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**Auditing Daily Prices :
Administrative and Investment Errors**

by

Anthony Asher and Rita Cham

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Division of Economic and Financial Studies
Macquarie University
Sydney NSW 2109 Australia

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AUDITING DAILY PRICES: ADMINISTRATIVE AND INVESTMENT ERRORS

Anthony Asher and Rita Cham
Australian Prudential Regulation Authority

1 Introduction

The Australian Prudential Regulation Authority (APRA) is responsible for “regulating bodies in the financial sector in accordance with other laws of the Commonwealth that provide for prudential regulation or for retirement income standards.”¹

Many of the life insurance companies and superannuation funds it regulates offer investment unit linked products. Although statistics are not collected on the extent of “unitisation”, retail funds, priced daily, account for over \$200 billion or 15% of the assets regulated by APRA. Of the order of another \$100 billion is held by unit trusts that are not regulated by APRA.

Unit linked products do not represent a particularly difficult prudential challenge. Regulators are concerned that:

- unitholders are properly informed about the nature of the underlying investments, often expressed in terms of the investment management being “true to label”;
- unitholders are properly informed of the charges being made,
- fiduciary responsibilities, to act with care and avoid conflicts of interest, are met; and
- there are no administrative errors.

The determination of daily unit prices is however a relatively complex exercise that involves valuing all assets and liabilities accurately every time the prices change. Most difficult are the liabilities and assets that arise from taxes on capital gains to be realised in future. Daily pricing faces ongoing time pressures. Administrative problems are regularly reported to regulators, and sometimes in the Australian press.

Underperformance related to fiduciary failure is always a possibility. An APRA research project reported in Coleman *et al* (2003), found significant differences in the investment performance reported by different types of funds. This project raised questions as to whether these differences could be explained by factors beyond the control of investment managers or whether they were related to charges and poor asset selection. As a

¹ *Australian Prudential Regulation Authority Act 1998 - Section 8*

continuation of the project, we investigated whether published daily prices could be examined for evidence of persistent underperformance.

The published daily movements in unit price were used to:

- a) estimate the average asset allocation over the past year,
- b) estimate daily price movements consistent with this asset allocation and compare them with the actual price movements, and
- c) compare the cumulative effect of these estimated or fitted movements with the actual movements over the past year.

The results from (a) provide a check on whether the fund is investing “true to label”.

Graphs of (b) and (c) show whether there have been significant price movements over the year that are not explained by our estimates. Significant in this context means something of 0.5% upwards in a day.

We also calculate the total “overperformance” for the year relative to the asset allocation that has been determined, after an approximate adjustment for taxes.

2 Developing the analysis

2.1 The data

We investigated the unit prices for superannuation funds of ten large investment administration platforms (mainly life insurance companies) based in Australia. The unit prices and the prices for the relevant indices were obtained from Bloomberg. The selection of length of investigation period was a trade-off between obtaining sufficient data points and a desire not to have to repeat the exercise too frequently, and the loss of accuracy that would arise as asset allocations change. We elected to use one year (256 trading days) from 1 September 2003. The investigation was restricted to funds that were active for the length of the full year as it made it easier to run the spreadsheet analysis. As a result 640 funds were studied. These included local and international equity, property, bond and mixed funds as shown in the table in section 2.8 below.

2.2 Estimating the asset allocation

Estimating the asset allocation as a prelude to measuring underperformance was suggested by Sharpe (1992). He was however interested in longer term performance and management style, and used monthly data.

Daily data obviously provides more information over a shorter time period and allows for a more accurate analysis. The results would be relatively more accurate for funds where asset allocations were stable, and where the stocks chosen tracked the relevant indices fairly closely.

2.3 The model

In order to make the absolute value of the coefficients meaningful, we standardised all unit prices and index prices to a base of 1 at the beginning of the investigation period. The estimated coefficients for each index therefore provided estimates of the proportion of assets allocated to the investments represented by the index.

$$SP_t = \text{Price}_t / \text{Price}_0.$$

SP_t = Standardised price at time t

Unit prices cannot be statistically regressed against index values because of the autocorrelation inherent in stock prices. We therefore analysed daily differences of these standardised prices, on the assumption that they would be effectively stationary.

We specified the model as:

$$DD_t = a + b_1 F_{1t} + b_2 F_{2t} \dots + b_{23} F_{23t} + \varepsilon_t \quad (1)$$

Where DD_t is the observed daily differences of the fund on day t ; F_{it} 's are the observed daily differences of the 23 indices chosen; a is a constant; b_i 's estimate the asset allocation of the fund and ε_t an error term.

From the values A and B_i derived from equation (1), it is possible to determine fitted daily differences:

$$FDD_t = A + B_1 F_{1t} + B_2 F_{2t} \dots + B_{23} F_{23t} \quad (2)$$

Fitted standardised prices (FSP) can also be calculated as:

$$FSP_T = SP_0 + \sum_{t=1}^T FDD_t = SP_0 + FDD_1 + FDD_2 + \dots + FDD_T \quad (3)$$

These fitted prices would be correct if the allocation to the assets in the underlying indices does not change over the year, the return earned exactly replicated the corresponding underlying indices and there were no expenses and tax. The allocation to the assets in each index will be some weighted average over the year.

The constant in the model incorporates the persistent effects of stock selection, transaction costs, interest earnings, on any portion of the fund not allocated to an index, and fees. The error term therefore includes the total of investment bets against the average asset allocation, deviations of interest income and expense accrual from the constant and unit pricing errors. Errors would be expected to be visible to the extent that they were larger and less frequent than tracking errors.

2.4 Statistical justification

Because the alternative indices are correlated (indeed many overlap), multicollinearity means that ordinary regression produces meaningless data with significant negative coefficients for some indices. While negative coefficients are theoretically possible, we felt entitled to assume no asset shorting, consistent with the governing regulations². Asset allocation weightings were therefore constrained to be non-negative, and (except for the currency weighting) sum to 100% or less. Sharpe's model is effectively extended further by the inclusion of a variety of different indices, a constant and a currency hedging factor.

The model is estimated by minimising the error sum of squares ($\sum \varepsilon_i^2$) using Solver in MS Excel, in a similar approach as Atkinson & Choi (2002). This approach is related to accuracy and tracking error investigations documented by Frino *et al* (2004), Pope & Yadav (1994) and Roll (1992).

We measured the goodness of fit by calculating the reduction of sum of squares $1 - (\sum \varepsilon_i^2) / (\sum DD_i^2)$, which does not significantly differ from the R^2 measure defined as $1 - \text{Var}(\varepsilon) / \text{Var}(DD)$. We use R^2 to refer to our statistic in the balance of this paper.

Pope and Yadav (1994) point out that negative serial correlation in errors will result in overstatement of the variance of errors when based on high frequency data, and vice versa. As discussed in section 2.8 below, statistical significance turned out to be of little interest to us, so there was no point in accurately determining the size of the variance.

2.5 Choice of indices

The indices were limited to those available on Bloomberg. No extensive testing was done, but we chose those we believed would be most likely to differ from each other, and to reflect the portfolios we were examining. Having constrained the coefficients and being largely unconcerned about statistical significance, there was no obvious reason to avoid overlapping indices or over-determination. The use of a whole year's data meant that there were enough observations not to need to restrict the number of indices to use. The list used is shown in sample output shown in the appendix. For consistency with the determination of the unit prices, the indices are accumulation indices denominated in Australian dollars. The amount "unallocated" is the difference between 100% and the sum of the coefficients of the indices (excluding currency).

We included Australian and World all share indices lagged by one and two days respectively to allow for the possibility of historic pricing, which turned

² Superannuation Industry (Supervision) Act 1993 - Sections 67, 95 and 97

out to be relatively common particularly with multi-manager and international funds. The more volatile the unit price, the more historic pricing exposes the fund to possible manipulation. Where an entity is inconsistent with price delays (as occurs with multi- manager funds where the different managers use different lags), the weights of the lagged indices are indicative of the proportion of price changes that are sensitive to market returns on previous days.

2.6 Hedging

The value of the Australian Dollar (AUD) in US dollars (USD) was included as an index. This ignored any hedging in other currencies, and effectively assumed that the fund enters into hedging contracts with no link to the changes in the value of foreign assets in their home currency. This is likely to reflect the short run position, but is unlikely to be true over the year. It is nevertheless more tractable and attempts at refinement proved unhelpful. During the investigation period the AUD was more volatile than previous years, and appeared to have a significant impact on the price of some funds. We attempted to refine our analysis to accommodate possible changes in hedging policy by splitting AUD into three phases that roughly coincided with the different trends in the value of the AUD. This attempt improved the goodness of fit by less than 1%, and so is not reported.

2.7 Checks on validity

We used three methods, initially, to check the validity of our methodology:

2.7.1 ASX 100 index

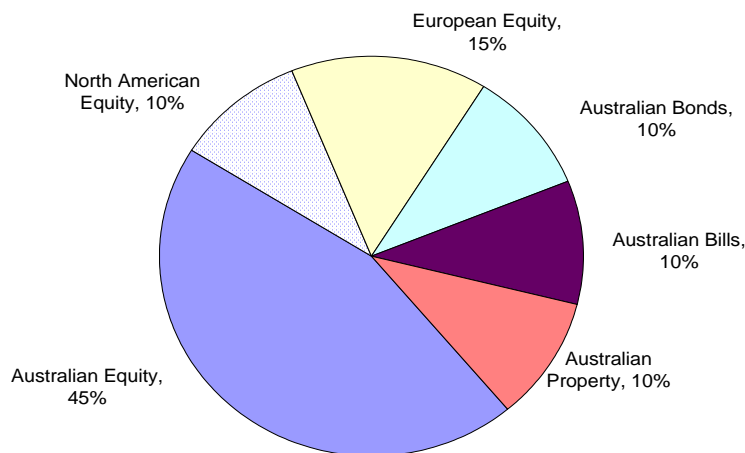
We compared the actual capitalizations of the constituents of the ASX 100 index with fitted data from the model (estimating the “allocation” of the index to each of its constituents). The results were reasonable, but distorted by shares for which we did not have prices for the full period.

Another index consisting of the 94 shares that were included in ASX 100 for the full year was constructed and compared with estimates from our model. About 90% of the estimates fell within 0.025% of the actual weightings and a R^2 of 1.000000 was achieved. This was pleasing as it implied we had more than enough data to use the 23 indices we wanted (far fewer than the 94 shares).

2.7.2 Balanced fund, with changes to asset allocation

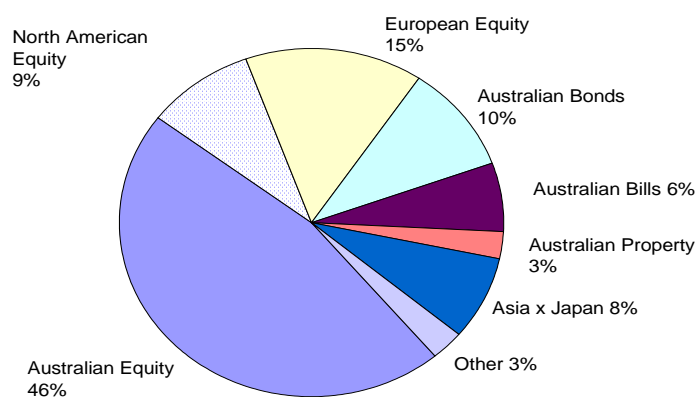
We also constructed a passive unhedged balanced portfolio consisting of allocations to eight different indices. The model was able to identify correctly the portfolio (within 1%) and produced a R^2 of 99.97%. The results again demonstrated that, given a static portfolio, quality data and an appropriate selection of indices, this method will accurately estimate the asset allocations. The allocation is shown in Figure 1a.

Figure 1a: Static portfolio



This portfolio was then altered so that, for the second half of the year the 10% of the assets invested in Australian property was exchanged for Asia ex Japan equity. The R^2 fell to 97% although it still selected the correct indices and gave an acceptable estimation of the asset allocation - as can be seen from Figure 1b.

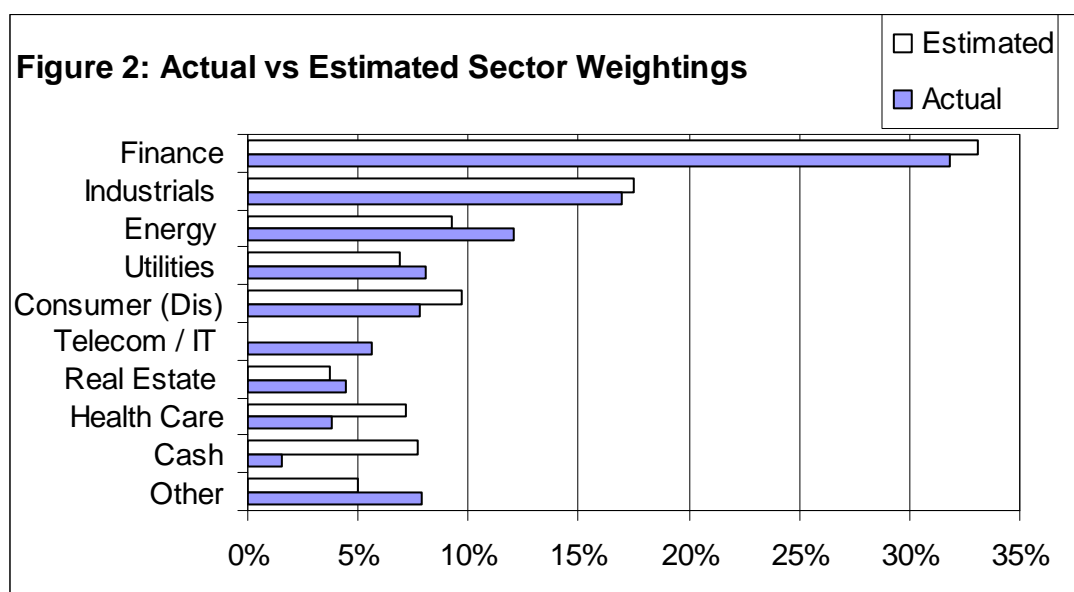
Figure 1b: Rotating 10%



We then constructed a portfolio initially of a 100% Australian growth portfolio, and 10% of the portfolio was "rotated" each quarter, first to European, then Japanese and the finally North American shares. The model identified the 90% Australian component of the portfolio but failed to find the appropriate international shares.

The method cannot therefore be regarded as robust for changes to tactical asset allocation of this magnitude.

2.7.3 US mutual funds with known asset allocations



For US mutual funds, the set of indices used was revised to consist of the GICS sector indices of SPX 500, real estate securities index, several regional indices, global bonds index and Euro/USD. Prices of 34 mutual funds from a large fund manager were analysed. The estimated asset allocations of 15 domestic funds are broadly consistent with those published by the funds manager, after allowing for some differences in industry classifications. Figure 2 shows the actual and estimated allocations of a domestic growth and income fund. Reasonable estimates were achieved, although the 5% in Telecom and IT stocks was not identified, and the cash significantly overestimated. This may reflect fee deductions.

The analysis of international and global asset allocation funds failed to distinguish correctly between different regions. In particular there appeared to be a bias towards the US consumer discretionary and telecom/IT sectors. The reasons probably relate to multi-collinearity amongst the indices and the use of an insufficient variety of indices and currencies.

It would seem that we would need to know more about the details of US pricing before the model could be properly calibrated.

Overall, our initial impression was that fairly accurate estimates could be achieved with the appropriate selection of indices. As we examined the data, it emerged that the use of the model to examine errors in daily prices of a short term nature, is not overly dependent on accurate asset allocations. Relative performance, on the other hand, is largely dependent on asset allocation, and comparisons are unreliable if the asset allocation is relatively inaccurate - which will normally be indicated by a lower R^2 .

2.8 Statistical significance?

At this stage, no attempt has been made to estimate the statistical significance of the errors. The significance is distorted by multi-collinearity, autocorrelation, any number of pricing idiosyncrasies and errors, and the effects of significant changes in asset composition.

The practical issue at stake is materiality rather than significance, and most funds worked off the 0.3% rule of thumb adopted by the industry body, Investment and Financial Services Association³. For many funds, visual evaluation of the deviations allowed us to pick out anomalous movements smaller than 0.3%. In other cases, our approach was to choose between five and ten large anomalies from each entity - in order to keep the enquiry to a manageable size.

It might, in due course, be possible to derive algorithms for determining which types of anomaly are worth investigating, but the wide variety of possible errors, and the tax and other peculiarities that may explain anomalies, make it likely that an experienced eye running over the graphs we produced will be able to identify the most likely problems more reliably.

The table below shows the R^2 values for the different types of fund. The values are lower for debt funds as the daily differences are more uniform and subject to rounding errors and so less susceptible to "improvement". Analyses with an R^2 under 50% are obviously less reliable, but as shown in section 4.4 below, not without value.

Asset type	Funds	R^2 over 80%		R^2 under 50%	
<i>Unknown</i>	57	15	26%	10	18%
<i>General equity</i>	307	119	39%	52	17%
<i>Specialised equity</i>	123	58	47%	25	20%
<i>Debt</i>	59	13	22%	22	37%
<i>Mixed equity and debt</i>	94	34	36%	14	15%
TOTAL	640	239	37%	123	19%

An analysis of R^2 s by administrative platform partly indicated their policy on tracking errors relative to benchmark indices, and partly the quality of the unit pricing process. The proportion of different entities' funds with an R^2 over 80% varied from 4% to 70%.

3 True to label?

Bloomberg staff told us that Australia was unique in not requiring unit trusts to disclose their asset allocation. One of APRA's regulatory concerns is that the funds are indeed investing in a manner consistent with their disclosed strategy. The funds were mainly classified by their managers as follows.

³ See [http://www.ifsa.com.au/IFSAWeb/Attach.nsf/Attachments/Standards+and+Guidance+Notes+-Incorrect+Pricing+of+Scheme+Units+Guidance+Notes/\\$File/4GN_Incorrect_Pricing_of_Scheme-Units.pdf](http://www.ifsa.com.au/IFSAWeb/Attach.nsf/Attachments/Standards+and+Guidance+Notes+-Incorrect+Pricing+of+Scheme+Units+Guidance+Notes/$File/4GN_Incorrect_Pricing_of_Scheme-Units.pdf)

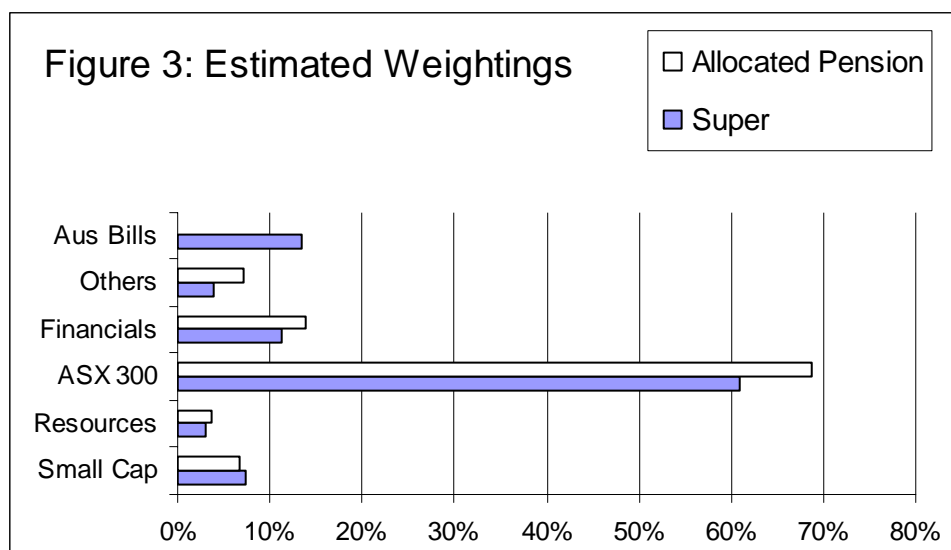
- Share, property or bond funds,
- Growth funds, which might be expected to have as much as 20% in fixed interest investments,
- Balanced funds with up to 40% in fixed interest, and
- Capital stable funds, with 60% and more in fixed interest.

3.1 Tax effects

It soon became clear that the results would have to be interpreted cautiously. In particular, there was a bias towards fixed interest assets. Most of this appears to arise from tax effects. Australian superannuation funds pay tax at 15% on investment income less expenses, and on capital gains realised with a year. The rate for the latter falls to 10% for gains realised after a year.

Up to 15% of the fitted weighting in bonds and bills may therefore be recognized as a tax effect, which reduces both daily gains and losses. In reality where future tax benefits or liabilities are discounted and shares can be kept over an extended period, the actual tax rate applied may be as little as 6%.

Figure 3 shows the estimated weightings for an Australian equity investment option, offered as an allocated pension fund and as a superannuation fund. Allocated pension funds are not liable for tax and it can be observed that the superannuation fund has a 15% weighting in bills, while other weightings are proportionately less than the pension fund. Provision is made daily for the tax which is paid quarterly to the Australian Tax Office. While interest is normally earned on this provision, the average balance would be some one eighth of the annual tax provision: it is not clear why the full 15% appears to be allocated to bills.



We had expected larger amounts in unallocated - effectively earning no return. In other funds, we did obtain a higher proportion as 'unallocated',

but it appeared to be accompanied by lack of fit often due to lags, as well as large number of reported zero changes in the unit price.

3.2 Results

As might be expected from larger entities, and especially as there are no particular advantages in mislabelling, we found only a handful of funds with incorrect Bloomberg labels, and all appeared to be genuine errors of communication between Bloomberg and the administrator.

There were 6 specialist Australian funds for which we failed to produce reasonable or helpful estimates - as we appeared not to have identified appropriate indices. Five of them were fixed interest funds, one a small cap fund and another largely invested in the industrials sector.

4 Pricing errors

A number of common errors were found.

4.1 Zero changes

We found that over 100 funds, excluding cash funds, had a large number of zero changes in their unit prices - ranging from 20 to 130 days out of 256. Apart from reducing the power of the model - on average, 10 zero changes reduced the R^2 by 3.7% - a large number of zero changes indicates, in itself, ongoing problems with the administrative processes that we were effectively auditing. APRA supervisors have increased their level of oversight of those entities where this was a problem.

4.2 Price lags

If, from the poor fit or a heavy weighting (more than 20%) in the lagged indices, it appeared that the units were historically priced, then we repeated the analysis with all indices lagged by one.

Out of the ten companies we investigated, three used forward pricing, three a mix of methods, while the rest appeared to have delays of up to 3 days. This could present a problem if indeed the prices were published the same day as they were applied to transactions and were volatile - so allowing for "market timing".

Those funds with price lags had, on average, lower R^2 by some 4% per day. Possible explanations would include other administrative problems or inconsistent lags for different assets. Price lags appear often to be an indicator of non-automated systems inevitably subject to greater errors.

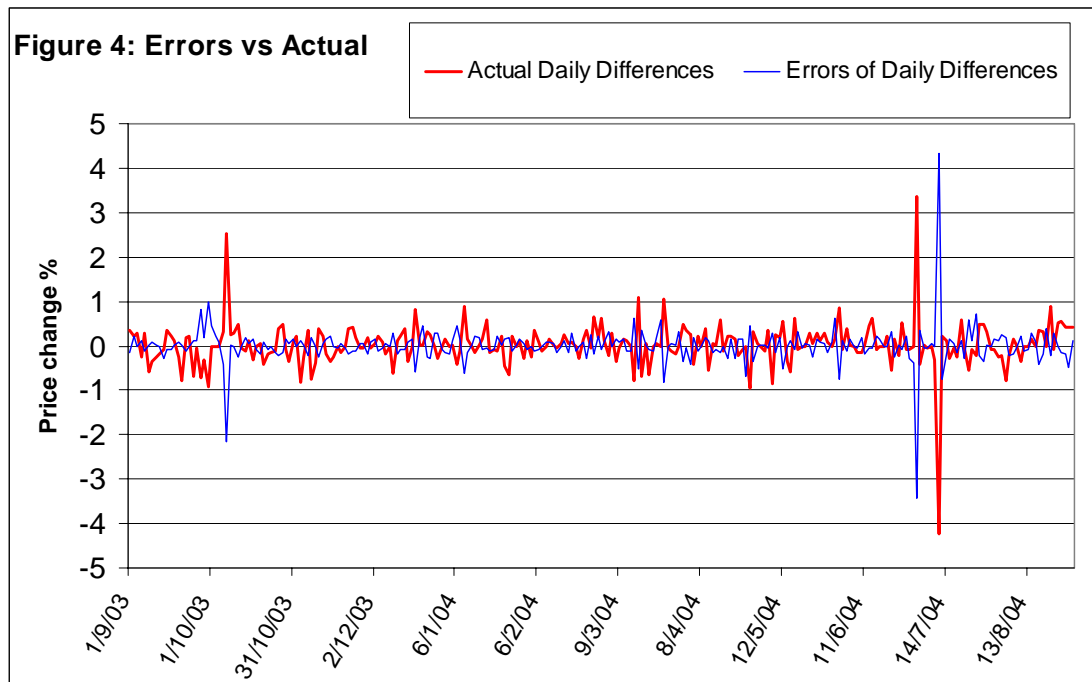
4.3 Investment or measurement errors?

Sharpe (1992) suggested that the R^2 indicates how much the price volatility can be attributed to changes in its asset allocation, and in stock selection.

As the previous two sections have shown, it is also reduced, sometimes more significantly, by administrative problems. On average our model was able to explain 72.9% of the daily price movements but only 44% of price movements of those funds with obvious pricing errors.

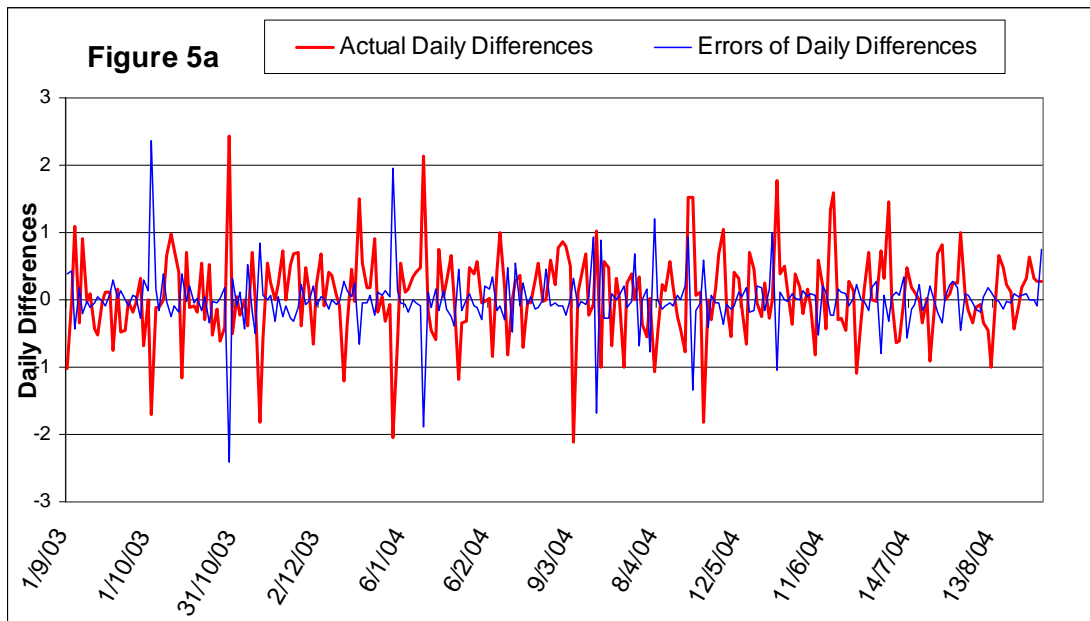
4.4 Obvious errors in reporting

The actual daily differences and the errors (residuals) over the investigation period were graphed. Large spikes in the graph suggested a pricing error. Figure 4 gives an example, for a diversified fund.

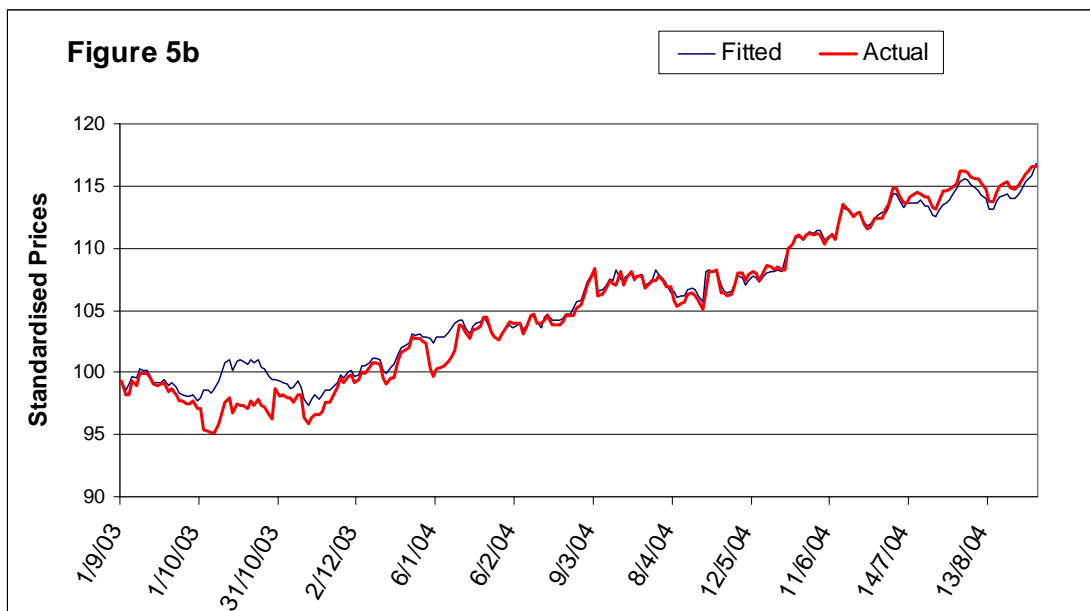


The jumps in October 2003 and July 2004, with their corrections about a week later, clearly suggest errors. Regulated entities would be expected to correct the unit price and compensate unitholders. The published prices should also be corrected to enable unitholders to check their allocations, independently, and to make accurate performance comparisons.

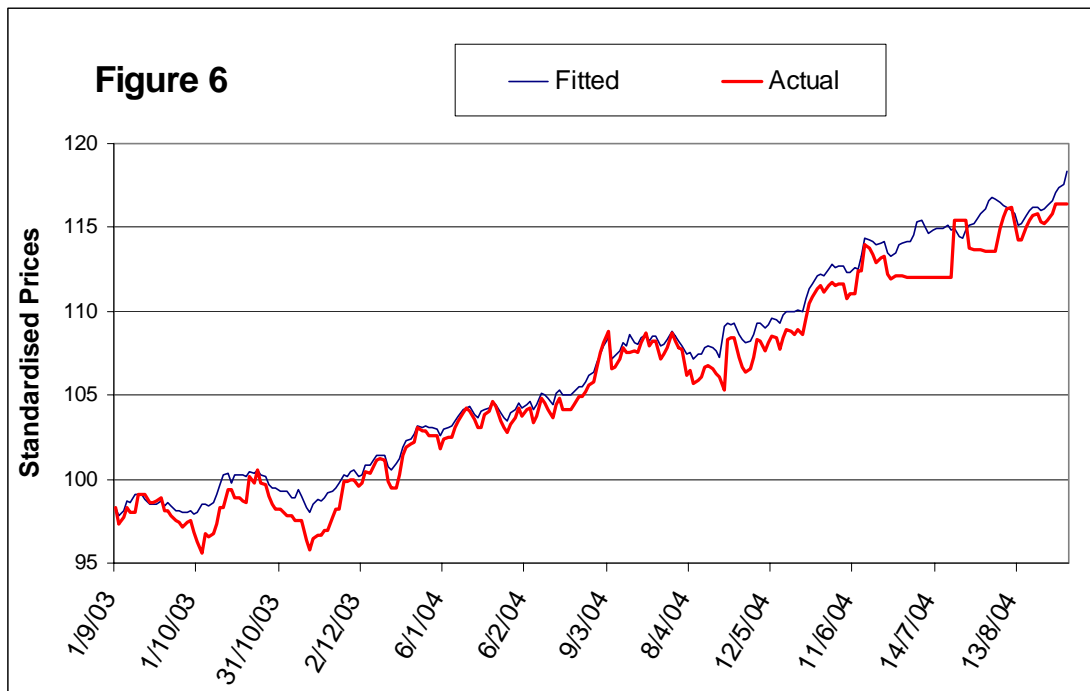
It is true however that any graph of the unit price would pick up such an egregious error. Not all errors are as easy. Figure 5a gives another example, this time of a real-estate fund.



The daily movements are more volatile if not erratic, which should not be the case for a property fund, but it would not be immediately clear that there were problems if one was examining the actual daily differences or the prices shown in Figure 5b. That there is a problem becomes clearer when looking at the fitted prices in Figures 5a and 5b especially when the actual dates can be read. The drop in the price on 1 October 2003 and the increase a month later, and the similar pattern after 1 January 2004 make it highly likely that there were errors made as part of a quarterly process.



Errors could even be found in funds with relatively low R^2 . Figure 6 is derived from a real estate fund with an R^2 of 33%. Apart from the obvious problem of the price "freeze" in July 2004, the other deviations from the fitted also proved to be errors.



5 Identifying performance shortfalls

The overperformance for one year (as % p.a.) is calculated taking into account the trend component from our analysis, estimated franking credits and capital gains tax. Management and administration expenses were not included.

$$\text{Overperformance} = 256 A + (\text{SP}_{256} - \text{FSP}_{256}) - \% \text{unallocated} \times 5\% \quad (4)$$

The estimated amount of tax paid is calculated as

$$\text{Tax Paid} = 15\% \times (\text{SP}_{256} - \text{SP}_0) - 25\% \times (5\% \text{ of Australian Stocks}) \quad (5)$$

The first term estimates amount of income and capital gains tax, and the second term the franking credits received, assuming a 5% dividend rate and franking credit of 25%, which approximated the averages being paid on Australian shares in 2003. The annual tax adjusted performance is then equal to the sum of (4) and (5).

Of the 640 funds analysed, the average tax adjusted underperformance is some 1.78%. We believe that this is somewhat less than the average fee, which suggested that the average fund may have beaten its benchmarks. Different managers have averaged between -4% and 2.77%.

We have been particularly cautious in drawing conclusions about individual funds or managers. Poor fits are clearly unreliable, and the underperformance of some funds can be explained by higher disclosed fees. Only 3 funds with an R^2 of over 90% underperformed by less than 5%, and two of these had higher disclosed fees. Stock selection appeared to explain the third.

A more sophisticated analysis over a number of years, which could allow for changing investment styles, might well identify more persistent under-performance that would be prudentially worrying. Such a project does not fit APRA's current priorities.

6 Outcomes

The anomalies for each managing entity were collated and given to the respective supervisors, who relayed the questions to the entity concerned. Both supervisors and entities were given more detailed explanations of the analysis and possible interpretations of the data.

Following investigation by the supervised entities, the following reasons for the anomalies were reported to us.

- Prices were wrongly transferred to Bloomberg.
- Errors have been made in manually reversing transactions originally made in error.
- Interest and dividend accruals were incorrectly distributed.
- Tax was incorrectly calculated, or significant changes had been made to the method for used to determine the accrual of deferred tax assets or liabilities.
- Three managing entities with generally lower R^2 values were found to have widespread and systematic errors with their pricing mainly related to accruals. Two were already in the process of investigating and correcting the problems. A third was alerted to the problems by our queries.

The entities questioned have largely responded positively to the investigation, in some cases asking for copies of the Excel workbook.

It is clear that good practice in unit pricing means that the daily price movements are compared with known movements in the underlying asset prices as determined by the change in the indices. The method suggested here has the advantage that it uses publicly available data that can be checked by unitholders and is not reliant on information taken from the administrators. It therefore reflects a true segregation of the duties of auditors and administrators.

The method also illustrates the power of appropriately designed graphs in the facilitating the rapid audit of large volumes of data.

7 Conclusion

Daily prices, not surprisingly, can be used to reveal the underlying asset allocations of unitised funds.

The model developed can be used to confirm that unitised funds are invested "true to label," identify errors in daily unit pricing and egregious

examples of persistent underperformance. It thus provides a useful tool for auditors and regulators.

It could also be used to provide relatively up-to-date information on the significant investment holdings of competing investment managers.

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APPENDIX: Sample Output

FUND	XXX	Global Shares
Benchmark	#N/A N Ap	
Type	SUPER	Global Equity
Estimated Asset Allocation		
0% UNALLOCATED		
0% AS30-1		ASX 500 LAG 1
0% ASA38 Index		Aus Small Cap
0% ASA45 Index		ASX 200 Resources
1% ASA52 Index		ASX 300
0% ASA5FIN Index		ASX 200 Fins
6% ASA5INDU Index		ASX 300 indust.
1% GDLGAT Index		Aus Growth
6% GDLVAT Index		Aus Value
0% GDDUEURO Index		Europe
6% GDDUJN Index		Japan
9% GDDUNA Index		North America
9% GDUECAXJ Index		Asia x Japan
3% GDUEEGF Index		Emerging Markets
2% GDUEWFXA-1		World x Aus LAG 1
1% GDUEWFXA-2		World x Aus LAG 2
10% GDUGWXA Index		World Growth
9% GDWUIT Index		World IT x Aus
7% MXWOOSC Index		World Small Cap x Aus (Pindex)
0% ACPALL Index		Aus Bonds
0% AUBI Index		Aus Bills
28% SBWGNADU Index		World Bonds
33% AUD Curncy		Aus Dollar
0% ASA6PROP Index		Aus Property

Number of Zero Changes 3
Reduction of SS 81%

-8.74% Annual Overperformance
(Unadjusted for fees and tax)

-0.54% Estimated Tax

-9.28% Annual Overperformance net of tax

Assumptions

- 15% Capital Gains Tax
- 25% Franking Credits
- 5% Dividends as % of Australian Shares

1 The main question here is why the underperformance?
2 Could also ask whether 28% bonds is correct - it may be that they have invested in infrastructure and utilities that move with interest rates.

