsymbol{\sigma}$, so that the covariance between the risky assets and inflation is zero. In this instance each agent holds $\frac{1}{\lambda}W$ in the log portfolio and $\left(1-\frac{1}{\lambda}\right)W$ in the domestic bill, and the currency hedge ratios are simply ratios of log portfolio weights. The universal hedge ratio formulated by Black (1990a, 1990b) can be seen as a cross-country aggregation of equation (7). If bills are held in zero net supply across the world, and all investors have the same homothetic utility function, then in equilibrium, investors will hold currency hedges in the ratio $\left(1-\frac{1}{\lambda}\right)$. Black's (1990a) estimate of this ratio (around 75-80 per cent), however, depends on a number of general assumptions, including the contention that returns to holding currency are non-zero by virtue of Siegel's paradox (Siegel 1972). Perold and Schulman (1990) argued for unitary hedge ratios. Their famous 'free lunch' proposition was founded on the view that foreign currency exposure introduced unpriced risk to portfolios by adding volatility for zero return. But unitary hedges are unlikely to be optimal in a model with many risky assets.

A position at the opposite extreme was advocated by Froot (1993). He maintained that the impact of purchasing power parity (PPP) on exchange rates meant that the best protection for long-run real purchasing power was achieved by not hedging. Froot argued that the 'free-lunch' exists only if real exchange rates follow a random walk. On the other hand, if real exchange rates and/or asset prices follow a mean-reversion process (the model above assumes stationary processes), then horizon effects become important in portfolio choice (Samuelson 1991,[4] and recently, Campbell, Viceira and White 2002). A critical drawback of Froot's approach is the weak empirical evidence for PPP. Most early tests of PPP convergence found that the exchange rate is indistinguishable from a Martingale, and while some studies offer support for the proposition over a 4-5 year horizon (Rogoff 1996), Cashin and McDermott (2003) put the half-life of deviations from PPP for Australia between 8 and 13 years. (Confidence interval upper bounds were infinite.) Convergence to PPP may only exist in the very long run so currency hedging can still reduce portfolio volatility out to a medium-term as long as 15 years. Whenever domestic purchasing power is stochastic and real exchange rates deviate from PPP, short-horizon currency hedging can add value.

(ii) Empirical analysis

Many empirical studies have made a *prima facie* case for currency hedging, but demonstrating that the evidence is robust has proven more difficult. Conventional mean-variance analysis is used as a myopic, discrete-time approximation to the model described above. This method generates precisely-weighted portfolios but relies on estimates of unknown expected returns and

[4] Samuelson showed that agents will hold larger allocations to risky assets whose returns show mean reversion but asset processes which exhibit momentum will be given less weight.

covariances. Sample means of asset returns are poorly estimated; parameter uncertainty has greatly reduced the empirical power of the theoretical model.

Empirical studies over the past few decades have mainly supported currency hedging of international portfolios, subject to some qualifications. Firstly unitary and zero hedging are usually dominated by partial hedging strategies (Adler and Dumas 1983, Solnik 1998). Secondly fixed interest portfolios benefit more from hedging than equity portfolios, because of the greater contribution of exchange rate volatility to the overall volatility of the asset (Jorion 1989). Thirdly portfolios with low total allocations to international assets may find hedging-related improvements are not worth the ongoing costs (Jorion 1989). Fourthly optimal hedging strategies perform better out of sample when optimization methods acknowledge parameter uncertainty (Jorion 1985, Eun and Resnick 1988, 1997). Fifthly the sub-optimality of currency overlay approaches and other two-step optimization procedures, easy to demonstrate theoretically (Grinold and Meese 2000), is also supported empirically (Glen and Jorion 1993), but may not mean that overlays are useless (Jorion 1994). Sixthly selective hedging rules which acknowledge the superiority of the random walk model of the exchange rate do better than unconditional hedging (Glen and Jorion 1993, Eun and Resnick 1997, Morey and Simpson 2001), and finally, more complex return processes do not necessarily negate the advantages of currency hedging (Ang and Bekaert 2002). From the perspective of an AUD investor, Beggs, Brooks and Lee (1989) and Izan, Jalleh and Ong (1991) confirm the advantages of hedged equity and bond portfolios subject to (at least the first four of) these caveats.

Estimation risk clouds the results of many empirical studies. In particular, the sample means that are used to approximate unobserved expected returns are measured with a low precision. At the same time, the finely-tuned optimisation process is sensitive to small changes in the input parameters and will amplify measurement errors (Michaud 1989), frequently generating implausibly large long and short positions, or corner solutions where asset classes are given zero weights. Consequently calculations of optimal hedging strategies are not immune to estimation risk. Using bootstrap techniques to derive the empirical distribution of the optimal hedge ratio in a variety of portfolios, Gardner and Stone (1995) demonstrate that confidence bands around the optimal hedge can be so large as to render the number useless for practical purposes (i.e., they encompass zero and one).

Parameter uncertainty has motivated the use of *ad hoc* constraints on the allocation pattern (such as equally-weighted portfolios) or Bayesian adjustment of the means and/or covariances according to a plausible prior. (See Jorion 1985, 1986 for the Bayes-Stein shrinkage estimator, and Black and Litterman 1991, Connor 1997, Pastor 2000 and Qian and Gorman 2001 for methods based on market equilibrium priors.) Almost any technique which flattens the mean vector toward a common value, or forces portfolio weights away from the extremes tends to reduce the impact of estimation risk.

To summarize, theory proposes that risk averse agents who are internationally diversified will be better off if they can simultaneously choose holdings of foreign currency to improve the risk/return profile of their portfolios. Most empirical evidence favours at least partial hedging of stock and bond portfolios, though there is no *a priori* reason to expect a specific hedging ratio. Neither is there any evidence, theoretical or empirical, for the default 'hedge-bonds-not-stocks' position of the majority of Australian funds managers. However the presence of estimation error makes discerning significant portfolio improvements difficult, and calls for scrutiny of the vector of expected returns. The remainder of this paper evaluates whether Australian investors would have been better-off if the asset choice set available to them over the post-float period had been widened to include conventionally and selectively hedged bonds and equities. Section IV outlines the data and methodology.

IV. Portfolio construction

We are interested in the question of currency hedging from the perspective of a member of a balanced defined contribution fund. Balanced funds typically include domestic and international fixed interest and equities, cash and property. In the interest of clarity, and on the basis of data availability, the asset classes are limited to fixed interest, equities and cash. Further, the majority of assets overseas for Australian managed funds are sourced in the United States so we consider fixed interest and equity returns from that country only.[5]

(i) Data

Data sources and transformations are explained in detail in Appendix 2. All observations are end-month, and the sample runs from April 1983 to June 2003. Bond and equity returns are proxied by returns indexes which assume all coupons/dividends are reinvested. Cash returns are the 30-day Bank-Accepted Bill yields. All returns are calculated in real terms, using the change in the current-period Private Consumption deflator, linearly interpolated from the quarterly observations. This amounts to an assumption that domestic inflation is known with certainty each period. In addition to these five asset classes, the portfolio is augmented by four hedged assets.

(ii) Hedging

As noted above, returns to a conventionally hedged fixed interest or equity portfolio under covered interest parity are well approximated by the underlying local market return plus the domestic-foreign interest differential. *Conventional* hedged asset returns used in this analysis are calculated as the sum of the annualised monthly local return to the underlying US stock or

[5] To the extent that currencies from Europe, UK, Japan and Asia may provide cross-currency hedging, then excluding these smaller contributors could bias outcomes.

bond index and the Australia-US 30-day interest differential, less domestic inflation. As flagged earlier, we also test a *selective* hedging rule that is conditional on the sign of the domestic-foreign interest differential. Selective hedging is motivated by the evidence that the forward rate is not an unbiased predictor of the future spot rate (Engel 1996). In fact it is generally *negatively* related to the change predicted by the interest differential (the forward discount) at short horizons.[6] A negative covariance indicates that forward discounts are associated with appreciating spot rates. Persistent prediction errors in the forward rate can be exploited in a selective rule: hedge when the AUD is selling at a discount (positive interest differential) and do not hedge when it is at a premium (negative interest differential). The selective hedge returns for US equity and bond series was calculated by 'hedging' only when the domestic-foreign interest differential was positive.

Both conventional and selective hedge returns are adjusted for costs by deducting 20 basis points (annualized) from returns each period.

(iii) Model inputs

This leaves us with nine asset classes: Australian bonds, equities and cash, and unhedged, conventionally hedged and selectively hedged US bonds and equities. Annualised summary statistics are reported in **Table 1**. Note that *ex post* optimization results reported below use sample means and covariances as inputs. Historical sample means reported in Table 1 are estimated with low precision, and results from *ex post* experiments may not be reliable indicators of future performance for the reasons canvassed in Section III.

Alongside *ex post* allocations we derive a set of optimizations using the historical covariance matrix and a vector of estimated long-run equilibrium returns, consistent with forecasts of equity

[6] When the interest differential is positive, the AUD is expected to depreciate (sells at a discount), and when the interest rate is negative the forward rate is predicting an appreciation (sells at a premium).

premiums (Campbell 2001, 2002) and uncovered interest parity (UIP)(Meredith and Chinn 2003). The real return (before hedging costs) to domestic and foreign equities is set at 7 per cent p.a., bonds at 4.0 per cent, and cash at 1.0 per cent.[7] Flattening the returns vector moderates allocations and potentially reduces estimation risk.

Table 1: Fixed long-run returns and sample summary statistics

per cent p.a., 1983:4-2003:6

	Fixed Mean	**Sample Mean**	**Std. Dev.**
US Bonds	4.0	5.9	12.4
- selective hedge	3.8	9.3	6.8
- conventional hedge	3.8	7.6	5.4
US Equities	7.0	9.6	17.4
- selective hedge	6.8	13.0	15.7
- conventional hedge	6.8	11.2	16.0
AUS Cash	1.0	4.8	0.9
AUS Bonds	4.0	6.0	5.4
AUS Equities	7.0	9.6	19.2

[7] Imposing long-run equilibrium conditions on the returns vector alters allocations more radically than using Bayesian shrinkage which maintains the ranking of sample means while flattening towards the grand mean.

Correlation	**US**	**hedged**		**US**	**hedged**		**AUS**	**AUS**	**AUS**
	Bonds	**selec.**	**conv.**	**Equity**	**selec.**	**conv.**	**Cash**	**Bonds**	**Equity**
US Bonds	1	0.619	0.518	0.465	-0.003	-0.093	0.007	0.014	-0.300
- selec. hedge		1	0.799	0.213	0.183	0.024	0.035	0.210	-0.142
- conv. hedge			1	0.210	0.172	0.167	0.135	0.334	-0.104
US Equities				1	0.832	0.801	0.048	0.096	0.314
- selec. hedge					1	0.967	0.062	0.186	0.520
- conv. hedge						1	0.092	0.207	0.538
AUS Cash							1	0.039	0.003
AUS Bonds								1	0.367
AUS Equity									1

Table 1 shows that both methods of currency hedging lower the standard deviations and raise the returns to US fixed interest and equities in real AUD terms, but selective hedging generates higher return/risk ratios than conventional hedging. Notice also that *any* hedging raises correlations between portfolio assets, indicating that currency risk is at least partly diversifiable. Nonetheless the correlation matrix points to benefits from diversifying offshore and to currency hedging.

(iv) Model

Mean-variance analysis acts as a myopic, discrete time analogue to the portfolio problem set out in equations (1-5). It is consistent with utility maximization if preferences are quadratic, or if returns are elliptically distributed (Ingersoll 1987). Moreover, the single period horizon is optimal over multiple horizons when agents have log utility or where returns distributions are independent and identically distributed (iid). Where these assumptions do not hold exactly, mean-variance optimization can be a local approximation with more or less costly errors.[8]

The problem is to choose portfolio weights to minimize variance for any given level of return, subject to full investment and short-selling constraints.[9]

$$\min \frac{1}{2} \sum_{i,j}^{N} \sigma_{ij} w_i w_j \tag{8}$$

subject to:

$$\begin{aligned} \sum_{i}^{N} E(r_i) w_i &= E(r_p) \qquad (9) \\ \sum_{i}^{N} w_i &= 1 \\ w_i &\geq 0, \text{ for all } i = 1, 2, \ ..., n. \end{aligned}$$

Solving this problem over a range of values for $E(r_p)$ generates efficient frontiers that are piecewise linear (Markowitz 1959). Assets for which the non-negativity conditions are binding are given zero weights, but may move from 'out' to 'in' as the return constraint is varied. If the choice set includes both hedged and unhedged foreign bonds, for example, the optimal hedge ratio for any piecewise section of the frontier is equal to the proportion of hedged to unhedged bonds. Speculative hedging is ruled out, however, since the ratio is bounded between zero and one.

Our aim is to test whether the default 'hedge-bonds-not-stocks' rule of Australian fund managers was significantly costly to investors over the post-float period. To do this we conduct a series of comparisons between a *benchmark* portfolio and four more or less restricted choice sets. The benchmark portfolio (**B**) is optimi

zed over conventionally hedged US bonds but unhedged equities, mimicking the default choice

[8] See Ang and Bekaert (2002) for discussion of the costs of myopia and iid strategies in the presence of regime switches.

[9] Superannuation regulations in Australia preclude borrowing except under restricted conditions. See CCH (2002) for relevant legislation.

set, but without restricting total offshore allocations. Four alternatives are evaluated: domestic only (**D**); benchmark plus conventionally hedged equities and unhedged bonds (**C**); and choice over all nine assets including the selective hedges (**A**). Optimal allocation weights and efficient frontiers are set out in Section V.

V. Gains to diversified portfolios

In this section, three methods of comparison are used to evaluate currency hedging: optimal allocations, efficient frontiers and certainty equivalents. Allocations based on the historical sample mean vector and the alternative long-run equilibrium fixed means are considered. In each case we are interested in the relative performance of the default rule, proxied by the benchmark portfolio (**B**), and alternative hedging rules (**C** and **A**).

(i) *Ex post* portfolio allocations

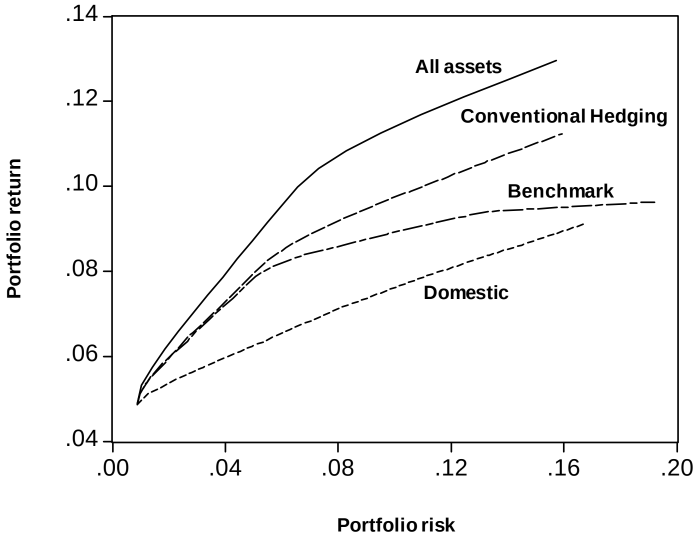
Ex post portfolio allocations for the Benchmark (**B**) and alternative choice sets (**C**, **A** and **D**) are shown in **Figures 3.1-3.4** in Appendix 3.[10] Three features are noteworthy. Firstly hedged assets are preferred to unhedged assets whenever the choice set includes them. Secondly selectively hedged assets are preferred to conventionally hedged and unhedged classes when the set is widened to **A**. The portfolio is optimally 'fully' hedged in both (**C**) and (**A**). Thirdly over moderate to low levels of risk aversion, total allocation offshore is higher than the 20 per cent we currently observe in Australian superannuation funds. Theoretical analysis has shown that a failure to consider hedging in portfolio choice sets can result in lower allocations offshore (Grinold and Meese 2000, Jorion 1994), but whether this has influenced Australian fund managers is still

[10] Risk aversion levels on the horizontal axes are consistent with negative exponential utility defined over returns to wealth, such that $U = 1 - e^{-\lambda r_p}$ and λ is the coefficient of risk aversion. If returns are normally distributed, expected utility can be written in the familiar certainty equivalent form $E(u) = E(r_p) - \sigma_p^2 \frac{\lambda}{2}$. With appropriate scaling, we can back out levels of risk aversions from the portfolio returns and standard deviations across an efficient frontier. If returns are not normally distributed, this is an approximation in the neighbourhood of r_p.

a matter of conjecture.[11] (See Battellino 2002 for an affirmative opinion.)

The *ex post* advantages of conventional and selective hedging are indicated by a leftward shift in efficient frontiers, as in **Figure 2**. An agent willing to tolerate a standard deviation of 12 per cent annually would have gained around 50 basis points by investing offshore according to the benchmark, around 100 basis points through adding conventionally hedged equities and another 100 basis points by selectively hedging. There are no gains to including unhedged bonds.

Figure 2: Ex post efficient frontiers for choice sets A-D.



Efficient frontiers for ex post optimal portfolios, domestic only D, benchmark, B, conventionally hedged, C, and selectively or conventionally hedged A.

(ii) Fixed return portfolio allocations

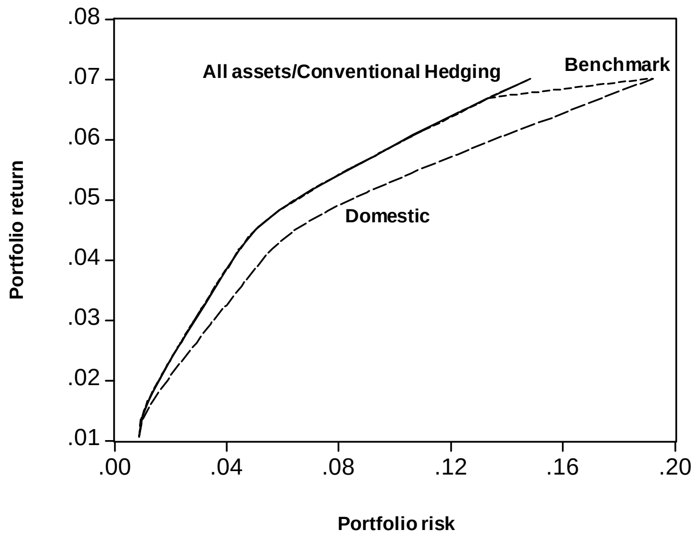
Discarding the historical sample mean in favour of the fixed forecasts changes the allocations markedly. **Figures 3.5-3.8** in Appendix 3 graph portfolio weights for the benchmark and alternative portfolios with long-run expected returns. Note that the lower equity premium, combined

[11] Home bias is a long-standing empirical puzzle. Lewis (1999) provides a survey.

with UIP, has increased allocations to bonds and allowed a higher weight to domestic assets. Hedged US equities play a relatively minor role, the optimizer preferring the slightly higher return available to the unhedged US and domestic equity assets. The hedge ratio for *selectively* hedged US equity (still the better equity hedging rule) is no higher than 20 per cent. By contrast, *conventionally* hedged US fixed interest is dominant. The gains to widening the asset choice set under these assumptions are much smaller.

Efficient frontiers for these optimizations are shown in **Figure 3** and confirm the indications of the allocation charts. Differences between portfolios **B**, **C**, and **A** are much smaller than the *ex post* results indicated.

Figure 3: Fixed return efficient frontiers for choice sets A-D



Efficient frontiers for fixed return optimal portfolios, domestic only D, benchmark, B, conventionally hedged, C, and selectively or conventionally hedged A.

(iii) Certainty equivalent payoffs

The difference between two certainty equivalents is the amount an agent would be prepared to pay each period to switch from one set of payoffs to another.[12] We select the optimal portfolio under choice sets **A-D** for investors with high ($\lambda = 10$), moderate ($\lambda = 5$) and low ($\lambda = 1$) risk aversion. We then calculate the portfolio return and variance for each portfolio, which gives a certainty equivalent for **A-D** using the standard expression:

$$E(u) = E(r_p) - \sigma_p^2 \frac{\lambda}{2} \tag{10}$$

This method isolates the amount the agent would be willing to pay to switch out of the default 'hedge-bonds-not-stocks' constraint toward an alternative choice set. **Table 2** reports switching gains for the *ex post* and fixed return optimizations.

Table 2: Switching gains, per cent p.a.

	Risk Aversion		
	Low	**Moderate**	**High**
Ex post **portfolios**	$\lambda = 1$	$\lambda = 5$	$\lambda = 10$
A - selective/conventional hedging	3.60	1.44	0.75
C- conventional/unhedged	1.52	0.42	0.09
D- domestic only	-1.24	-1.85	-1.40
Fixed return **portfolios**			
A - selective/conventional hedging	0.28	0.08	0.01
C- conventional/unhedged	0.11	0.00	0.00
D- domestic only	-1.1	-1.10	-0.60

[12] See Bollerslev and Zhang (2003) for a recent application of this technique to a related problem.

On an *ex post* basis, all risk averse investors would have been willing to pay for currency hedging of US equity portfolios over the sample period. An investor of moderate risk aversion for example, would have paid 1.44 per cent p.a. to include selectively hedged US bonds and equities, and around 40 basis points to have conventionally hedged US equities added to the choice set. (Remember that all hedged returns are already discounted by 20 basis points to allow for costs.) The more risk tolerant investor would have paid up to 3.6 per cent per year for selective hedging. However the forward-looking fixed return portfolios are little different from the benchmark and gains to choosing from asset set **A** are at most 28 basis points. Finally it is worth noting that benefits from international diversification of about one per cent p.a. are evident for both sets of portfolios.

VII. Barrett-Donald tests

Next we adapt tests for second-degree stochastic dominance [SD2], developed by Barrett and Donald (2003) [B-D], to compare the in-sample performance of the benchmark and alternative asset choice sets under short-sales constraints. Our aim is to assess whether improvements measured by certainty equivalents are attributable to chance. The test is applied to the distributions of in-sample returns produced by each set of optimal portfolio weights at low, moderate and high levels of risk aversion. Demonstrating that returns to portfolios **A**, **C** or **D** dominate returns to the benchmark **B** is evidence of a significant improvement in investor welfare.

Standard tests for performance improvement developed by Jobson and Korkie (1982, 1989) and Huberman and Kandel (1987), are based on spanning conditions. A benchmark set of assets spans the space of additional assets if the returns on the new assets can be mimicked, up to an orthogonal error, by a linear combination of returns to the benchmark assets. Gibbons, Ross and Shanken (1989) showed that this was equivalent to an F test over maximal Sharpe ratios, or a Wald test in the less restricted GMM framework. (See also Bekaert and Urias 1996.) Testing for spanning relationships becomes more difficult in the presence of short-sales constraints since any test must account for the piece-wise nature of the efficient frontier. (See Glen and Jorion 1993 and de Roon et. al. 2001.)

Spanning conditions assume that investors can create unlimited linear combinations of asset sets to maximise efficiency. On one hand, the SD2 tests reported here are inferior to spanning tests since they compare only two specific distributions of portfolio returns. On the other hand they are a better representation of the choices offered to most superannuation investors, who are typically restricted to a few relatively fixed allocation 'options' rather than the infinite possibilities envisaged under spanning conditions.

Second degree stochastic dominance (SD2) sets out the conditions under which any risk averse agent prefers one risky asset (portfolio) to another. Specifically, following B-D[13], consider two samples of portfolio returns $\{Y_i\}_{i=1}^{M}$ and $\{X_i\}_{i=1}^{M}$with cumulative distributions (CDFs) G and F. Portfolio Y will be preferred to portfolio X by any agent whose utility over returns, $U(r)$, obeys $U'(r) \geq 0$, $U''(r) \leq 0$ when:

$$\int_o^r G(s)ds \leq \int_o^r F(s)ds \tag{11}$$

for all r. Note that B-D derive the test over support $[0, \bar{r}]$ where $\bar{r} < \infty$, but state that the results extend to the situation where the lower bound is a finite number. Clearly the returns distributions tested here are not bounded at zero. To make application of the test tractable, each *pairing* of returns distributions was shifted to the right by the same fixed positive amount, sufficient to ensure a lower bound of zero for r.

The null hypothesis to be tested is that G (weakly) dominates F to the second degree, against

[13]Income distributions rather than portfolio returns are the subject of Barrett and Donald (2003).

the alternative that it does not:

$$
\begin{aligned}
H_o &: \int_o^r G(s)ds \leq \int_o^r F(s)ds \;\; \text{for all} \;\; r \in [0, \bar{r}], \\
H_1 &: \int_o^r G(s)ds > \int_o^r F(s)ds \;\; \text{for some} \;\; r \in [0, \bar{r}].
\end{aligned} \tag{12}
$$

As B-D point out, the null hypothesis includes the case where G and F coincide at each value, a situation that can be identified by reversing the positions of the competing distributions in the hypotheses and retesting.

From random samples of equal size, the test statistic is given by:

$$
\hat{S}_2 = (\frac{M}{2})^{1/2} \sup_r [\mathcal{I}_2(r; \hat{G}_M) - \mathcal{I}_2(r; \hat{F}_M)], \tag{13}
$$

where:

$$
\begin{aligned}
\hat{F}_M(r) &= \frac{1}{M} \sum_{i=1}^{M} 1(X_i \leq r), \qquad \hat{G}_M(r) = \frac{1}{M} \sum_{i=1}^{M} 1(Y_i \leq r), \\
\mathcal{I}_2(r; \hat{G}_M) &= \frac{1}{M} \sum_{i=1}^{M} 1(Y_i \leq r)(r - Y_i),
\end{aligned}
$$

and $1(\cdot)$ is the indicator function, returning the value 1 when $(X_i \leq r)$ and zero otherwise. The sample estimate of $\hat{S}_2$ is then compared with a critical value generated by bootstrapping the original samples. A test-statistic distribution is constructed by drawing a random sample (with replacement) from X_i, to make an estimate of $\hat{F}^*_M(r)$ and drawing another random sample with replacement from Y_i, to construct $\hat{G}^*_M(r)$. Dependence is imposed by forcing the random draw to pick a matched pair (the same element) from the vectors of observed returns.[14] Then compute

[14]B-D assume independence but independence is improbable in this case since, to the extent that allocation weights coincide, the portfolio returns share common shocks.

$$\bar{S}_2^{F,G} = (\frac{M}{2})^{1/2} \sup_r [(\mathcal{I}_2(r; \hat{G}_M^*) - \mathcal{I}_2(r; \hat{G}_M)) - (\mathcal{I}_2(r; \hat{F}_M^*) - \mathcal{I}_2(r; \hat{F}_M))] \tag{14}$$

over multiple replications to build an empirical distribution and generate a 'p'-value for $\hat{S}_2$.[15]

The null hypothesis in the Barrett-Donald test is that distribution G dominates distribution F. Failure to reject this hypothesis is evidence for SD2 particularly if the reverse null is rejected. In the event that neither null can be rejected, the test is inconclusive. **Table 3** below sets out the results of testing SD2 of **A**, **C** and **D**, over the benchmark asset set, **B**, at the specified level of risk aversion. Results marked *, **, *** indicate *failure to reject* the null hypothesis that 'alternative dominates benchmark' and *rejection* of the 'benchmark dominates alternative' null hypothesis at the 10, 5, and 1 per cent significance level. A hyphen '-' indicates inconclusive results. When domestic portfolios **D** were tested against the benchmark, some results indicated that the benchmark unequivocally dominated the domestic portfolio. In these cases the significant results are marked by # symbols.

Table 3: Tests for second order stochastic dominance

[15] Gauss code for the B-D tests are available from the websites of the authors.

	Risk Aversion		
	Low	**Moderate**	**High**
Ex Post **Portfolios**	$\lambda = 1$	$\lambda = 5$	$\lambda = 10$
A - selective/conventional hedging	**	**	*
C- conventional/unhedged	-	-	-
D- domestic only	-	##	##
Fixed Mean **Portfolios**			
A - selective/conventional hedging	***	**	***
C- conventional/unhedged	*	-	-
D- domestic only	-	##	##

In line with earlier international studies, test results here confirm that a selective hedging rule based on the *ex ante* forward discount results in significantly better outcomes for risk averse investors (de Roon et. al. 2003). On the other hand, simply adding conventionally hedged equities to a portfolio would not have significantly improved outcomes over the post float period. Finally, at moderate levels of risk aversion, internationally diversified portfolios, even where equities are unhedged, are better than domestic-only holdings.

VII. Conclusions

International diversification has been offered to Australian superannuation investors with considerable fanfare over the past two decades, but the associated foreign exchange risk has sometimes been glossed over. In fact, surveys have verified that most fund managers have used a 'hedge-bonds-not-stocks' rule. We evaluate this practice by comparing the mean-variance efficiency of the rule with two alternative strategies: a conventional one-month-ahead forward exchange rate hedge over both bonds and stocks, and a selective hedge triggered by the sign of the *ex ante* interest differential. This work differs from previous Australian studies by offering choice over both conventional and selective hedging strategies and in mimicking the diversification problem of a balanced-fund member. Further, the analysis has both a forward and backward-looking perspective: the *ex post* effectiveness of currency hedging is assessed using historical sample mean returns, while the more uncertain future returns are proxied by imposed long-run forecasts. In addition, the perennial problems of parameter uncertainty are addressed by using Barrett-Donald (2003) tests of second order stochastic dominance to compare different portfolios.

Looking back, we find that selective hedging would have produced significant gains for most investors. In certainty equivalent terms, agents would have paid between 75 and 360 basis points p.a. to have international bonds and stocks hedged whenever the interest differential was positive. Gains to including conventionally hedged equities, however, were smaller and not statistically significant. Looking forward, the advantages to currency hedging were less clear-cut and different for stocks and bonds. The best strategy for bonds was a complete, conventional hedge, whereas selective hedging at a ratio below 20 per cent was better for stocks. On one hand, the improvements to welfare achieved by the forward-looking plan were apparently small, but on the other hand they represented a statistically significant gain. Introducing unhedged bonds to portfolios did not improve outcomes.

Overall results show that currency hedging can have dramatic effects on internationally diversified portfolios. Recent renewed interest in alternatives to 'hedge-bonds-not-stocks' among funds managers is justified.

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Appendix 1: Derivation of equation (6)

The following outlines the derivation of hedge ratios with stochastic inflation following Adler and Dumas (1983). Using the set-up in equations 1-5, by Bellman's equation the investor chooses

$$
\begin{aligned}
0 &\equiv \max_{C,\mathbf{w}}[V(C,P,t) + L^v J(P,W,t)] \qquad (1.1)\\
L^v J(P,W,t) &= \begin{pmatrix} J_P & J_W & J_t \end{pmatrix} \begin{pmatrix} P\pi \\ W(\mathbf{w}'(\boldsymbol{\mu}-\mathbf{r})+r)-C \\ 1 \end{pmatrix} \\
&\quad +\frac{1}{2}Tr\begin{pmatrix} P\boldsymbol{\sigma}_\pi' & W\boldsymbol{\sigma}'\mathbf{w} \end{pmatrix} \begin{pmatrix} J_{PP} & J_{PW} \\ J_{WP} & J_{WW} \end{pmatrix} \begin{pmatrix} P\boldsymbol{\sigma}_\pi \\ W\mathbf{w}'\boldsymbol{\sigma} \end{pmatrix} \\
&= J_P P\pi + J_W[W(\mathbf{w}'(\boldsymbol{\mu}-\mathbf{r})+r)-C] + J_t \\
&\quad +\frac{1}{2}J_{PP}\boldsymbol{\sigma}_\pi\boldsymbol{\sigma}_\pi' P^2 + J_{PW}WP\mathbf{w}'\boldsymbol{\sigma}\boldsymbol{\sigma}_\pi' + \frac{1}{2}W^2 J_{WW}\mathbf{w}'\boldsymbol{\sigma}\boldsymbol{\sigma}'\mathbf{w}.
\end{aligned}
$$

Homogeneity of degree zero of $V(\cdot)$ and Euler's theorem allows us to write:

$$
\begin{aligned}
J_P &\equiv -(\frac{W}{P})J_W && (1.2)\\
J_{PW} &\equiv -(\frac{1}{P})J_W - (\frac{W}{P})J_{WW} && (1.3)\\
J_{PP} &\equiv \frac{W}{P^2}[2J_W + WJ_{WW}] && (1.4)
\end{aligned}
$$

Using identities (1.2-1.4) and collecting terms gives:

$$
\begin{aligned}
0 &\equiv \max_{C,\mathbf{w}}\{V(C) + J_W[W(\mathbf{w}'(\boldsymbol{\mu} - \mathbf{r}) + r - \pi + \boldsymbol{\sigma}_\pi\boldsymbol{\sigma}'_\pi - \mathbf{w}'\boldsymbol{\sigma}\boldsymbol{\sigma}'_\pi) - C] + J_t \\
&+\frac{1}{2}W^2 J_{WW}[\boldsymbol{\sigma}_\pi\boldsymbol{\sigma}'_\pi - 2\mathbf{w}'\boldsymbol{\sigma}\boldsymbol{\sigma}'_\pi + \mathbf{w}'\boldsymbol{\sigma}\boldsymbol{\sigma}'\mathbf{w}]\} && (1.5)
\end{aligned}
$$

And first order conditions give the optimal portfolio weights:

$$
\begin{aligned}
0 &= J_W[(\boldsymbol{\mu} - \mathbf{r}) - \boldsymbol{\sigma}\boldsymbol{\sigma}'_\pi] - WJ_{WW}\boldsymbol{\sigma}\boldsymbol{\sigma}'_\pi + WJ_{WW}\boldsymbol{\sigma}\boldsymbol{\sigma}'\mathbf{w} \\
\mathbf{w} &= \frac{-1}{W}\frac{J_W}{J_{WW}}(\boldsymbol{\sigma}\boldsymbol{\sigma}')^{-1}[(\boldsymbol{\mu} - \mathbf{r}) - \boldsymbol{\sigma}\boldsymbol{\sigma}'_\pi] + (\boldsymbol{\sigma}\boldsymbol{\sigma}')^{-1}\boldsymbol{\sigma}\boldsymbol{\sigma}'_\pi. && (1.6)
\end{aligned}
$$

Define relative risk aversion:

$$
\lambda \equiv -W\frac{J_{WW}}{J_W}. \tag{1.7}
$$

Collecting terms gives a two-fund separation result:

$$
\mathbf{w} = \frac{1}{\lambda}(\boldsymbol{\sigma}\boldsymbol{\sigma}')^{-1}(\boldsymbol{\mu} - \mathbf{r}) + \left(1 - \frac{1}{\lambda}\right)(\boldsymbol{\sigma}\boldsymbol{\sigma}')^{-1}\boldsymbol{\sigma}\boldsymbol{\sigma}'_\pi. \tag{1.8}
$$

Appendix 2: Data

The data used are monthly from 1983:4 to 2003:6, at the last working day. Monthly returns are expressed as log changes $\mu = \ln(P_t/P_{t-1})$ and annualized as $\mu_y = 12\mu$. The standard deviation per month is estimated by $\sigma = \sqrt{\frac{1}{m-1}\sum_{i=1}^{m}(\mu_i - \bar{\mu})^2}$ where m is the number of observations. The annualized standard deviation is $\sigma_y = \sigma/\sqrt{1/12}$. Unhedged returns are $\mu_{AUD} = \mu_{USD} + s - \pi$, where s is the log change in the exchange rate and π is the log change in the price deflator (all annualised). Conventionally hedged returns are $\mu_{AUD,h} = \mu_{USD} + i_{AUS} - i_{US} - \pi$, where i indicates the 30-day risk-free rate. The selectively hedged series uses $\mu_{AUD,h}$ when $i_{AUS} - i_{US}$ is positive and μ_{AUD} when it is negative. There are a range of expenses associated with forward exchange rate hedging. These include the spot exchange rate spread, roll costs (i.e. the expense of changing the maturity of a forward contract from one date to another), the costs of maintaining a cash float for settlement, and the potential expense of liquidating part of the underlying asset position in the event that the cash float is exhausted. Reasonable estimates of hedging costs range from 15 to 25 basis points per annum (Muysken and Burt 2000, Dales and Meese 2003). To allow for these costs, an additional 20 basis points is deducted from the annualized return for every observation in both hedged series

Australian Equity: Datastream Total Market returns index for Australian in AUD, TOTMKAU(RI), covering 160 stocks.

US Equity: Datastream Total Market returns index for United States in USD, TOTMKUS(RI), covering 1000 stocks.

Australian Bonds: Datastream Tracker Index for Australia in AUD, TAUGVAL(RI). This series begins in 1987. Percentage changes prior to 1987 were calculated from the Commonwealth Bank All Maturities Bond Index, supplied by AMP Henderson.

US Bonds: Datastream Tracker Index for United States in USD, TUSGVAL(RI).

Australian Cash: 30 Bank-accepted Bill yield, Reserve Bank of Australia Bulletin Database.

US Cash: Datastream 30 day Bankers Acceptance mid-rate, USBA30D.

Exchange rate: Inverse of USD/AUD exchange rate from Reserve Bank of Australia Bulletin Database.

Price index: Private Consumption deflator, monthly series linearly interpolated from quarterly data in Eviews, Reserve Bank of Australia Bulletin Database.

Appendix 3: Optimal Portfolio Allocations

Figure 3.1: ***Ex post*** **(B)**

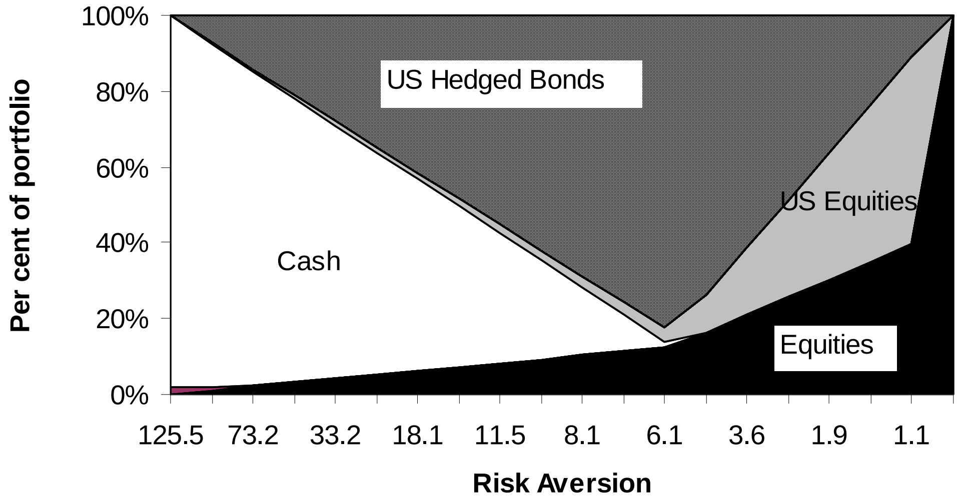

Figure 3.2: ***Ex post*** **(C)**

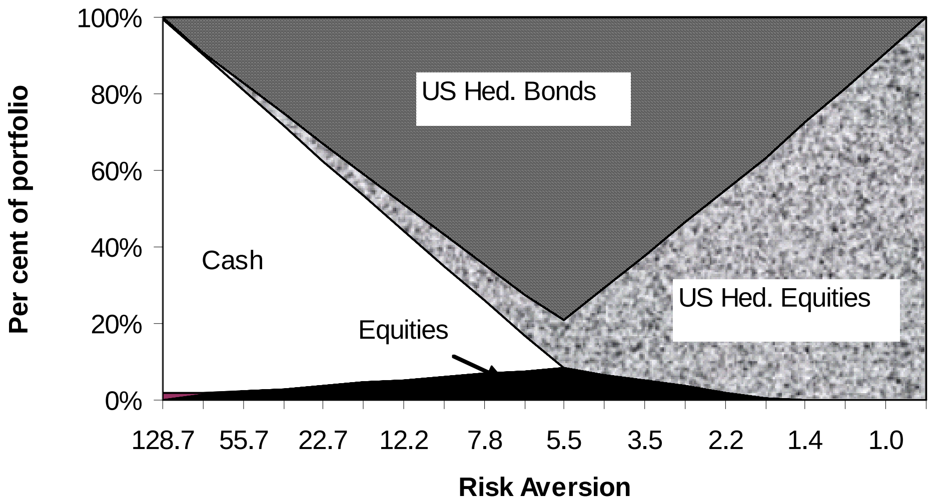

Figure 3.3: ***Ex post*** **(A)**

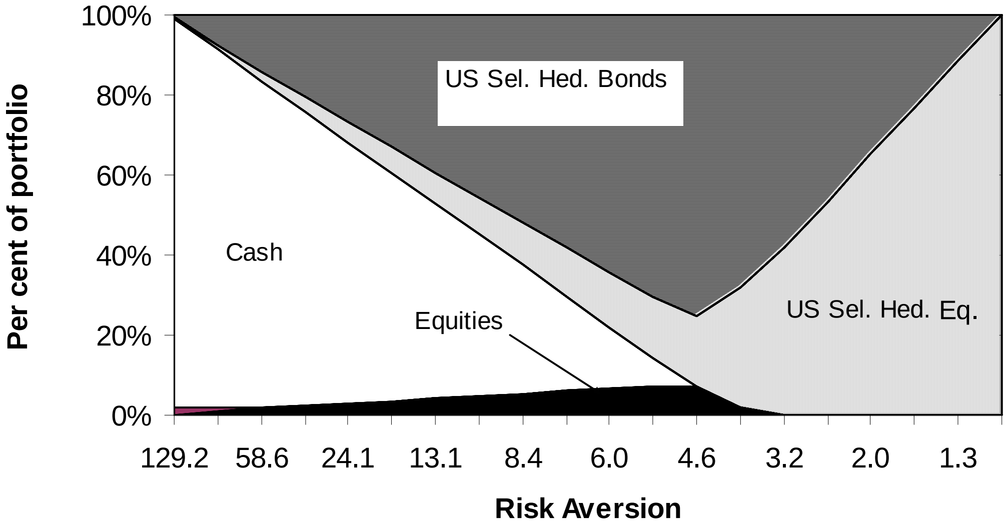

Figure 3.4: E*x post* **(D)**

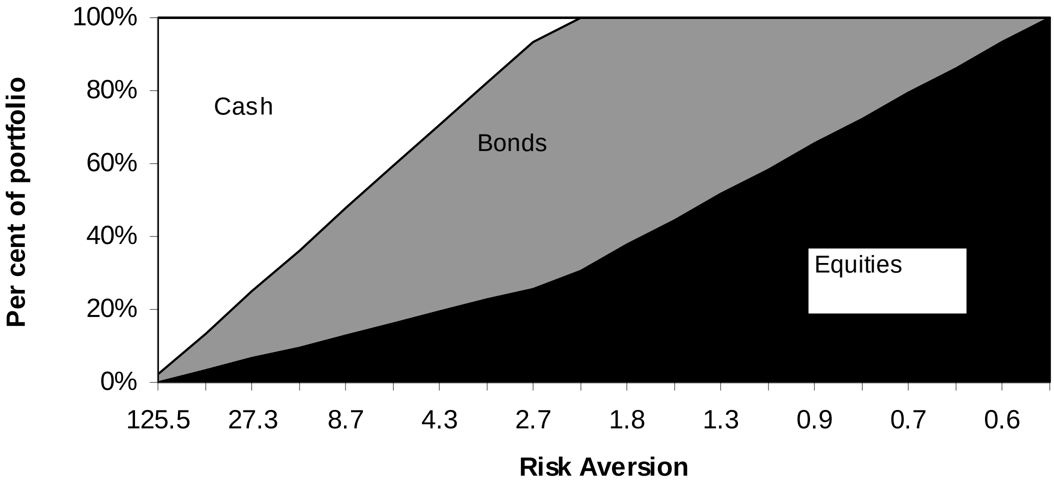

Figure 3.5: Fixed returns (B)

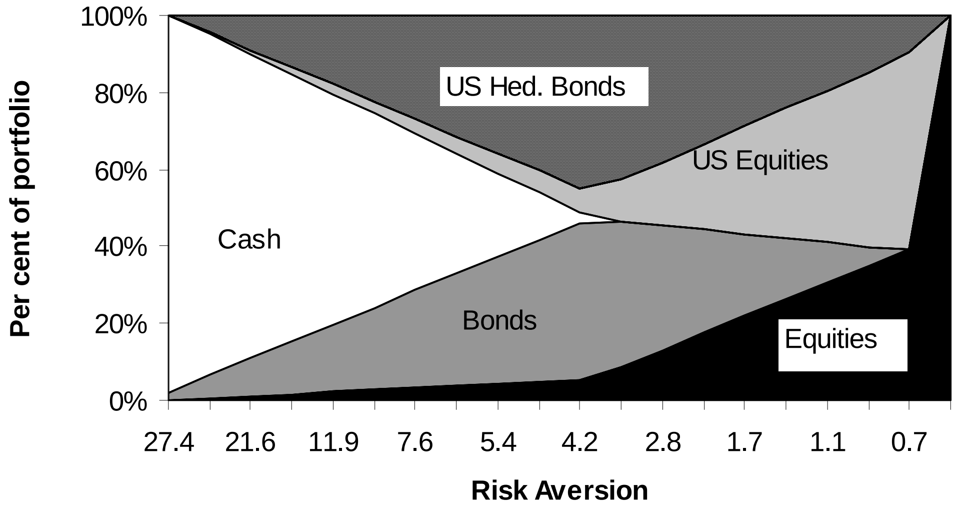

Figure 3.6: Fixed returns (C)

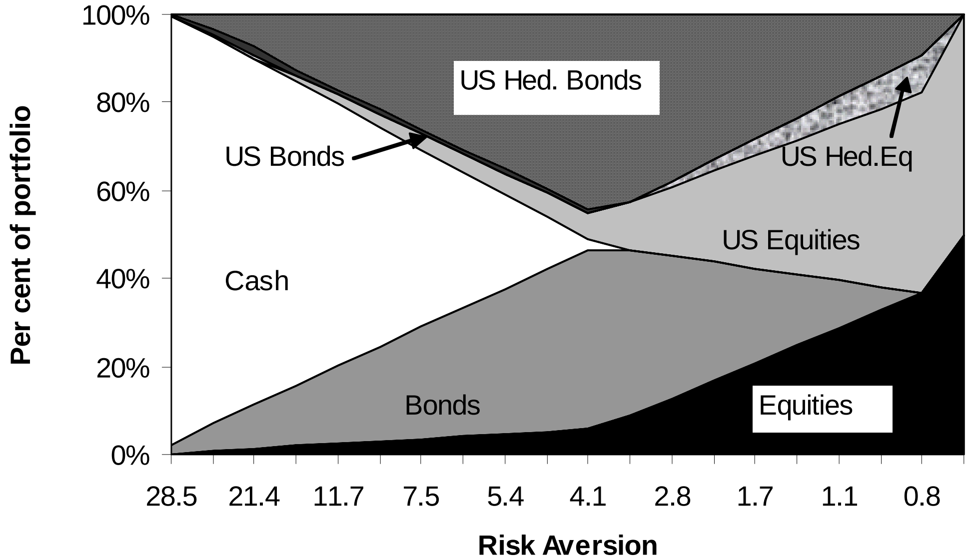

Figure 3.7: Fixed returns (A)

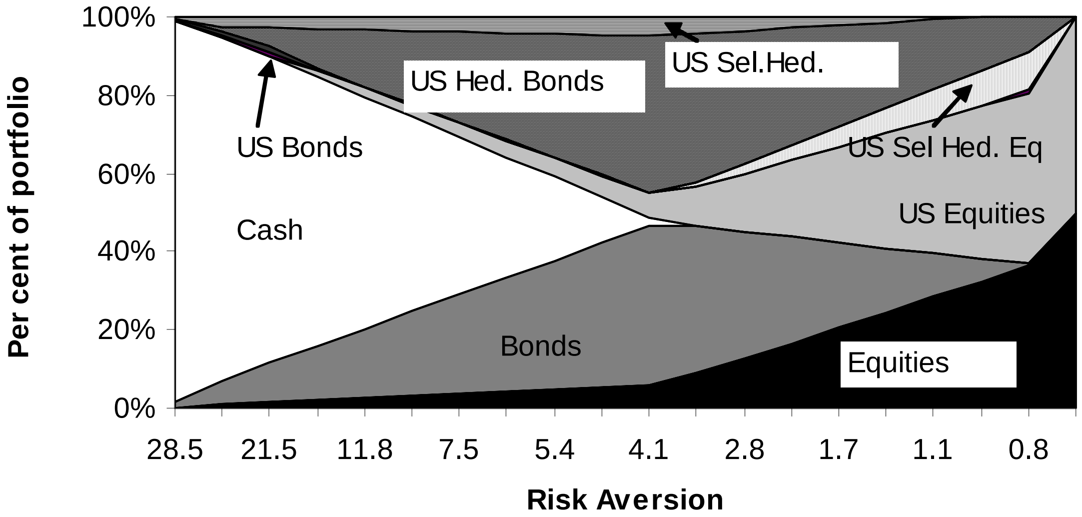

Figure 3.8: Fixed returns (D)