PRICEWATERHOUSECOOPERS

Gold Bullion and Superannuation Investment Policies

A review and analysis of the role that gold bullion could play in the investment policy of Australian superannuation funds

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1 Executive summary

This Report is an independent research Report that analyses the possible impact of the addition of gold bullion as a separate asset class within an investment portfolio. However this Report makes *no recommendations* as to whether gold bullion should be included within investment portfolios of Australian superannuation funds.

The Report has two major sections. The first reviews the historical evidence whilst the second uses a macro economic and investment simulation model and a gold return simulation model which produces a distribution of possible future outcomes.

As part of the historical review, it was concluded that:

- Gold bullion has characteristics in terms of risk and return that suggests it is very different from the traditional asset classes
- The correlation coefficients of the investment returns for gold bullion with all other asset classes are slightly negative or close to zero
- The introduction of gold bullion would have had different impacts for the 1992-97 and 1997-2002 periods. In the earlier period it would have reduced the return by about 0.1-0.2% pa for each 1% of gold bullion investment. However, for 1997-2002, the introduction of gold would have had virtually no impact on the investment return
- The introduction of gold bullion into the portfolio during the last 5 or 10 years would have reduced the volatility of the investment returns, as measured by the standard deviation of monthly returns
- Efficient investment portfolios, as measured by the efficient frontier, would have included exposure to gold bullion for the period 1997-2002. For the 10 year period to June 2002, some gold allocation would have been efficient if a reduced risk level was desired, together with the corresponding lower return.

A PricewaterhouseCoopers macro economic and investment simulation model, including a gold bullion module developed for this assignment, has been used to simulate the distribution of projected investment returns of Australian superannuation funds.

The simulations show that the introduction of gold bullion:

- Reduces the spread of possible investment returns as the probability of an extreme outcome is less likely
- Reduces the median return by 0.3-0.4% pa in most cases, where there is a 5% exposure to gold
- Requires an expected return from gold bullion of 6.5% pa to cause a portfolio including 5% gold bullion to have a preferred risk-return position when compared to the performance from other typical investment portfolios.

2 Introduction

This Report has been prepared for the Directors of Investor Resources Limited in line with our engagement letter of 17 September 2002. It may be used by Investor Resources Limited in discussions with third parties. However, it is stressed that PricewaterhouseCoopers Actuarial is *making no comments or recommendations* as to whether gold bullion should be included within investment portfolios.

This Report:

- analyses the historical relationships between the price of gold bullion (in Australian dollars) and the investment performance of the major asset classes (namely Australian equities, overseas equities, fixed interest, property and cash)
- develops the efficient frontiers for investors, using the last 5 and 10 years data
- develops a model that simulates returns from gold bullion prices, as expressed in Australian dollars
- integrates this gold pricing model into the PricewaterhouseCoopers macro economic and investment simulation model, which includes Australian and overseas equities, fixed interest, property and cash
- simulates a distribution of projected investment returns for a typical superannuation fund, including and excluding gold bullion as an asset class
- uses the simulation model to estimate the expected rate of return for gold bullion that is required to make it an attractive investment for superannuation funds, when compared to other asset classes.

3 Historical review

3.1 The asset classes reviewed

This Report compares the investment performance of gold bullion with the following asset classes and their respective benchmarks:

Australian equities:	S&P/ASX 300 Accumulation Index
Overseas equities:	MSCI World Index ex Australian (unhedged)
Fixed Interest:	UBSWA Composite Index (since October 1989)
	CBBI All Maturities, All series (pre October 1989)
Property:	S&P/ASX 300 Property Accumulation Index
Cash:	UBSWA Bank Bill Index (since Sept. 1987)
	ASX 90 day Bank Bill (pre September 1987)

It is noted that these benchmarks are consistent with benchmarks published in industry magazines, such as *Superfunds.* The gold bullion prices used have been obtained from the Reserve Bank of Australia data, adjusted for the $A/$US exchange rate, also obtained from the Reserve Bank.

The Australian share market accumulation index represents all sectors within the market. Traditionally, this has included a number of gold mining shares, which has given investors an indirect exposure to movements in the gold price. However, the value of listed gold mining shares has decreased in recent years. In fact, the previously used ASX gold index declined from 4.4% of the total market capitalisation at 30 June 1996 to 1.3% at 30 June 2001 and 2.5% at 30 June 2002.

The above mentioned asset classes have been chosen as they represent the major assets held by Australian superannuation funds. Table 1 shows the total assets for Australian superannuation funds as at 30 June 2002.

Table 1: The assets of Australian superannuation funds as 30 June 2002

Asset class	Assets ($ bill)	% of total
Equities in units and trusts	231.1	44.5
Overseas	100.5	19.3
Interest bearing securities	83.9	16.2
Cash and deposits	38.5	7.4
Land and buildings	28.4	5.5
Loans and placements	21.2	4.1
Other assets	15.8	3.0
Total	**519.4**	**100.0**

Source: APRA, Superannuation Market Statistics

3.2 The periods under review

This Report will review history for the following three periods:

- 31 December 1983 to 30 June 2002
- 30 June 1992 to 30 June 2002
- 30 June 1997 to 30 June 2002

The first starting date represents the end of the year following the floating of the Australian dollar. This represents a natural starting point as the price of gold bullion, when expressed in Australian dollars (ie unhedged), will be affected by movements in the value of the Australia dollar.

The next two periods represent the last ten and five years respectively. These periods were chosen as they represent recent history but do not concentrate on short term results, which can be volatile. Furthermore, superannuation funds are long term investors and their investment policy should not pay undue attention to short term movements.

Each period concludes with the end of the last financial year in Australia. All superannuation funds have now reported their investment performance for periods ending 30 June 2002. This closing date therefore provides a natural comparison date.

3.3 The returns, volatility and correlations

Tables 2 to 4 show the annual returns and volatility for each of the six asset classes for each period using the above benchmarks. The volatility (or risk) measure represents the annualised standard deviation, based on monthly returns.

It should be noted that throughout this Report, all returns are shown before any allowance is made for taxes and expenses. This means that each asset class will be treated on its merits and no assumptions have been made about the tax position of the investor.

Tables 2 and 3 show that over the longer periods, there have been higher returns for equities and property and lower returns for cash and gold bullion.

On the other hand, Table 4 shows that the compound annual returns for the last 5 years have been lower and, with the exception of property, are concentrated in the 4.5-7% pa range for all asset classes.

However, in the development of any investment policy, both the returns and volatility of various asset classes should be considered. For each period, the highest volatility occurs for equity investments and gold bullion with lower volatility for cash and fixed interest. Based on these historical returns and risk measures, gold bullion shows a low rate of return and a high level of volatility.

Table 2: The annual returns and volatility: December 1983 - June 2002

Asset class	Return % pa	Risk (std dev)
Australian equities	12.42	17.75
Overseas equities	13.79	16.38
Fixed interest	11.58	5.16
Property	12.17	11.64
Cash	6.95	2.01
Gold bullion	1.57	14.26
CPI	4.09	-

Table 3: The annual returns and volatility: June 1992 - June 2002

Asset class	Return % pa	Risk (std dev)
Australian equities	11.00	13.03
Overseas equities	10.95	12.74
Fixed interest	8.37	4.69
Property	12.04	10.04
Cash	5.89	0.31
Gold bullion	2.09	12.99
CPI	2.52	-

Table 4: The annual returns and volatility: June 1997 - June 2002

Asset class	Return % pa	Risk (std dev)
Australian equities	7.08	12.99
Overseas equities	6.48	14.27
Fixed interest	6.77	3.81
Property	11.03	10.66
Cash	5.30	0.17
Gold bullion	4.67	14.33
CPI	2.74	-

A key strategy in the construction of any investment policy is to consider the benefits that can arise from diversification across different asset classes. In particular, the volatility of portfolio returns, can be reduced through the introduction of assets that are not strongly correlated with each other.

In practice, the returns from most asset classes are positively correlated with each other. For example, and as would be expected, the returns from Australian equities are positively correlated with the returns from overseas equities (unhedged).

Tables 5 and 6 show the historical correlation coefficients that have existed between the returns of the major asset classes with the Tables based on monthly and quarterly returns, respectively.

It is noted that the returns for quarterly periods can hide some of the volatility that exist with monthly returns. In addition, the correlations based on the quarterly returns for the last 5 years are based on only 20 data points. For this reason, the results based on quarterly returns for 1997-2002 should be treated with some caution.

The following comments can be made in respect of these correlations:

- There is a strong positive correlation between the investment returns achieved from the Australian and overseas equity markets
- The fixed interest returns tend to be positively correlated with both the Australian equity and property markets
- Cash returns tend to have a low correlation with all asset classes except fixed interest, where it is clearly positive for each period
- The correlations of the returns for gold bullion are slightly negative or close to zero for all asset classes. A negative correlation with the returns for Australian equities exists in all cases.

These low correlations suggest that the characteristics of gold bullion are different from other assets. It is also noted that gold bullion:

- Pays no income through interest payments, dividends or rent. That is, this Report assumes allocated gold bullion as distinct from unallocated gold bullion, where lease income is payable
- Has a price that is subject to events and/or market sentiment beyond the Australian economy
- Has a value that is determined purely by the market
- Has experienced a low rate of return and yet one that is more volatile than either cash or fixed interest
- Is sometimes considered to be a currency in it own right
- Is subject to different forces of demand and supply from those that affect other asset classes.

In the light of these characteristics, the historical correlation coefficients, and the very different returns and volatility achieved by gold bullion, it is concluded that gold bullion represents a different type of asset from the typical asset classes used by Australian superannuation funds.

With this conclusion in mind, it is now appropriate to consider the historical effects of including gold as a separate asset class within an investment portfolio.

Table 5: The correlation coefficients for monthly returns

Period: 31 December 1983 to 30 June 2002

	Gold Bullion	Australian Equities	Overseas Equities	Property	Fixed Interest
Australian Equities	-0.166				
Overseas Equities	0.117	0.326			
Property	-0.100	0.679	0.273		
Fixed Interest	-0.080	0.345	0.048	0.400	
Cash	0.010	0.058	0.090	0.054	0.230

Period: 30 June 1992 to 30 June 2002

	Gold Bullion	Australian Equities	Overseas Equities	Property	Fixed Interest
Australian Equities	-0.136				
Overseas Equities	-0.034	0.435			
Property	0.104	0.533	0.239		
Fixed Interest	0.061	0.356	0.099	0.481	
Cash	-0.017	0.056	0.061	0.063	0.399

Period: 30 June 1997 to 30 June 2002

	Gold Bullion	Australian Equities	Overseas Equities	Property	Fixed Interest
Australian Equities	-0.178				
Overseas Equities	-0.134	0.442			
Property	-0.008	0.531	0.148		
Fixed Interest	0.067	0.139	-0.080	0.464	
Cash	0.029	-0.016	-0.006	0.048	0.386

Table 6: The correlation coefficients for quarterly returns

Period: 31 December 1983 to 30 June 2002

	Gold Bullion	Australian Equities	Overseas Equities	Property	Fixed Interest
Australian Equities	-0.113				
Overseas Equities	0.202	0.498			
Property	0.014	0.727	0.296		
Fixed Interest	0.041	0.194	0.140	0.390	
Cash	0.022	0.099	0.132	0.083	0.342

Period: 30 June 1992 to 30 June 2002

	Gold Bullion	Australian Equities	Overseas Equities	Property	Fixed Interest
Australian Equities	-0.222				
Overseas Equities	0.056	0.496			
Property	0.257	0.331	0.111		
Fixed Interest	0.318	0.135	0.133	0.622	
Cash	-0.004	0.048	0.114	0.146	0.507

Period: 30 June 1997 to 30 June 2002

	Gold Bullion	Australian Equities	Overseas Equities	Property	Fixed Interest
Australian Equities	-0.483				
Overseas Equities	-0.244	0.556			
Property	0.193	0.067	-0.241		
Fixed Interest	0.473	-0.553	-0.300	0.453	
Cash	0.266	-0.156	-0.073	0.179	0.525

3.4 The benchmark and alternative portfolios

To assess the possible effects of including gold bullion within the investment portfolio of Australian superannuation funds and other long term investors, it is helpful to construct a benchmark portfolio, which may be considered to represent a typical superannuation fund.

Table 1 showed the asset allocation for Australian superannuation funds as at 30 June 2002. However, it is also appropriate to review the asset allocation that has actually occurred during the last 3 years. Table 7 shows these asset allocations and the benchmark portfolio that will be used in this Report. This benchmark portfolio also reflects the fact that about two-thirds of Australian superannuation funds are often invested in equities with the balance invested in the other asset classes.

Table 7: Asset allocation of the Australian superannuation industry

	Asset allocation as at			Benchmark portfolio
Asset class	**30 June 00 %**	**30 June 01 %**	**30 June 02 %**	**%**
Australian equities	42.3	45.1	44.5	46.0
Overseas equities[1]	18.3	18.6	19.3	20.0
Interest bearing securities	19.3	16.0	16.2	20.0
Land & buildings	5.5	5.5	5.5	6.0
Loans & placements	4.9	4.6	4.1	-[2]
Cash & deposits	6.4	7.3	7.4	8.0
Other assets	3.3	2.9	3.0	-[3]
Total	**100.0**	**100.0**	**100.0**	**100.0**

Source: APRA, Total Superannuation Assets

Notes

1 The APRA statistics only show overseas assets and do not show the split between equities, fixed interest and other asset classes. It is assumed that the majority of overseas investments represent equity investments.

2 The loans and placements have been added to interest bearing securities.

3 The other assets have been distributed across all classes.

Table 8 shows the annual returns and standard deviations, before fees and taxes, that would have been achieved for this benchmark portfolio for the last 5 and 10 years, using the returns based on the indices shown earlier. For this purpose, it is assumed that the portfolio is rebalanced at the end of each month.

Table 8: The returns and volatility for the benchmark portfolio

Period	Annual return % pa	Risk measure Standard deviation
1992-2002	10.40%	8.15%
1992-1997	13.58%	8.17%
1997-2002	7.31%	8.11%

The impact that the inclusion of gold bullion within an investment portfolio would have had on the returns and volatility during the last 10 years will now be explored.

Of course, there are a large number of ways that the benchmark portfolio could be adjusted to include gold bullion. Table 9 shows the results for the following approaches:

- A 5% holding of gold bullion with a reduced exposure of 2% in Australian equities and a 1% reduction in each of overseas equities, fixed interest and cash
- A 5% holding of gold bullion with a corresponding reduction of 5% in particular asset classes (namely, Australian equities, overseas equities, fixed interest or cash)
- A 10% holding of gold bullion with a reduced exposure of 4% in Australian equities and a 2% reduction in each of overseas equities, fixed interest and cash
- A 10% holding of gold bullion with a corresponding reduction of 10% in particular asset classes (namely, Australian equities, overseas equities, fixed interest or cash/property).

Each portfolio is rebalanced monthly to maintain the stated asset allocation proportions.

Table 9 shows quite different results for the last two 5 year periods. For 1992-97, the introduction of gold would have reduced the return by approximately 0.1-0.2% pa for each 1% of investment in gold bullion. However, in most cases, the volatility would also have reduced, thereby highlighting the risk-return trade-off.

For 1997-2002, the introduction of gold bullion has virtually no impact on the portfolio return but reduces the volatility measure in every case.

Table 9: The impact of introducing gold bullion into the benchmark investment portfolio for 1992-2002, 1992-97 and 1997-2002

Portfolio	1992-2002		1992-1997		1997-2002	
	Return	Std. dev.	Return	Std. dev.	Return	Std. dev.
Benchmark	*10.40%*	*8.15%*	*13.58%*	*8.17%*	*7.31%*	*8.11%*
+ 5% gold across classes	10.07%	7.76%	12.94%	7.84%	7.28%	7.66%
+ 5% gold for Aust. equities	10.00%	7.50%	12.81%	7.58%	7.26%	7.40%
+ 5% gold for overseas equities	9.98%	7.70%	12.77%	7.85%	7.27%	7.55%
+ 5% gold for fixed interest	10.13%	8.01%	13.06%	8.03%	7.27%	7.97%
+ 5% gold for cash	10.25%	8.11%	13.24%	8.20%	7.34%	8.01%
+ 10% gold across classes	9.73%	7.43%	12.29%	7.57%	7.23%	7.29%
+ 10% gold for Aust. equities	9.58%	6.93%	12.03%	7.06%	7.19%	6.79%
+ 10% gold for overseas equities	9.56%	7.35%	11.96%	7.60%	7.21%	7.11%
+ 10% gold for fixed interest	9.84%	7.92%	12.54%	7.94%	7.21%	7.90%
+ 10% gold for 5% cash, 5% property	9.78%	7.83%	12.56%	7.96%	7.07%	7.69%

Table 10: Differences from the benchmark in returns and standard deviations for 1992-2002, 1992-97 and 1997-2002

Portfolio	1992-2002			1992-1997			1997-2002		
	Δ Return	Δ Std. dev.	Δ Return / Δ Std. dev.	Δ Return	Δ Std. dev.	Δ Return / Δ Std. dev.	Δ Return	Δ Std. dev.	Δ Return / Δ Std. dev.
+ 5% gold across classes	-0.33%	-0.39%	0.85	-0.64%	-0.33%	1.94	-0.03%	-0.45%	0.07
+ 5% gold for Aust. equities	-0.40%	-0.65%	0.62	-0.77%	-0.59%	1.31	-0.05%	-0.71%	0.07
+ 5% gold for overseas equities	-0.42%	-0.45%	0.93	-0.81%	-0.32%	2.53	-0.04%	-0.56%	0.07
+ 5% gold for fixed interest	-0.27%	-0.14%	1.93	-0.52%	-0.14%	3.71	-0.04%	-0.14%	0.29
+ 5% gold for cash	-0.15%	-0.04%	3.75	-0.34%	+0.03%	*	+0.03%	-0.10%	-0.30
+ 10% gold across classes	-0.67%	-0.72%	0.93	-1.29%	-0.60%	2.15	-0.08%	-0.82%	0.10
+ 10% gold for Aust. equities	-0.82%	-1.22%	0.67	-1.55%	-1.11%	1.40	-0.12%	-1.32%	0.09
+ 10% gold for overseas equities	-0.84%	-0.80%	1.05	-1.62%	-0.57%	2.84	-0.10%	-1.00%	0.10
+ 10% gold for fixed interest	-0.56%	-0.23%	2.43	-1.04%	-0.23%	4.52	-0.10%	-0.21%	0.48
+ 10% gold for 5% cash, 5% property	-0.62%	-0.32%	1.94	-1.02%	-0.21%	4.86	-0.24%	-0.42%	0.57

* Not shown as the return decreased whilst the volatility increased to provide a negative result. However this negative result has a very different cause to the negative result achieved for the second 5 year period for this portfolio.

Table 10 shows the reduction in return and risk that would have occurred with the addition of gold bullion. For each period the ratio of the reduction in return to the reduction in risk is calculated. The lower the ratio, the better the outcome in terms of the risk-return trade-off. Ideally, there is a negative ratio as occurred for a gold for cash substitution in the last 5 years where a higher return was achieved for a lower level of portfolio risk. In the first 5 years, the best relative result was achieved in respect of a substitution of gold bullion for Australian equities. Again, these results highlight the very difference experience over the two 5 year periods.

Figures 1 and 2 plot the returns and risk for the benchmark portfolio and some of the alternative portfolios for the last 5 and 10 years respectively. The 5% and 10% spread options represent the alternative portfolios when the asset allocation is reduced for a range of asset classes.

Figure 1: Risk-return trade-off for 1997-2002

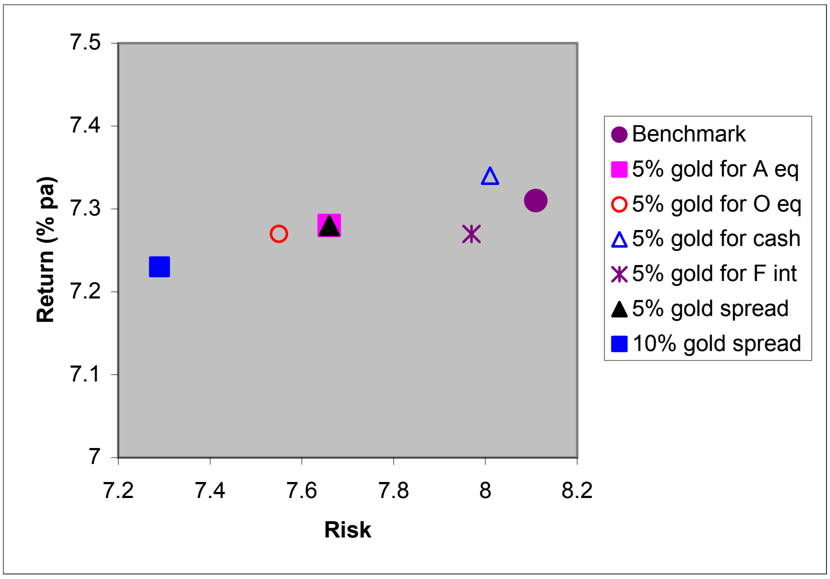


Figure 2: Risk-return trade-off for 1992-2002

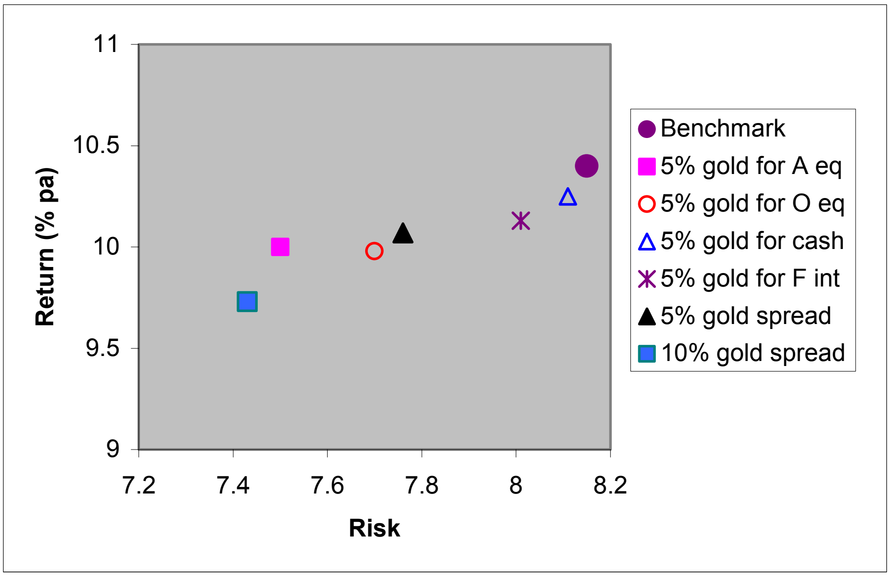


Figure 1 highlights that for 1997-2002, the introduction of gold bullion had virtually no impact on the investment return but does reduce the risk measure. Figure 2, representing the last 10 years, shows a more typical risk-return trade-off, with lower returns corresponding to reduced volatility. The actual effect over the 10 year period depends on the asset class that had its allocation reduced.

These graphs confirm that the addition of gold bullion to the benchmark portfolio reduces the volatility of the investment return for both periods, but the impact on investment return is less consistent.

3.5 Efficient frontiers

The previous section presented the historical returns and risk measures for the benchmark portfolio and several hypothetical portfolios which included gold bullion. An alternative presentation discussed in the finance literature is to calculate the efficient frontier for the nominated asset classes based on historical returns and correlations.

In essence, the efficient frontier will show the "best" asset allocation for the period being assessed, using the risk-return criteria. That is, a theoretical portfolio will lie on the efficient frontier if it provides the maximum return for the period, at the given risk level, or the minimum risk for a given rate of return.

For the purposes of this exercise we will consider that the allocation for each asset class could be within the following ranges:

- Australian equities: 35-50%
- Overseas equities: 10-25%
- Fixed interest: 10-35%
- Property 0-10%
- Cash: 5-10%
- Gold bullion: 0-10%

The feasible portfolios are calculated by increasing the possible allocation for each asset class by increments of 2.5%. Naturally, the total asset allocation percentages must add up to 100%, thereby eliminating certain combinations. Each portfolio is rebalanced monthly.

Figures 3, 4 and 5 plot the risk and return measures for all the possible portfolios for the last 10 years and the two 5 year periods. In each figure, the benchmark portfolio and an alternative portfolio, representing a 5% asset allocation to gold bullion with the reduction spread across all asset classes, is also shown. Figure 6 shows the results using the same scale.

The 10 year results show compound returns ranging from 9% to 10.8% pa with the risk measures ranging from 6% to 9%. At the medium to higher risk levels (i.e. standard deviations greater than 6.5%) the efficient frontier includes no gold bullion allocation. On the other hand, at the lower risk levels, the best returns are achieved with some exposure to gold bullion. However, the two 5 year periods exhibit contrasting results.

For 1992-97, the features of the portfolios that lie on the efficient frontier are similar to those for the 10 year period. That is, for medium to high levels of risk, no gold bullion allocation would have been desirable but at lower levels of risk, the efficient portfolios include exposure to gold bullion.

On the other hand, the results for 1997-2002 as highlighted by Figures 5 and 6 are quite different and are consistent with the discussion in the previous section. For this period, the returns for all portfolios are much more concentrated with the total range being only 0.6% per annum whilst the range of risk values is larger.

The efficient frontier for 1997-2002 has a unexpected shape, being two sides of a parallelogram. In this period, the most efficient portfolios were on the left hand side of the parallelogram with each of these portfolios having some exposure to gold bullion for the period. Figure 6 highlights this result as very little extra return was achieved during this period to compensate for the additional volatility.

Figure 3: Risk-Return for possible portfolios for 1992-2002

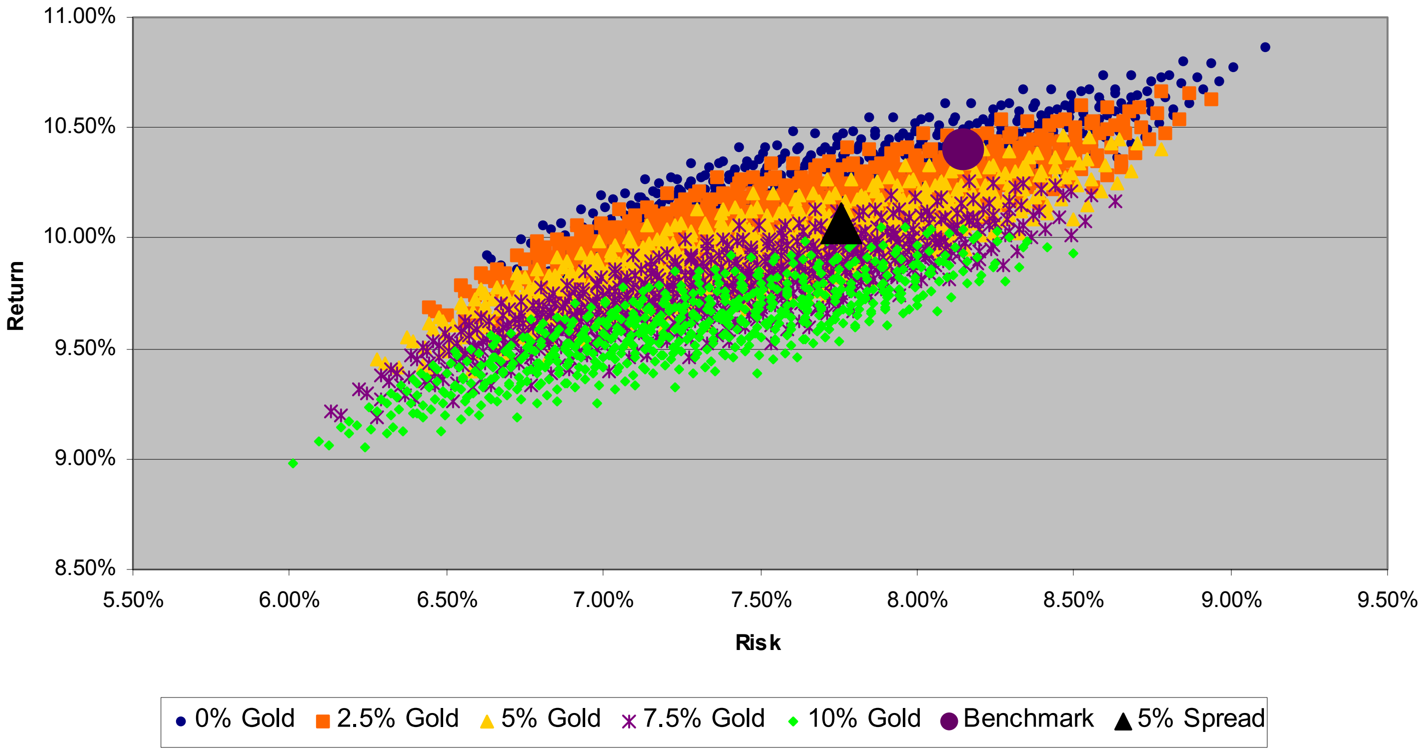


Figure 4: Risk-Return for possible portfolios for 1992-1997

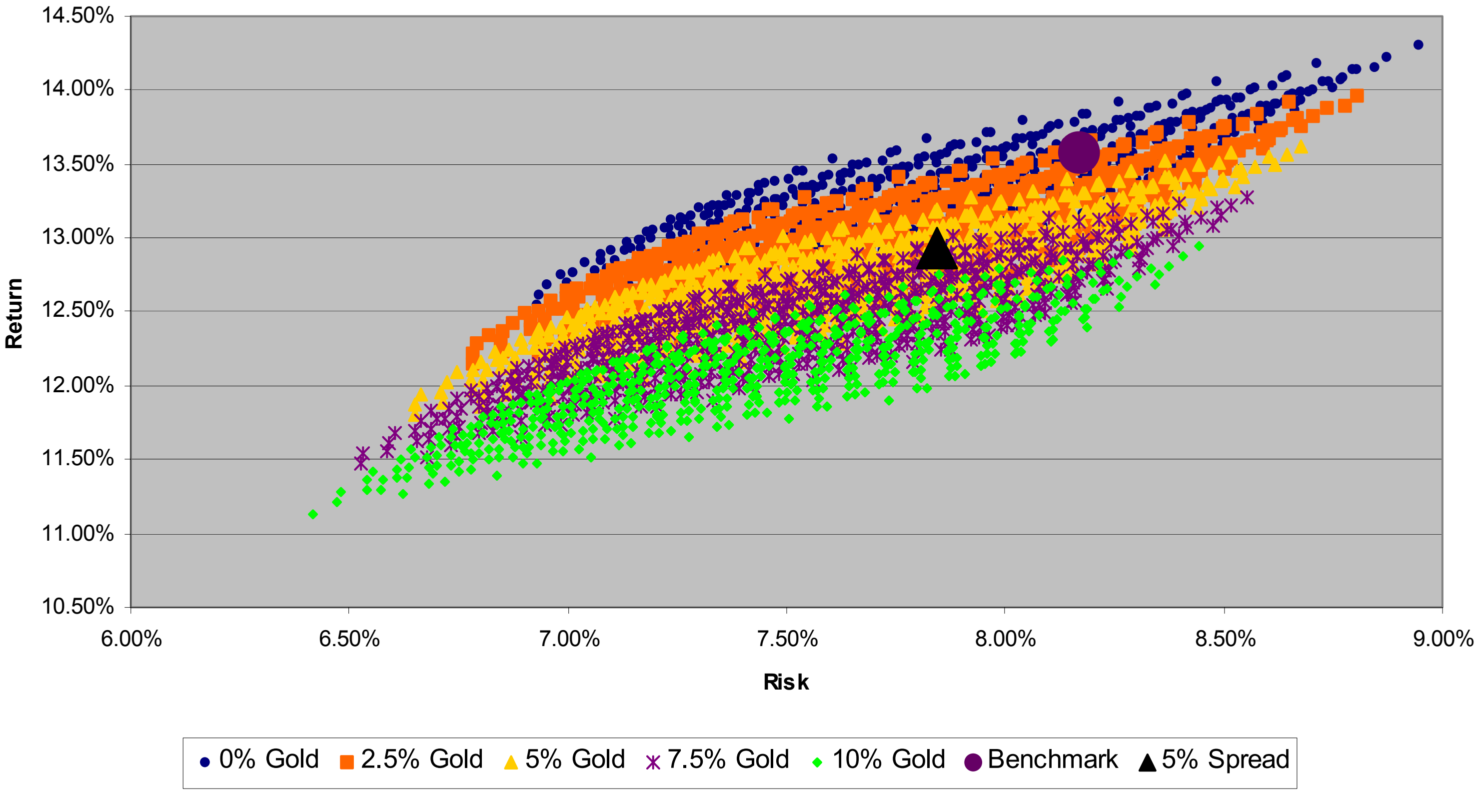


Figure 5: Risk-Return for possible portfolios for 1997-2002

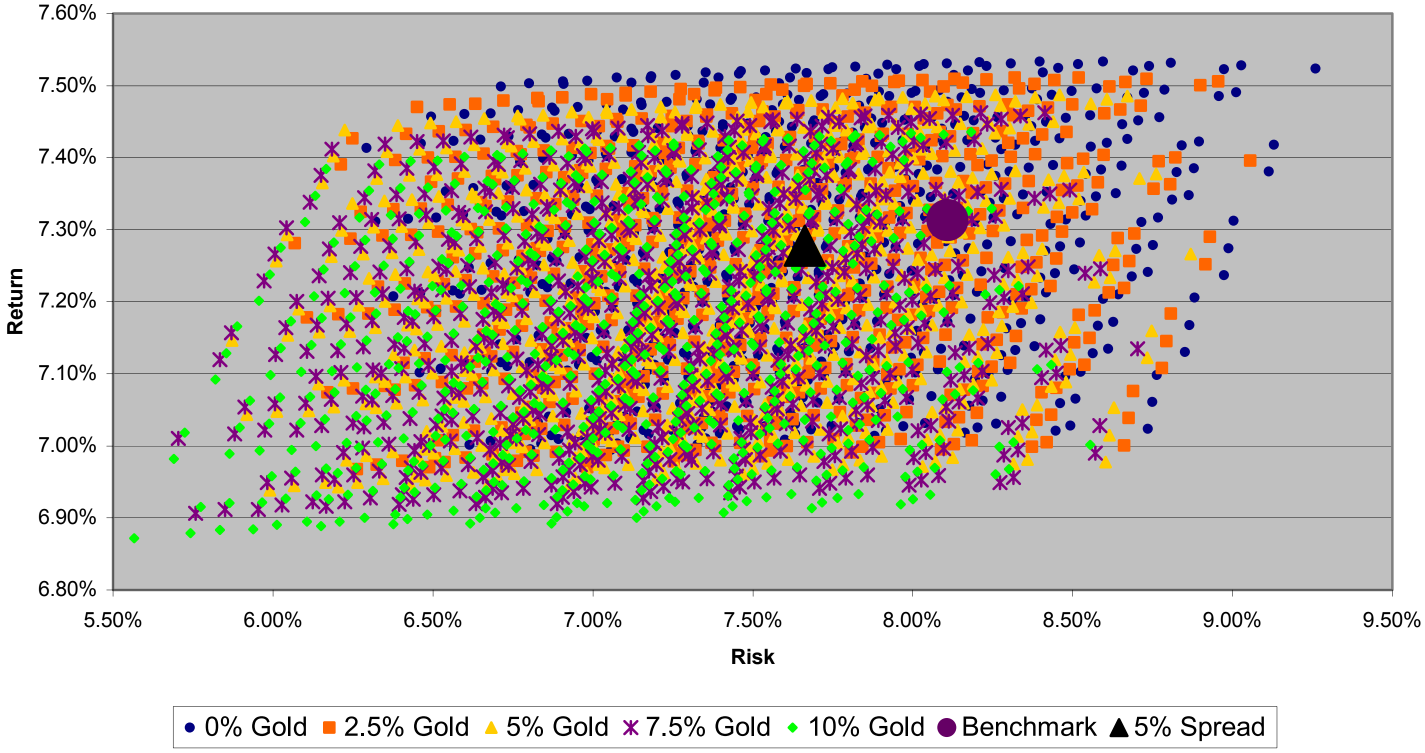
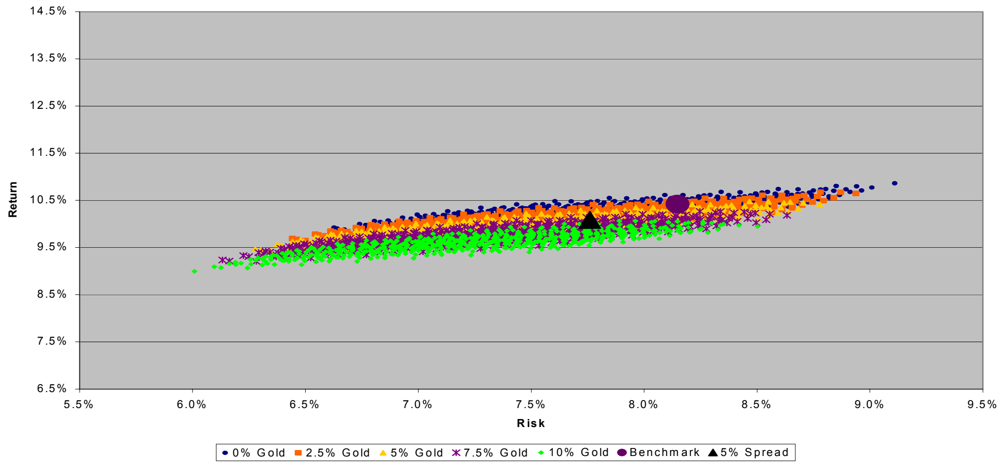
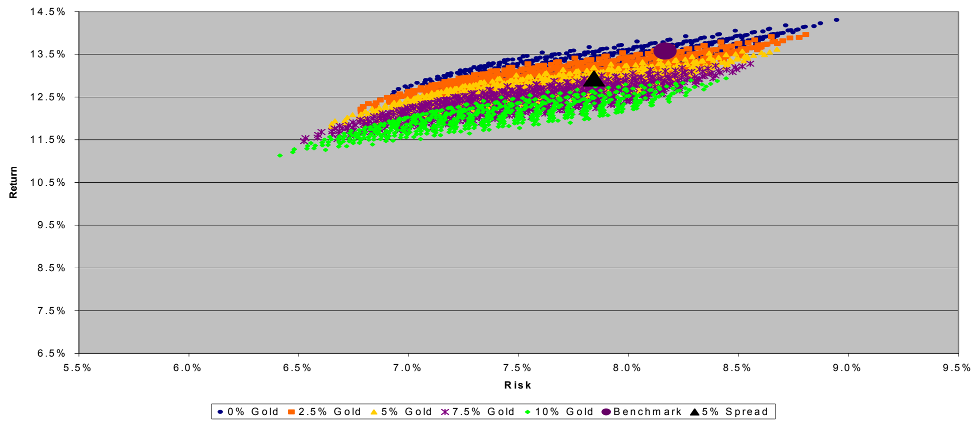


Figure 6: Risk-Return for possible portfolios using the same scale

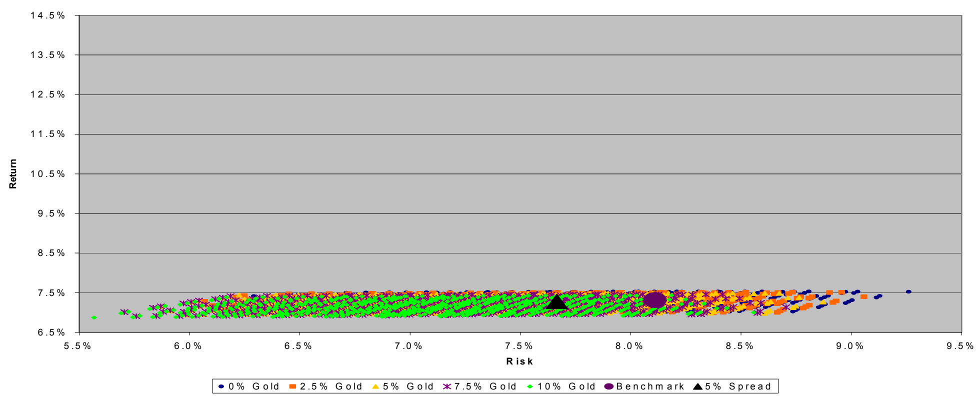
1992-2002



1992-1997



1997-2002



3.6 Conclusions from the historical review

The previous sections have reviewed the historical performance of the major asset classes used by Australian superannuation funds and the impact on the results of the inclusion of gold bullion.

It is concluded from this review that:

- The correlation coefficients of the investment returns for gold bullion with all other asset classes are slightly negative or close to zero
- Gold bullion has characteristics in terms of risk and return that suggests it is very different from the traditional asset classes
- The introduction of gold bullion would have had different impacts for 1992-97 and 1997-2002. In the earlier period it would have reduced the return by about 0.1-0.2% pa for each 1% of gold bullion investment. However, for 1997-2002, the introduction of gold would have had virtually no impact on the investment return
- The introduction of gold bullion into the portfolio during the last 5 or 10 years would have reduced the volatility of the investment returns, as measured by the standard deviation of monthly returns
- Efficient investment portfolios, as measured by the efficient frontier, would have included exposure to gold bullion for the period 1997-2002. For the 10 year period to June 2002, some gold allocation would have been efficient if a reduced risk level was desired, together with the corresponding lower return.

4 Simulations of the future

4.1 The macro economic and investment model

PricewaterhouseCoopers Actuarial has developed a proprietary macro economic and investment simulation model which represents an extension of the ERCH model developed by Glen Harris. Further details on the standard ERCH model are found in the following papers:

- Harris G. (1994), On Australian Stochastic Share Return Models for Actuarial Use, *Institute of Actuaries of Australia Quarterly Journal,* September.
- Harris G. (1995), A Comparison of Stochastic Asset Models for Long-Term Studies, *Institute of Actuaries of Australia Quarterly Journal,* September.

This original model was fitted using Australian economic and investment data from 1949. It considered the following seven financial series:

- Real GDP growth
- Price inflation
- Share price index returns
- Share dividend yields
- 13 week Treasury note yields
- 2 year Commonwealth government bond yields to maturity
- 10 year Commonwealth government bond yields to maturity.

The ERCH model uses historical relationships between the economy and the capital markets, together with error terms, to simulate distributions of investment returns. In addition, certain limits are placed on the standard deviation of the error terms to avoid extrapolating volatilities beyond the observed range.

The original model has been adjusted by PricewaterhouseCoopers to reflect recent economic conditions and has been extended to include a wider range of asset classes. These modifications and the selection of a set of initial conditions are such that the model produces an arbitrage free set of returns over a 3-5 year time horizon.

It should be stressed that the ERCH simulation model is *not* a predictive model. That is, it does not predict investment or economic conditions for the periods under consideration. Rather, it produces a distribution of possible outcomes.

The starting date selected for running the ERCH model can be significant, due to the relationships within the model. The following simulations have been based on a neutral starting date which means that no assumptions are made about the state of the markets at the starting date.

The expected long term gross annual returns (or mean returns) used for the major asset classes within the simulations are as follows:

- Australian equities: 9.2%
- Overseas equities: 10.3%
- Fixed interest: 6.1%
- Property: 8.2%
- Cash: 4.8%

In addition, the expected inflation rate is 2.5% per annum, midway between the Reserve Bank's 2-3% range.

Using the benchmark portfolio discussed earlier, the simulations provide a median gross return of 8.1% pa over 3 years. As this return is *before* taxes and fees, such a median return is consistent with a recent submission by the Institute of Actuaries of Australia to the Senate Select Committee on Superannuation which used a long term investment return for Australian superannuation funds of 7% pa, *after* taxes and fees.

4.2 The gold bullion component

One objective of this Report is to add gold bullion as an asset class to the macro economic and investment simulation model described in the previous section. Such an outcome will enable us to assess the impact of introducing gold bullion on the simulated results.

Appendix A outlines the data sources used in analysing the historical trends of gold prices while Appendix B describes the statistical tests that were carried out to determine the most suitable gold price series to be used in the simulations. Appendix C identifies the model used and estimates the parameters. It also reviews any links with other economic variables.

This analysis and testing led us to develop a model that used the logarithm of the change in the gold prices each quarter and comprised the following major components:

- a negative relationship with the previous price movement, and
- an error term that allows for random fluctuations.

The initial value was chosen so that the distribution of returns reflected the long term assumption made about future gold returns. The base case assumption is that gold will maintain its real value over the simulated period. Such an outcome is consistent with other research that suggests that gold maintains its real value[1] over the long term. Within the Australian context, this is broadly consistent with the experience over the last 10 years.

The use of an error term without any direct relationships with the returns from other asset classes, as explained in Appendix C, is also consistent with the low correlation coefficients presented earlier.

In summary, history does not provide any evidence that the future gold price can be modelled within a robust statistical model linked to the returns of other asset classes. Furthermore, whilst we have used an expected return for gold that is consistent with the long term expected inflation used in the simulations, there remains considerable uncertainty in this figure such that this assumption should not be viewed as our expectation of the future return from gold bullion.

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[1] Stephen Harmston, Gold as a Store of Value, World Gold Council, Research Study No. 22, November 1998.

4.3 The simulation results

The simulated investment returns were generated by combining the ERCH model described in Section 4.1 and the gold bullion model described in Section 4.2 and Appendix C.

Section 3.4 discussed the benchmark portfolio and a range of alternative portfolios. For the purposes of these initial simulation results, the following five investment portfolios have been simulated:

- The benchmark portfolio
- A 5% holding of gold bullion with a reduction of 2% in Australian equities and a 1% reduction in overseas equities, fixed interest and cash (shown as 5% spread)
- A 5% holding of gold bullion with a reduction of 5% in Australian equities (shown as 5% for A eq)
- A 5% holding of gold bullion with a reduction of 5% in overseas equities (shown as 5% for O eq)
- A 10% holding of gold bullion with a reduction of 4% in Australian equities and a 2% reduction in overseas equities, fixed interest and cash (shown as 10% spread).

Figure 7 shows the distribution of the simulated returns from these investment portfolios for a 3 year period.

The result is that the investment portfolios which include an exposure to gold bullion have:

- a slightly lower expected return (that is, there is a slight shift of the distribution to the left); but
- the tails of each distribution (both at the top and bottom ends) are smaller and therefore less likely to occur.

That is, the inclusion of gold bullion reduces both the expected return and the volatility in the investment returns.

This reduction in volatility also causes a reduction in the probability that the investment return is below a particular figure that may be deemed by trustees or investors to be unreasonable, unacceptable or indicative of a high level of risk. In some cases, this unacceptable figure could be a negative return whereas in other cases, it could be a return below say, minus 5%. Table 11 shows the probability that the 1 or 3 year returns are below zero or minus 5% for each portfolio.

Table 11: The probability of breaching certain returns for 1 or 3 years

Investment Portfolio	Probability that the 1 year return is below		Probability that the 3 year return is below	
	0%	-5%	0%	-5%
Benchmark	22.7%	11.3%	6.0%	3.0%
5% spread	22.3%	10.7%	5.8%	2.9%
5% for Aust equities	21.7%	10.0%	5.4%	2.5%
5% for Overseas equities	22.3%	10.2%	5.6%	2.8%
10% spread	22.3%	10.2%	5.7%	2.7%

As expected from the earlier results, the introduction of gold bullion reduces the probability that the annual return is below either of the nominated returns.

The general results are also presented in Table 12 which shows the median, 5th and 95th percentiles and standard deviation for the portfolios. For example, this Table shows that the spread of simulated returns for the benchmark portfolio from the 5th percentile to the 95th percentile for 1 year is from –9.3% to +28.9% but is reduced to a range from –8.4% to +26.6% assuming a 10% allocation to gold. This reduced spread is confirmed by the decline in the standard deviation of the simulated returns from 10.7% to 9.8%. In this example, the median return reduced from 8.3% to 7.7%.

These results have been based on an expected return on gold bullion of 2.5% pa (equivalent to 0% real). However, as noted earlier, the gold simulation model has considerable uncertainty within it and is not related to any asset class or economic variable within the Australian economy.

An alternative approach to assess whether gold bullion could form part of a superannuation fund's investment strategy is to estimate the minimum return that gold bullion would need to achieve such that it could be considered to add value to the investment portfolio within a risk-return framework. The simulation approach outlined above will now be used to tackle this issue.

Figure 7: Distribution of simulated investment returns – 3 year period

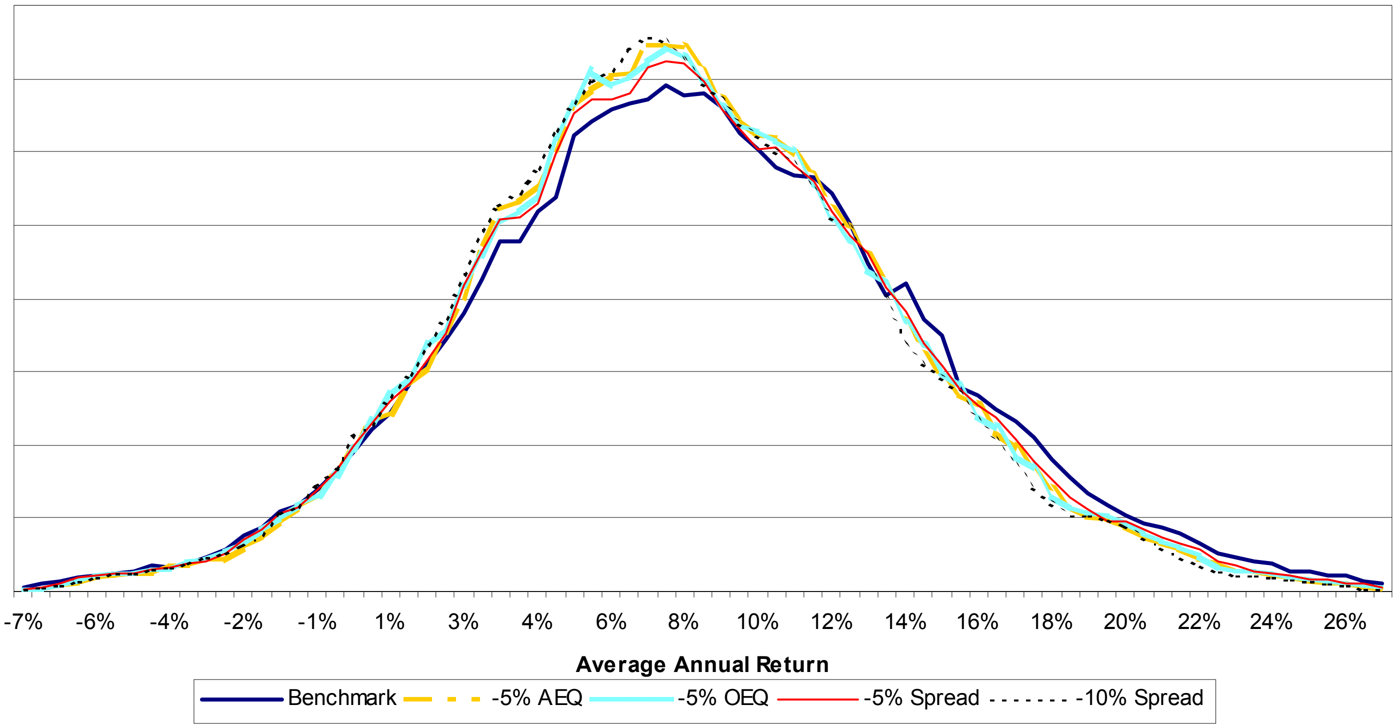


Table 12: Selected percentiles and standard deviation of compounded annual returns for selected investment portfolios

Portfolio	Projection Period: 1 year					Projection Period: 3 years					Projection Period: 5 years				
	B'mark	5% spread	5% for A eq	5% for O eq	10% spread	B'mark	5% spread	5% for A eq	5% for O eq	10% spread	B'mark	5% spread	5% for A eq	5% for O eq	10% spread
5th %ile	-9.26%	-8.80%	-8.29%	-8.61%	-8.37%	-0.43%	-0.36%	-0.15%	-0.26%	-0.33%	1.87%	1.86%	1.97%	1.88%	1.80%
50th %ile (median)	8.25%	7.98%	7.92%	7.83%	7.70%	8.10%	7.83%	7.78%	7.73%	7.56%	8.29%	8.01%	7.93%	7.92%	7.74%
95th %ile	28.94%	27.65%	26.85%	27.12%	26.57%	18.46%	17.75%	17.32%	17.42%	17.03%	15.34%	14.79%	14.49%	14.55%	14.25%
Standard deviation of simulated returns[1]	10.71%	10.25%	9.90%	10.05%	9.83%	5.30%	5.08%	4.91%	4.98%	4.88%	3.80%	3.65%	3.53%	3.57%	3.51%

Note: The standard deviations shown here represent the standard deviations of the compounded annual returns from the 10,000 simulations. They do not correspond to the standard deviation measures used in Section 3 to measure the volatility or risk of historical returns. It is noted that these standard deviations decrease for longer periods as the spread (or distribution) of the simulated investment returns reduces with longer periods. Such an outcome is not surprising as negative returns are often, but not always, followed by positive returns.

4.4 Simulations and the gold return threshold

As shown in the earlier evidence (including Figure 6, which showed the three efficient frontiers), there has not been a constant risk-reward trade-off within the Australian investment markets during the last 10 years. In fact, it has changed considerably. Therefore, based on this historical evidence, we are unable to determine the 'correct' risk-reward trade-off for the years ahead. Instead, we will estimate the trade-off by establishing a more conservative investment portfolio and then using the simulation model to compare the simulated returns from this conservative portfolio with the previously used benchmark portfolio.

Table 13 compares the asset allocation for this conservative portfolio with the previous benchmark. The change has been to reduce exposure to the equity markets by 15% of the portfolio (10% Australian and 5% overseas) and to allocate these funds to interest bearing securities.

Table 13: Comparisons between the benchmark and conservative portfolios

	Benchmark	Conservative
Asset allocation	%	%
Australian equities	46	36
Overseas equities	20	15
Interest bearing securities	20	35
Land & buildings	6	6
Cash & deposits	8	8
Total	100	100

Table 14 shows the median compound annual returns for the two portfolios, the standard deviation of the simulated returns and the probability that the simulated return will be negative for three periods. The results are as expected, with the conservative portfolio:

- having a lower median for the simulated returns,
- having less variability, as indicated by a lower standard deviation of the simulated returns, and
- being less risky from an investor's perspective with a lower probability of a negative return.

These results confirm the existence within the simulated results of the expected risk-return trade-off as asset allocation is changed.

Table 14: The simulated returns for the benchmark and conservative portfolios for 1, 3 and 5 years

	Benchmark	Conservative
1 year period		
Median return pa	8.25%	7.72%
Standard deviation of simulated returns	11.30%	8.87%
Probability of return < 0%	22.65%	18.94%
3 year period		
Median return pa	8.10%	7.65%
Standard deviation of simulated returns	5.44%	4.28%
Probability of return < 0%	5.96%	3.23%
5 year period		
Median return pa	8.29%	7.84%
Standard deviation of simulated returns	3.87%	3.07%
Probability of return < 0%	1.47%	0.46%

In terms of measuring risk within the simulated results, we have decided to use the probability of a negative return. The reasons are threefold. First, it is a simple measure and can be easily understood. Second, the use of the standard deviation of the simulated returns is likely to lead to confusion between this measure and the commonly used standard deviation of monthly returns to measure volatility, as used in Section 3 of this Report. That is, these two standard deviations do not represent the same measure. Third, the conclusions based on this risk measure relating to negative returns are broadly consistent with those that are achieved using the standard deviation of the simulated returns.

Having established a broad relationship between risk and return for the different simulated investment portfolios, it is now possible to assess the minimum expected return that gold bullion would need to achieve to be considered a possible investment.

Figure 8 maps the median[2] returns and risk measures for the benchmark and conservative portfolios together with a portfolio where 5% of the benchmark portfolio is transferred from equity investment (in a 2:1 ratio between Australian and overseas equities) to gold bullion. As noted earlier, the expected return from gold bullion is very difficult to model and we have therefore shown the results using the following three assumptions concerning the expected (or mean) return from gold bullion:

- 2.5% nominal, consistent with the mean inflation level used in the model
- 4.5% nominal, which is 2% higher than the mean inflation level
- 6.5% nominal, which is 4% higher than the mean inflation level.

[2] Median returns from the simulations are shown in Figures 8 and 9 in preference to the mean returns, as the mean returns can be affected by extreme values.

Figure 8 suggests that the minimum expected return required by gold bullion to be considered for inclusion in the investment portfolio in terms of the risk-return trade-off are as follows:

- an expected return greater than about 5.5% pa for a 1 year horizon
- an expected return greater than about 6.5% pa for a 3 year horizon
- an expected return greater than about 7% pa for a 5 year horizon.

Of course, it should be noted that these thresholds are in the context of the assumptions and distributions used for the other asset classes. If these distributions were to change, these thresholds would also change. In this respect, it is noted that the model uses an expected return for cash of 4.8% pa.

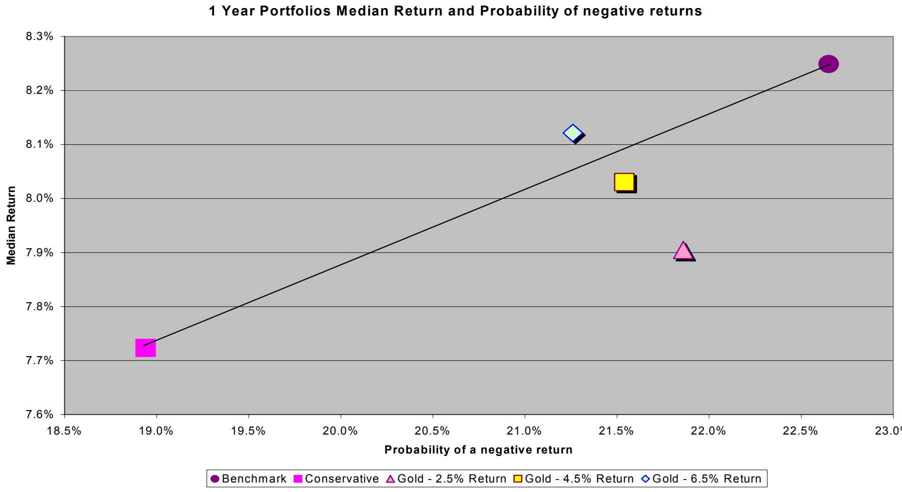
In the recent uncertain times, some trustees have adopted a more cautious approach than indicated by the asset allocation in the benchmark portfolio. To reflect this, an alternative benchmark portfolio has been constructed, where 5% of the equity investments (in a 2:1 ratio between Australian and overseas equities) have been allocated to cash, thereby increasing the cash allocation to 13%.

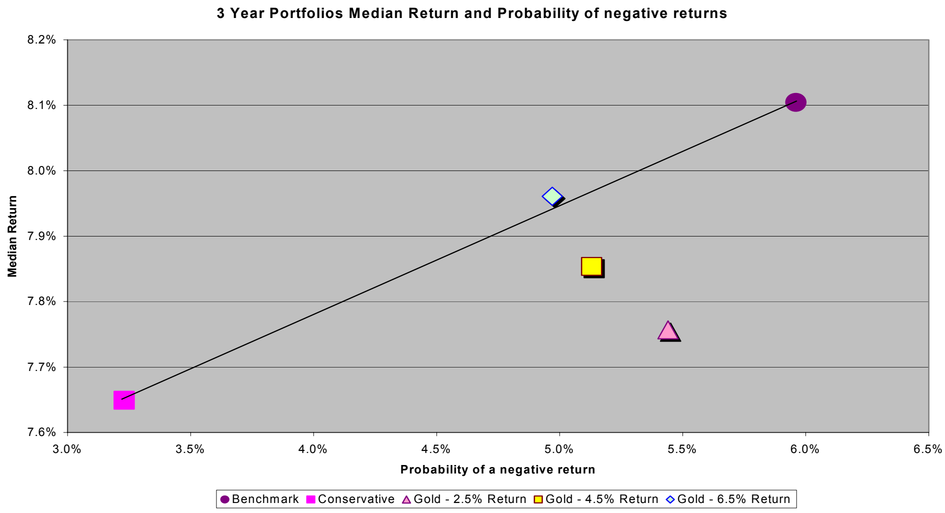
Figure 9 compares this alternative benchmark with the conservative portfolio and so constructs an alternative risk-return trade-off. Under these circumstances, the issue is the minimum expected return required by gold bullion such that a better risk-return result would be achieved if the extra 5% allocated to cash is transferred to gold bullion. The minimum expected returns for this to occur are:

- an expected return greater than about 4.5% pa for a 1 year horizon;
- an expected return greater than about 5% pa for a 3 year horizon;
- an expected return greater than about 5.5% pa for a 5 year horizon.

As may be expected, these thresholds are lower than the earlier figures due to the different risk-return trade-off. As before, these thresholds are also influenced by the assumptions and distributions used for the other asset classes.

Figure 8: The risk–return trade-offs using the benchmark and conservative portfolios





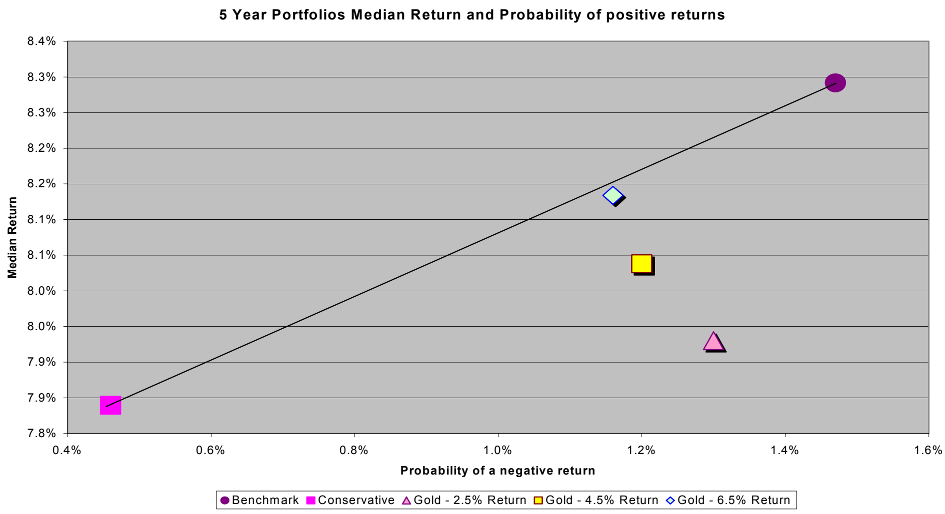
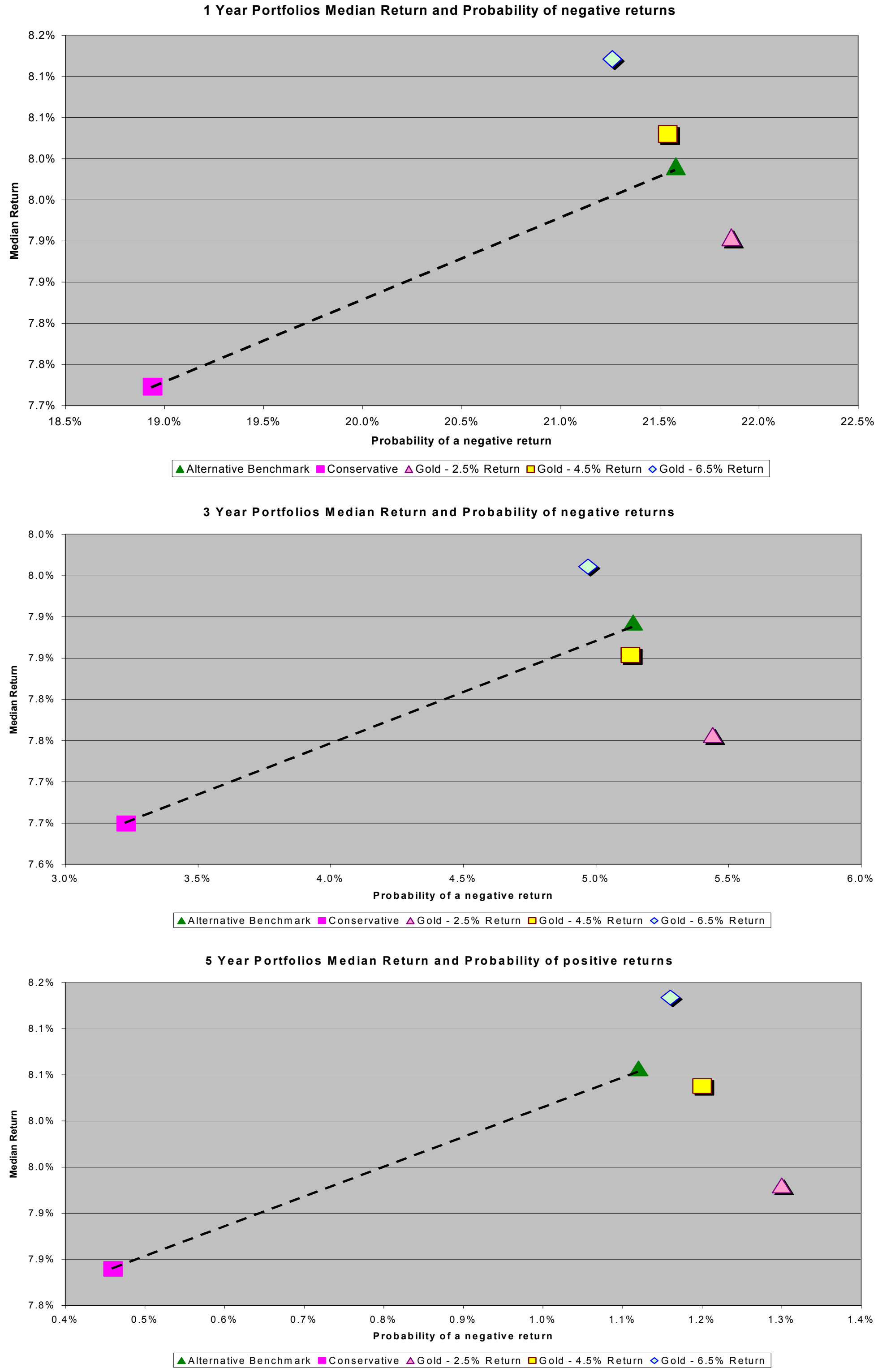


Figure 9: The risk–return trade-offs using the alternative benchmark and conservative portfolios



4.5 Conclusions from the simulations

The PricewaterhouseCoopers macro economic and investment model has been used to simulate the distribution of future investment performance of Australian superannuation funds. This model has been developed over several years and has been used in many assignments with major clients.

A gold bullion module was added to the model for this assignment. After considerable statistical testing and analysis it was found that the gold bullion price, when expressed in Australian dollars, has no strong causal relationships with the investment performance of other asset classes or the Australian economy. The gold module that was developed can be described as an autoregressive model with an error term.

This gold bullion module was combined with the macro economic and investment model to assess the impact of introducing gold bullion into the investment portfolio of Australian superannuation funds.

The simulations showed that the introduction of gold bullion:

- Reduces the spread of possible investment returns as the probability of an outcome in either tail of the distribution is less likely
- Reduces the expected return.

It was also shown that over a three year period, an expected rate of return from gold bullion of 6.5% pa (or 4% pa real) causes a portfolio including 5% gold bullion to have a preferred risk-return position than the performance generated from other typical investment portfolios

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Appendix A The data sources

Initially data from various sources was obtained and analysed to determine the most appropriate source to use in the model identification and parameter(s) estimation. In accordance with the requirements of a time series model, the criteria required of data is that:

- it is approximately normally distributed
- its variance as a function of time is constant (homoscedasticity) and
- the residuals are not mutually correlated (no serial correlation).

Data was obtained from the following sources:

- Perth Mint;
- World Gold Council;
- Bloomberg;
- Reserve Bank of Australia (RBA).

Perth Mint had monthly high, low and average Bid/Ask gold prices in both $US and $A along with average yearly $US and $A prices for the period January 1975 to August 2002. This data did not satisfy any of the above mentioned criteria and was not used further.

World Gold Council had average monthly and annual prices in $US for the period January 1971 to August 2002. Monthly averages are not suitable for our purposes although further analysis on the annual data was carried out. However this data did not satisfy any of the above mentioned criteria and was not used further.

Bloomberg had end of month prices for the period January 1987 to August 2002. Monthly data were very volatile and displayed strong heteroscedasticity and it was not possible to identify a simple functional form for the time-varying variance. Given our task is to construct a long term simulation rather than a short term prediction model, it was decided that the appropriate data frequency to consider were either quarterly or annual.

RBA provided end of month prices for the period January 1980 to August 2002 in $A. From this an annual and a quarterly data series was obtained and subjected to further analysis.

After considerable statistical analysis as outlined in Appendix B, the most appropriate data was the end of quarter data from the RBA and the most relevant period was from December 1988 to June 2002, a sample of 54 data points.

Appendix B The statistical tests

B1 The statistical tests used

This section contains a brief description of the statistical tests used to determine the appropriateness of a normal distribution, homoscedasticity and serial correlations. More details on specific tests can be found in reference [1].

Acceptance or rejection of the null hypothesis is on the basis of P-Values. Both a 1% and 5% level of significances, corresponding to 99% and 95% confidence intervals, were considered. If the P-Value, defined to be the likelihood of observing the value of the test statistic under the null hypothesis is greater than the level of significance (that is 1% or 5%), the null hypothesis is supported, otherwise it is rejected.

B1.1 Tests for Normality

Two formal tests are used to check the appropriateness of a normal population. These are the Chi-Square and Jarque–Bera test.

Chi-Square Test : This test statistic groups the expected and actual values into standard deviation bands. The null hypothesis is a normal underlying population.

Jarque-Bera Test : This test statistic involves the standard deviation and the kurtosis and the null hypothesis is also of a normal population. This is an asymptotic test and is therefore more appropriate for large samples

B1.2 Tests for Homoscedasticity

A process is said to be homoscedastic if the variance does not vary with time. Two formal statistical test used are the Likelihood Ratio test and the one-way analysis of variance (ANOVA).

Likelihood Ratio Test: This test statistic is expressed in terms of the relationship between the arithmetic and geometric averages of the sample variances. This is an asymptotic test and for large samples, the test statistics is asymptotically distributed as a Chi-Squared distribution. The null hypothesis is that the variances are constant.

ANOVA: This test statistic is a F-Distribution and the null hypothesis is the variances are equal and constant.

B1.3 Tests for Serial Correlation

Serial correlation occurs when consecutive values are dependent on each other. The presence of serial correlation implies that the residuals are dependent and so any inference made on such a model will not be stable in the long run. Two formal tests, namely, Auto Regressive Conditional Heteroscedasticity (ARCH) and Durbin-Watson test are used to detect serial correlation.

ARCH Test: This test statistic is the adjusted R^2 that can be shown to be approximately distributed as a Chi-Square distribution. The test can be performed for various lags under the null hypothesis that residual variances are not serially correlated. This test requires the residuals to be regressed on each other. We considered lags of 1, 2 and 3;

Durbin-Watson Test: The test statistic for the Durbin-Watson (DW) is not available in closed form. The statistical package SAS generates the critical values and associated P-Values. This is a two sided test that tests for negative and positive serial correlations. The test statistic requires the residuals to be regressed as an autoregressive process of various lags. We considered lags 1, 2, 3 and 4.

B2 Analysis of Results

These statistical tests were applied to

- the quarterly prices of gold,
- the first difference of the gold price,
- the natural logarithm of the gold price, and
- the natural logarithm of first difference of the gold price.

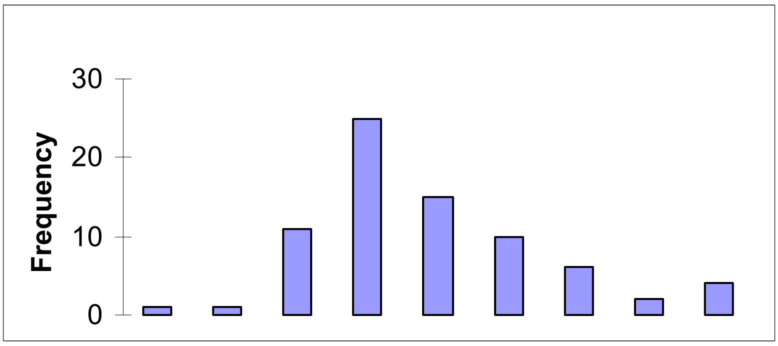
The natural logarithm of the first difference of price was found to be approximately normal, have constant variances and the residuals did not display serial correlation. In effect, this data was a realisation of a second order stationary time series.

The detailed analysis and results of the statistical testing for the four price series used for the period December 1988 to June 2002 are shown below.

B2.1 Quarterly Gold Price

Test for Normality

Sample Statistics	Values
Mean	492.82
Standard Deviation	42.16
Skewness	0.46
Kurtosis	2.79



The histogram shows that the assumption of normality is not supported by the quarterly gold price, despite the skewness and kurtosis not been significantly different from zero and three respectively.

Formally testing normality obtained mixed results. The Chi-Square test supported the null hypothesis while the Jarque-Bera test failed to support the null hypothesis at both the 1% or 5% levels.

Statistical Test	P-Values
Chi-Square	47.01 %
Jarque-Bera	0.00 %

Tests for Homoscedasticity

Statistical Test	P-Values
Likelihood Ratio	11.06 %
ANOVA	0.00 %

The Likelihood Ratio test supported the null hypothesis while the ANOVA test clearly fails to support the null hypothesis, with its P-Value of 0.00%. Therefore no clear conclusions can be drawn.

Tests for Serial Correlation

The P-Values for the ARCH test are:

Lags	P-Values
One	3.46 %
Two	4.45 %
Three	8.13 %

At lags one and two the residuals are serially correlated while at lag three the ARCH test supports the null hypothesis of no serial correlation.

P-Values for Durbin-Watson Statistics was generated by SAS for both positive and negative correlation.

Lags	P-Value : Positive	P-Value : Negative
One	<0.01 %	100.00 %
Two	<0.01 %	100.00 %
Three	<0.01 %	100.00 %
Four	0.40%	99.60 %

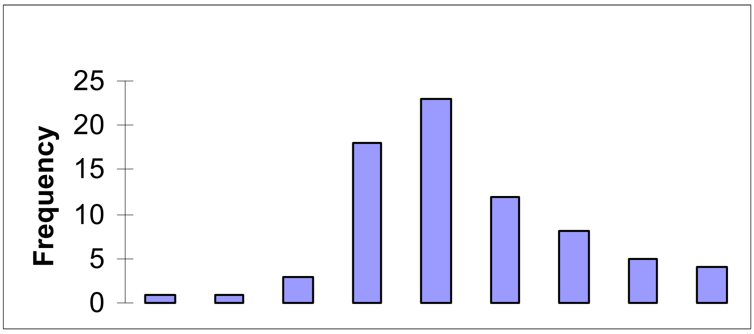
This shows that the null hypothesis is rejected for negative serial correlation and supported for positive serial correlation at all lags.

In summary, the quarterly price data does not support clearly the assumptions of a normal population, while there appears to be heteroscedasticity and serial correlation. Therefore, this price data cannot be used to develop a simulation model.

B2.2 Logarithm of Quarterly Gold Price

Test for Normality

Sample Statistics	Values
Mean	6.20
Standard Deviation	0.085
Skewness	0.26
Kurtosis	2.80



The histogram shows support for the assumption of normality. Both the skewness and kurtosis are not significantly different from zero and three, respectively.

Both the Chi-Square and Jarque-Bera test strongly support the null hypothesis.

Statistical Test	**P-Values**
Chi-Square	76.39%
Jarque-Bera	92.57%

Tests for Homoscedasticity

Statistical Test	**P-Values**
Likelihood Ratio	18.57 %
ANOVA	0.00 %

The Likelihood Ratio test supported the null hypothesis while the ANOVA clearly fails to support the null hypothesis. Therefore no clear conclusions can be drawn.

Tests for Serial Correlation

The P-Values for the ARCH test are:

Lags	**P-Values**
One	5.75%
Two	9.34%
Three	15.10%

The Null hypothesis is supported at all lags by the ARCH test as all P-Values exceed 5%.

P-Values for Durbin-Watson Statistics as generated by SAS for both positive and negative correlation are:

Lags	P-Value : Positive	P-Value : Negative
One	<0.01 %	100.00 %
Two	<0.01 %	100.00 %
Three	<0.01 %	100.00 %
Four	0.53%	99.47 %

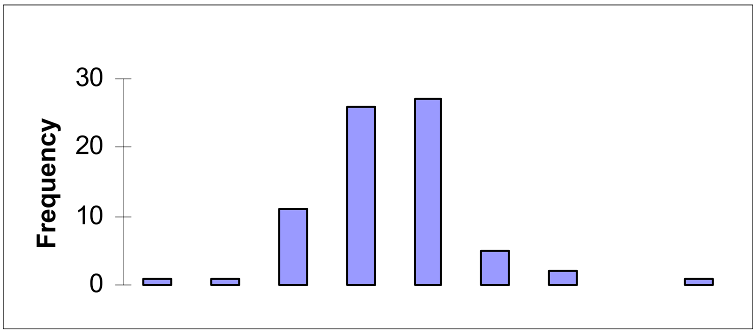
Durbin-Watson shows the residuals have positive serial correlation.

In summary, the logarithm of prices is a possible data set to build the simulation model. Further transformation or differencing may remove this positive serial correlation or a separate moving average model may be fitted to the residuals.

B2.3 Difference of Quarterly Gold Price

Test for Normality

Sample Statistics	Values
Mean	1.56
Standard Deviation	30.00
Skewness	0.44
Kurtosis	3.01



The histogram clearly shows an outlier that will distort the normality of the population. This also explains the small mean and large standard deviation.

The Chi-Square test does not account for this outlier and so supported the null hypothesis while the Jarque-Bera failed to support the null hypothesis. It should be noted that the P-Value for the Chi-Square statistics are not significantly different from that of the price data itself.

Statistical Test	P-Values
Chi-Square	76.55%
Jarque-Bera	0.00%

Tests for Homoscedasticity

Statistical Test	P-Values
Likelihood Ratio	76.55%
ANOVA	75.60%

Both the Likelihood Ratio test and ANOVA strongly support the null hypothesis.

Tests for Serial Correlation

The P-Values for the ARCH test are:

Lags	P-Values
One	91.72%
Two	84.81%
Three	92.02%

The Null hypothesis is supported at all lags by the ARCH test.

P-Values for Durbin-Watson Statistics as generated by SAS for both positive and negative correlation are:

Lags	P-Value : Positive	P-Value : Negative
One	99.53%	0.47 %
Two	27.44%	72.56%
Three	26.48%	73.52%
Four	66.67%	33.33%

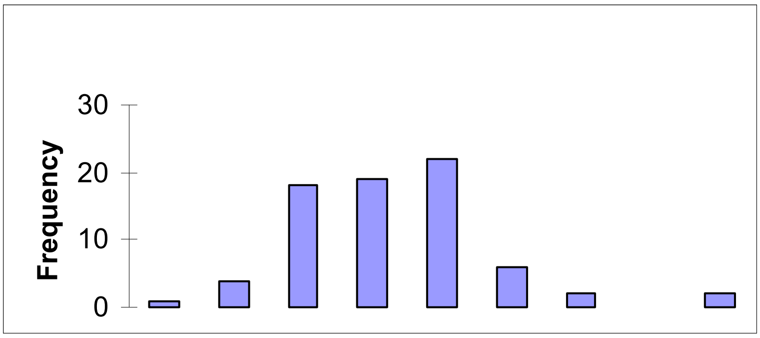
At lag one Durbin-Watson shows the residuals have negative serial correlation and no serial correlation at lags two to four.

So in summary, the difference of prices could have been used as a time series simulation model after the nature of the outlier is investigated.

B2.4 Logarithm of Difference of Quarterly Gold Price

Test for Normality

Sample Statistics	Values
Mean	0.003
Standard Deviation	0.061
Skewness	0.39
Kurtosis	2.94



The sample skewness and kurtosis shows that a normality approximation may be valid. The outlier does not distort the spread as much as it did for the first difference.

Statistical Test	P-Values
Chi-Square	54.81%
Jarque-Bera	97.89%

Both the Chi-Square and Jarque-Bera test strongly supports the normality assumption.

Tests for Homoscedasticity

Statistical Test	P-Values
Likelihood Ratio	79.48%
ANOVA	76.42%

Both the Likelihood Ratio test and ANOVA strongly support the null hypothesis.

Tests for Serial Correlation

The P-Values for the ARCH test are:

Lags	P-Values
One	82.55%
Two	79.06%
Three	91.48%

Null hypothesis is supported at all lags by the ARCH test.

P-Values for Durbin-Watson Statistics as generated by SAS for both positive and negative correlation are:

Lags	P-Value : Positive	P-Value : Negative
One	99.46%	0.54%
Two	32.25%	67.49%
Three	26.48%	73.52%
Four	71.85%	28.15%

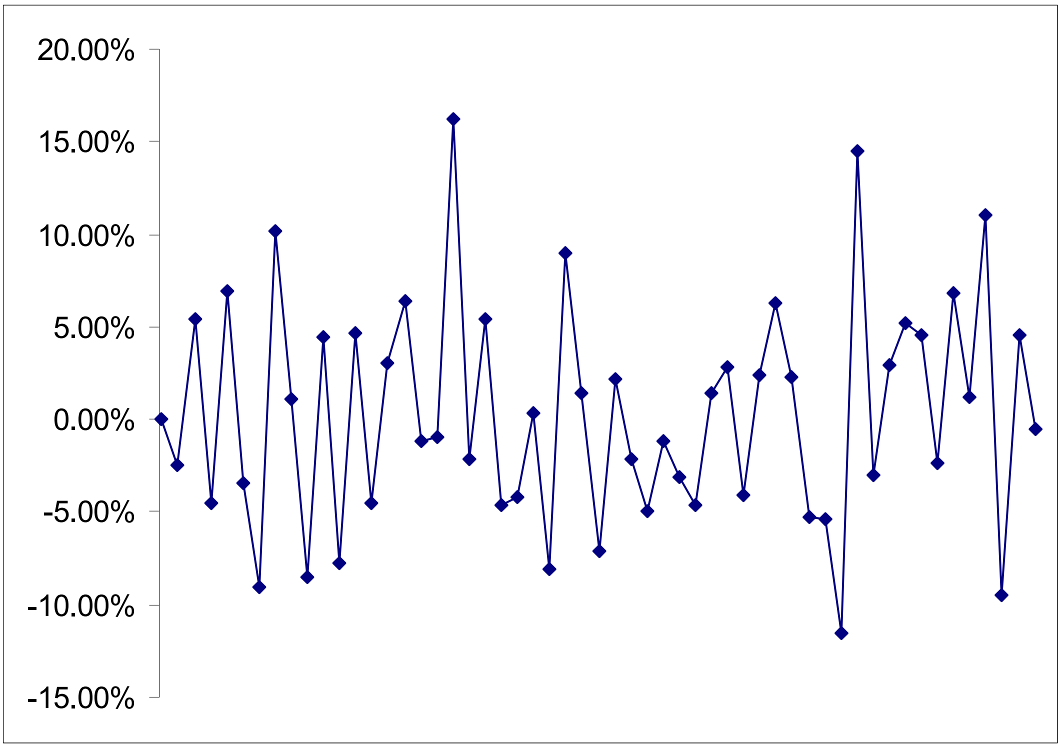
At lag one Durbin-Watson shows the residuals have negative serial correlation and no serial correlation at lags two to four.

In summary, the logarithm of difference of prices could be used as a time series.

In effect, the statistical tests do not provide a significant basis to choose between the logarithm of price and the logarithm of the price difference. Therefore other considerations need to be taken into account. We have selected the logarithm of the price difference as this has a natural interpretation as the continuously compounded rate of return.

Figure B1 shows the historical pattern of the logarithm of the first difference of the quarterly gold price.

Figure B1: Log of the First Difference of Quarterly Gold Price



Appendix C The gold model used

C1 Model Identification and Parameter Estimation

Examination of partial autocorrelation function (PACF) plots in SAS of the logarithm of price difference showed that the PACF had a single peak at lag 1 outside the two standard errors range. This indicated a possible Autoregressive process of order 1, that is AR(1).

Maximum likelihood method (MLM) was used to estimate the parameter.

MLM Parameter	Standard Error	P-Value
-0.333833	13.05 %	1.05 %

The P-Value is for the t-Statistic with the null hypothesis that the estimated parameter is zero. This null hypothesis at a 5% level of significance is not supported, hence the maximum likelihood estimate is significant.

Parameter stability was checked by re-fitting the model via the method of generalised least squares (GLS).

GLS Parameter	Standard Error	P-Value
-0.333833	13.05 %	1.35 %

The GLS parameter estimate and standard error are no different from that obtained via the MLM and the P-Value does not support the null hypothesis of a zero parameter.

To determine that an AR(1) process provided a balance between fidelity to data and parsimony of the model, we used Akaike Information Criteria (AIC) (see [2] and [3]). This approach requires the fitting of higher order models and examination of the AIC, where smaller values of AIC indicate better fits. Also the standard error and P-Values are considered. To this effect, we fitted an AR(2) model using the MLM.

Order of AR	AIC	Standard Error	P-Value
One	-150.33	13.05 %	1.05 %
Two	-145.22	14.10 %	74.23 %

The AIC for AR(2) has increased, supporting an AR(1) model. Also, the P-Value for the additional parameter strongly supports the null hypothesis of a zero value.

So the fitted model used for simulation is

$$X_t = -0.33383 * X_{t-1} + e_t$$

where $X_t = Log(G_t/G_{t-1})$ and G_t is the gold price in quarter t,
e_t is normally distributed with a mean of zero and a standard deviation of 0.061, and
X_0 is calculated such that the mean return for the simulated period is in line with the assumption used.

C2 Linkage with Other Economic Variables

We also attempted to identify if there were any additional economic variables or investment returns from other asset class returns that could be used as a explanatory variable for gold returns. This was done by using the GLS to fit these additional lagged variables to the AR(1) model above and observing the P-Value of the additional parameter. A small P-Value supports the hypothesis that the variable is an additional explanatory variable. The variables considered were GDP, CPI, Australian Equities return and Overseas Equities return.

Lagged Variable	P-Value
GDP	8.18%
CPI	67.88%
Australian Equities	9.84%
Overseas Equities	56.78%

At both 1% and 5% levels of significance, no other variable provides any additional information about gold returns.

C3 Diagnostics Checking

The final testing before the model can be used for simulation is to check that the residuals are approximately a white noise process. That is, they are independent and identically distributed normal variables.
In order to check this, we applied the same two tests used above, namely the Chi-Square and Jarque-Bera test for normality. In addition, we applied two other tests, the turning points test and the difference-sign test. Details of these can be found in the Reference [1].

Statistical Test	P-Value
Chi-Square	82.68 %
Jarque-Bera	97.43 %
Turning Points	58.70 %
Difference-Sign	58.79 %

All these tests strongly support the null hypothesis that the residuals are white noise.

References

[1] P.J Brockwell & R.A Davis, (1991) *Time Series: Theory and Methods*, Springer-Verlag New York.

[2] M. Pourahmadi, (2001), *Foundations of Time Series Analysis and Predication Theory*, Wiley , New York.

[3] H. Akaike, (1969), Fitting autoregressive models for predication, *Annals of the Institute of Statistical Mathematics*, Tokyo, 21, 243-247.