Does portfolio emulation outperform its target funds?

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Abstract

An emulation fund is designed to reduce trading activity, thereby lowering costs, for a multi-manager fund. It does this by delaying, and potentially combining, trading decisions from each employed fund manager to eliminate offsetting trades (e.g. one manager may buy a stock for her fund while another manager sells the same stock at approximately the same time for his fund). While lowering transaction costs is a key benefit of an emulation strategy, there has been little research that compares the reduction in transaction costs with the opportunity costs of delaying trade. Using reported equity trades for a large Australian pension fund we simulate the consequences of an emulation strategy. We find that simulated emulation trades underperform those trades made by the employed (or target) fund over our sample period. That is, the opportunity cost of delayed trading significantly outweighs transaction cost reductions. Overall, we do not find strong evidence to support emulation from a cost-benefit perspective before management fees and taxes.

JEL classification: G23

Keywords
Portfolio emulation, multi-manager, fund-of-funds, offsetting trades, market impact, brokerage

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Introduction

We investigate the potential benefits of portfolio emulation strategies to multi-manager investments. We do this with a case study analysing share transactions from a large Australian pension fund. An emulation fund is used to improve the efficiency of a multi-manager fund by reducing or eliminating offsetting transactions made by each multi-manager's investment fund. Rather than investing in a set of individually managed funds (we refer to these as the target funds), the emulation fund is a separate entity that invests so that it tracks the aggregate holdings of the target funds. The emulation portfolio does this by re-using the trading signals (buy or sell decisions) of each of the target funds. Typically, permission to re-use trade signals is obtained from each target fund manager on the condition that actions based on the signals are delayed by the emulation fund. This prevents competition for liquidity between the emulation fund and its target funds. In addition, this delay enables the emulation fund to compare trading signals from each target fund, making it possible to reduce or eliminate offsetting signals before trading (e.g. the manager of one target fund signals that they will buy a particular share while a manager of a different target fund signals that they will sell the same stock at the same time). This redundant trading would be realized by the multi-manager investor if they placed their funds directly in the target funds. However, the emulation fund may provide essentially the same portfolio exposure to the underlying shares in each target fund while potentially avoiding excess transactions and their related costs. Hence, we consider whether the transaction cost savings from internally offset signals within a simulated emulation fund outweigh the potential opportunity costs of delayed execution, relative to the actions of the target funds. We also examine whether some stocks are more suitable for emulation, and whether emulation funds perform better than the target funds in certain market conditions.

The efficacy of emulation funds is becoming an increasingly relevant topic to large multi-manager investors as more emulation products are introduced. These new emulation strategies are viewed as a way to enhance the benefits from creating a multi-manager portfolio. For example, multi-manager portfolios can mitigate manager-specific risk (e.g. Brands and Gallagher, 2004; Elton and Gruber, 2004; Sharpe, 1981). Further, multi-manager portfolios may be more economical for large institutional investors (such as pension, endowment and sovereign wealth funds) to outsource their stock-picking decisions to specialised funds, rather than developing these capabilities themselves. However, the decentralised nature of conventional multi-manager arrangements means that constituent fund managers do not actively communicate with one another, and this leads to questions of trading efficiency. The potential performance impact of transaction costs on investor wealth is well documented and can be considerable. For example, brokerage commissions are found to be a significant factor in fund performance, ranging from 0.11% of trade value in the US and 0.15% in Europe (e.g. Goldstein et al., 2009) to 0.20% in Australia (e.g. Parwada, 2003). On-market trading also incurs substantial price impacts. They have been found to be as high as 0.46% (e.g. Domowitz et al., 2001). In Australia, price impact on buys have been measured at 0.27%, while there appears to be no price impact on sells (e.g. Aitken and Frino, 1996). Similar figures have been reported by Comerton-Forde et al., (2005) and Gallagher and Looi (2003).

Emulation strategies are appealing as they reduce the volume of on-market trading and hence lower transaction costs. However, there is little academic research to investigate the effectiveness of altered trade timing – taking away the timing discretion of a target fund manager may be costly. Our study quantifies the transaction cost savings and any related potential costs associated with trade delay. We are able to do this because of the highly detailed data provided by a large Australian pension fund. We have Australian equities data that contains full details about the daily trades of each constituent fund manager for a particular multi-manager fund, covering the period 2005 through 2009 (inclusive). There are between 10 and 16 individual managers employed by the fund at any one time.

Simulating an emulation fund using transactions data from a large institutional investor we find that emulation lowers brokerage fees and price impact costs through reduced on-market trading. However, offsetting trades appear to incur an opportunity cost in the form of foregone crystallised gains; that is, in the target fund, buy signals are generally executed at lower prices than sell signals (within a relatively small period of time). More significantly, emulation also captures adverse price movements by failing to exploit the short-lived information value of the original trade signal. These consequences lead to significant losses that appear to outweigh the benefits of reduced transaction costs. Our simulation analysis show that over a five day lag window (typical of emulation products in practice), performance is reduced by up to 37.78 basis points of traded value. However, increasing the length of the delay seems to reduce underperformance as a result of both greater transaction cost reductions and lower opportunity costs of signal mistiming. We also show that stocks with lower market capitalisation incur larger net costs when emulated than larger stocks, and returns on style neutral stocks are less adversely affected than either growth or value stocks. Lastly, we note that emulation funds tend to underperform the most (relative to their target funds) during periods of overall market growth. During the downturn during the

Global Financial Crisis, there was no statistically significant difference between the emulation fund and the underlying target funds. Since our results are reported before fees, practical applications of this method must compare the fee structure of delegating management to active fund managers compared to the opportunity costs of investing through an emulation fund.

The remainder of the study is organised as follows. The next section provides a brief background on multi-manager investment arrangements as they relate to operational structures and market frictions. We then present a description of the data, followed by a description of the research design. The next section presents the empirical findings and the final section concludes.

Background

Previous studies show that delegating investment decisions to multiple active managers renders significant diversification benefits over single-manager investment. At the same time, the literature also documents significant implicit and explicit transaction costs associated with active funds management. Portfolio emulation is a strategy that seeks to retain the benefits of multi-manager investing while simultaneously reducing the volume of on-market trading in the emulation fund to restrict transaction costs. Addressing operational trade inefficiencies within a multi-manager context through other methods has been studied, but only in a limited way. Inventory funds (e.g. Ferguson, 1978 and Wagner and Zipkin, 1978) propose offsetting active manager trades against an index fund that periodically rebalances with the market, finding some brokerage and price impact savings. Studies of the construction and management of a portfolio of funds (e.g. DiBartolomeo, 1999; Elton and Gruber, 2004; Rosenberg, 1977; Sharpe, 1981) also note the operational trade inefficiency problem in passing. To date, we are not aware of any academic studies that directly assess the effectiveness of emulation funds.

Multi-manager strategies

Existing research on multi-manager vehicles generally concentrates on specific areas, notably on funds of hedge funds. Manager diversification is well covered in the literature. Lhabitant and Learned (2002) and Brands and Gallagher (2005) find that five to ten different managers is sufficient to achieve diversification benefits. Brands and Gallagher (2005) also argue that adding more funds beyond this point is detrimental to the skewness and kurtosis of portfolio returns. Gallagher and Gardner (2005) show that such over-diversification also decreases potential alpha. However, while these papers deal with alpha exposure efficiency in holdings, they do not investigate potential trade inefficiencies, which we address.

Our research is further motivated by claims from multi-manager investors that they generate value beyond that created by their constituent managers. Multi-manager investments charge additional fees (above those imposed by the underlying funds) to defray the cost of additional oversight and analysis. Brown et al. (2004) find that individual hedge funds tend to dominate funds-of-funds in terms of both after-fee return and Sharpe ratio. However, Ang et al. (2008) argue that the fees on fees charged by funds of hedge funds are justified. They argue that the correct benchmark should be the direct returns of an uninformed investor in the underlying hedge fund pool, rather than the constituent funds within funds of funds. Nevertheless, the authors find that funds-of-funds charged management fees on average of 1.5% and further incentive fees on top of those already charged by the underlying hedge funds. In contrast, emulation fund products are marketed on the basis that they have reduced operational costs, and hence help offset some of the additional expenses incurred by the multi-manager provider.

Emulation fund and centralised portfolio strategies

Trading redundancy in a multi-manager context refers to trades on opposite sides of the market executed by independently managed constituent managers that have a net zero effect on the overall portfolio's holdings position. Rosenberg (1977) was an early proponent of centrally managed multi-manager structures; his model proposed constituent managers provide explicit numerical forecasts on stock returns. Trading is then performed by the central manager based on a consensus of such forecasts. At the time the primary drawback of the model was that many fund managers were highly qualitative and thus could not readily provide solid numerical data. Sharpe (1981) recognised these difficulties and discussed a number of other issues involved with constructing and managing a portfolio of funds. DiBartolomeo (1999) builds upon the approach of Rosenberg (1977) by employing the underlying managers to run paper portfolios. In this system, the individual fund managers submit their trades to the central manager, who then uses these trades to generate the numerical forecasts required for Rosenberg's model. Both Rosenberg's and DiBartolomeo's approaches require considerable cooperation between the constituent fund managers and the central manager. In practice, managers may be reluctant to disclose alpha forecasts for privacy and intellectual property reasons. Elton and Gruber (2004) address this problem by assuming only partial information sharing between the underlying managers and the 'Central Decision Maker' – namely each fund manager will only share information about the portfolio, but not forecasts about individual securities. Nevertheless, these centralised portfolio approaches require a fundamental shift in the information flow paradigm.

Inventory funds are another centralised portfolio management system. An inventory fund acts as a 'buffer' between the trades of the individual managers and the market. Orders entered by the constituent managers are executed against the inventory fund, which periodically rebalances by routing orders to the market. As in emulation funds, offsetting trades within a predetermined period of time are netted. A variation of this is to structure the inventory fund so it tracks a market index within a specified band, rebalancing when active manager trades push its index tracking outside of the required range. These market index funds essentially contribute a passive investment component to the overall portfolio, and may take the place of other passive market investments. Ferguson (1978) presents a case against market index inventory funds by arguing that if managers are knowledgeable, then the offsetting mechanism will remove many valuable trades, while if managers were not knowledgeable, then a simple passive index fund should outperform a portfolio of active managers net of fees. Wagner and Zipkin (1978) study real and simulated inventory funds using US data and show cost savings of 0.8% of assets under management over a six month period (assuming total transaction costs of 1.5%). In practice, index inventory funds are not common within the multi-manager industry due to the complex framework of active and passive funds involved, and there is also a notable lack of recent literature on the subject matter.

Emulation funds act as agents which aggregate the trade 'signals' from their target funds and trade only on the net signals, albeit on a delayed basis. This is the source of the trade-off between transaction cost savings and the opportunity costs of timing. Since emulation funds do not require fund managers to disclose their trade intentions prior to order submission, and do not affect trading within the target fund, they are relatively simple to implement compared to traditional centralised management models. However, little is known about the general effectiveness of emulation funds. Our research fills this gap.

Data

Our main dataset comes from a major Australian superannuation fund. The data contains daily transaction data including the trade price, volume, manager ID and broker ID from 1 January 2005 to 31 December 2009. In particular, we focus on the active Australian Equities component of the fund. The Australian Equities component of our superannuation fund is among the largest in Australia. The portfolio includes managers from all major style groups. No emulation strategy is currently employed by the fund.

This proprietary data is augmented with daily stock price data sourced from the Securities Industry Research Centre of Asia-Pacific (SIRCA) Australian Equities Tick History (AETH) database. In addition, we use market capitalisation and dividend payment data from the SIRCA Share Price and Price Relative (SPPR) database, as well as earnings data from the Aspect Huntley database.

Potential biases

Since our data is entirely sourced from the active Australian Equities component of a single multi-manager fund, there will inevitably be biases present. Ainsworth et al. (2007) investigate a number of these biases in the Mercer Investment Consulting Manager Performance Analytics (MPA) database, many of which are also relevant to our situation. Survivorship bias here occurs at the multi-manager level – the fund is still actively managed and thus must belong to the subset of all multi-managers that have made investment decisions good enough to remain viable. However, within our multi-manager fund, there is no survivorship bias amongst constituent funds. All holdings and transactions data are available for both current and past managers.

There is a selection bias because only active fund managers approved by the multi-manager are hired and appear in the data. These tend to be larger managers that can better handle capacity issues (an ability to deploy large investment flows). However, this provides an opportunity to observe the impact of emulation in the context of an actual multi-manager (who brings a fund selection process) rather than by simulation. The fund selection and oversight process of our multi-manager is quite typical of the majority of multi-managers. The multi-manager employs an asset consultant, which makes recommendations for adding new managers and terminating existing managers. These recommendations are reviewed and (if approved) implemented by the investment team and board.[1] Finally, it is worth noting that this is a case study and that the transactions level funds management data makes it unique.

Descriptive statistics

[1] The March 2010 Chant West Survey reported that of the 49 multi-manager organisations that provided 238 products, 35 employed an external asset consultant (this excludes 3 asset consultants which also run their own funds).

From 2005 to 2009, the number of managers in the fund increased from 10 to 16.[2] This was the result of the replacement of a long/short fund in 2006, and additional hiring of fund managers in 2007 and 2008. Table 1 reports key summary statistics regarding the composition and performance of our multi-manager fund. The increase in total funds under management from AUD$6.78 billion in 2005 to AUD$8.35 billion in 2009 is partially accounted for by organic growth in the multi-manager fund, but also reflects net contributions to the fund.

While our data contains almost 75,000 individual daily trades, we perform our analysis on trade packages to mitigate the effects of autocorrelation between successive trades in the same package. We define a trade package following Chan and Lakonishok (1995) as a successive series of trades executed by one manager on a single side of the market, which is unbroken by any trade by the same manager on the opposite market side, or a trading gap of greater than five days. We find 72.98% of trades by value were part of trade packages defined in this way. After consolidating individual trades into packages, our dataset contains 23,173 individual trade packages. We infer hypothetical trade signals from these trade packages, and employ these, albeit on a delayed basis, to manage the emulation fund. Further reference to a 'trade' in the paper will be synonymous with a consolidated trade package, unless otherwise specified.

[INSERT TABLE 1 HERE]

Research design

Our analysis is set up as a trade-based event study. Trade signals are sequentially delayed for a specified lag period (five days by default) during which time part (or all) of the volume may be offset against opposing trade signals submitted by other constituent managers. During this process, outstanding volume is updated for the initial trade signal and subsequent offsetting trade signals. We define the offset ratio as the volume of the trade signal that can be offset by subsequent trade signals on the opposite market side, divided by the total volume of the trade package. Any outstanding volume from a trade signal is assumed to be executed on the trading day following the end date of the delay window, at an inferred market price. The offsetting window then initiates on the next trade signal that has non-zero volume. Figure 1 illustrates this process.

[2] One of the constituent funds at the start of the sample period was in fact a fund-of-funds portfolio. After the fund-of-funds was terminated, some of the underlying managers were retained – hence the nominal number of funds reported increased but the actual number of individual managers decreased.

This rolling window system differs slightly to the fixed discrete windows used in actual emulation products. The fixed windows execute net volume every n^{th} day, such that each trade within the window is lagged on average $\frac{n}{2}$ days. We choose a rolling window because discrete windows may induce varied results depending on the exact start date – two opposing trades within n days may or may not offset depending on whether the window cut-off date lies in between the two trades. Using rolling windows smooths this effect.

[INSERT FIGURE 1 HERE]

Explicit costs

We calculate commissions for daily trades in each security in our dataset as the net difference between cash flow associated with a trade and the trade value (volume × price), and is known explicitly. The brokerage reduction as a result of trade offsetting is thus calculated as the brokerage rate on the trade multiplied by the trade's offset ratio.

Implicit costs

Our definitions of price impact follow from the research designs that Comerton-Forde et al. (2005), Chiyachantana et al. (2004) and Keim and Madhavan (1996) employ. Firstly we use an open price benchmarked price impact measure, cited in Comerton-Forde et al. (2005) with Chiyachantana et al.'s (2004) market movement correction:

$$PI_{open} = \sum_{i}^{N} w_i\left(\frac{P_i - OP_1}{OP_1} - \frac{M_i - M_1}{M_1}\right) \tag{1}$$

Trade packages have been deconstructed into their N constituent trades. w_i is the volume weighting of each trade in the package, P_i is the trade price of trade i in the package, OP_1 is the opening on the first day of the trade package, and M_i is the value of the market index on the day of trade i. For robustness, we also use a volume weighted average price[3] (VWAP) benchmark following Chiyachantana et al. (2004):

[3] The use of the VWAP as a benchmark is subject to aggregation bias, as the trade price itself contributes to the daily VWAP. For trades that make up a small proportion of the day's trading, this is not expected to have a significant effect. However, larger trade packages may have a noticeable influence on the day's VWAP due to their market impact. Hence we expect some under-estimation of price impact when using the VWAP benchmark. There is also a temporal element: if the subject trade occurred earlier during the day, a greater proportion of the day's trades will be affected by the price impact of the subject trade, hence exaggerating the aggregation bias.

$$PI_{VWAP} = \sum_{i}^{N} w_i \left(\frac{P_i - VWAP_i}{VWAP_i}\right) \tag{2}$$

$VWAP_i$ is the volume-weighted average price of the security associated with constituent trade i in the package. As with commission, we estimate price impact reductions to be linearly scalable with the offset ratio.

Offset impact

When trade signals T_i and T_j (on the same underlying security) are offset in the emulation fund, we forgo the crystallisation of gains or losses due to the difference in their trade prices. The trade-to-trade price difference is a function of both the inter-day price movement and price impact incurred by both trades. Since the price impact has already been accounted for, only the change in benchmark prices are used to determine timing impact. Where the open price has been used to benchmark price impact, we use an open-to-open measure of inter-day price movement, and likewise, a VWAP-to-VWAP measure of inter-day price movement is used in association with VWAP-benchmarked price impact. We attribute half of the crystallised gains or losses between two offsetting trades to each trade. Hence the offset impact (OI) we attribute to trade signals is given by:

$$OI_i = OI_j = \frac{P_b - P_s}{2} \tag{3}$$

P_b is the benchmark price of the day of the buy order and P_s is the benchmark price on the day of the sell order. This represents the offset impact as the opportunity gain/loss of internally offsetting a pair of trade signals over executing both on market.

Timing opportunity costs

The execution delay on trade signals that are not fully offset introduces a trade mistiming impact. This is given by the movement in benchmark price (either open price or VWAP) between the day of the initial trade signal and the hypothetical execution day after the delay window. The timing opportunity cost (TOC) on trade signal i is therefore

$$TOC_i = P_{i+n} - P_i \; if \; buy \qquad (4)$$
$$TOC_i = P_i - P_{i+n} \; if \; sell$$

P_i is the benchmark price on day i and n is the lag window period.

Results

The following section is structured as follows. We first look at the implicit and explicit transaction costs that are present in our data set; we next discuss the overall effectiveness of running an emulation fund over the data set. We analyse the effectiveness of emulation over size, style and short-term and long-term market conditions respectively. Finally, we consider all of these factors in a multivariate context.

Historical transaction costs

This section reports the transactions costs incurred by our case study fund. Over the 2005 to 2009 data period, our case study multi-manager fund has explicit transaction costs of 15 basis points of total trade value. This represents on average 0.11% of funds under management per annum, which range between $6.8b and $9.1b over the sample period. This is slightly lower than previous, older Australian studies (e.g. Parwada, 2003) but not significantly different.

In comparison to previous studies (e.g. Aitken and Frino, 1996; Comerton-Forde et al., 2005; Gallagher and Looi, 2003), managers in our dataset incur much lower price impact costs in the same trade package consolidated context.[4] In Table 2, we report the price impact of the actual fund using the market movement adjusted open-to-trade measure[5] and a value-weighted version of the VWAP benchmark model described in Chiyachantana et al. (2004). For open-to-trade, we find a buy side price impact of 7.31 basis points and a sell side price impact of 12.21 basis points. In comparison to the literature, our finding of the sell price impact exceeding the buy side is unusual. This may reflect idiosyncratic qualities of managers in our particular dataset, or recent changes in trading dynamics. For our open-to-trade benchmark, we find a negative price impact of -4.91 basis points on the buy side and positive 0.72 basis points[6] on the sell side, though this is not statistically significant for sells.

[4] Individual trades are consolidated into trade packages following Chan and Lakonishok (1995).
[5] This methodology is used in Comerton-Forde *et al.* (2005) and based on the market adjustment methodology of Keim and Madhavan (1996) and Chiyachantana et al. (2004).
[6] The trade-weighted t-statistic on the VWAP benchmarked sell side price impact was not significant at the 10% cut-off.

[INSERT TABLE 2 HERE]

Overall effectiveness

In this section, we simulate an emulation fund of identical size to the target fund across our trading data using open-to-trade and trade-to-VWAP benchmarks over five, ten, fifteen and twenty day lag windows. We first look at the impact of different window sizes over the offset ratio, and then quantify what overall effect this has on implicit and explicit transaction costs, as well as timing consequences. Offset ratios resulting from different window sizes are presented in Figure 2. We find that more trade value is offset with longer windows, but at a diminishing marginal rate. The percentage of trade value offset is 24.9%, 38.2%, 45.8% and 50.7% for 5, 10, 15 and 20 day lag windows, respectively. We report trade value weighted cost savings of not undertaking an emulation strategy using trade-to-open measures in Table 3 Panel A and using trade-to-VWAP measures in Table 3 Panel B. The savings in total from using emulation across varying lag windows is negative and statistically significant. This loss is driven by the timing costs exceeding the brokerage commission and price impact saved through offset trades.

[INSERT FIGURE 2 HERE]

We find that the choice of benchmarks affects our results with emulation being worse when we use trade-to-open measures than when we use trade-to-VWAP. For example, using a five-day lag window and the open-to-trade benchmark, the emulation fund resulted in -37.78 basis points in incremental cash flows compared to the target fund. With a trade-to-VWAP measure, this was -22.25 basis points. The higher losses using the open-to-trade benchmark may reflect fund managers and/or brokers exploiting intra-day information on the original trade day: the open price on the first day in a particular trade package is not adjusted for the value of an information announcement later during the day, whereas trade-to-VWAP at least partially adjusts for this.

[INSERT TABLE 3 HERE]

For both measures however, emulation funds with shorter lag windows incur greater total costs compared to longer lag windows. This is primarily driven by a larger negative timing impact using shorter windows. For example in Table 3 Panel A (open price benchmark), the timing loss for a five-day window is -40.71 basis points while for a 20-day window it is only -27.07 basis points. In Table 3 Panel B (VWAP benchmark), the respective timing losses are -26.81 and -17.59 basis points.

We find greater savings in brokerage commission for emulation strategies with longer windows: 6.79 basis points using a five-day window and 16.71 basis points using a 20-day window. This is consistent with the fact that a greater proportion of trade signal volume can be internally offset with a longer delay window (Figure 2). Since internal offsetting seems to incur an opportunity cost on average, and longer delay windows increase the offset ratio, so we find that the total opportunity cost attributable to foregone crystallised gains in the emulation fund increases with lag period.

Market capitalisation

In this section, we analyse the impact that stock size has on the incremental cash flows generated by the underlying security in the emulation fund. Each month, we create ten portfolios based on the market capitalisation decile of the underlying security. Note that a particular stock may fall in different deciles in different months. As expected, portfolios of larger stocks have higher offset ratios than portfolios of smaller stocks, due to the higher trading frequency of larger stocks. Figure 3 shows the offset ratio in each of these size-based portfolios. Almost 40% of trade volume is offset in the decile of largest stocks, diminishing in an approximately linear manner to less than 10% for the smallest stock decile.

[INSERT FIGURE 3 HERE]

Table 4 provides a breakdown of the incremental performance drivers in each of these portfolios. Table 4 Panel A uses the open price benchmark and Table 4 Panel B uses the VWAP benchmark. We find that across the two benchmarking methods, emulation leads to small but statistically significant reductions in price impact costs in the first decile (largest stocks) only (5.06 and 2.19 basis points, respectively, for open price and VWAP benchmarks). In addition, the VWAP benchmark method also picks up -1.47 basis points of additional price impact cost in the 7^{th} decile. This indicates that the underlying trade signals in the target portfolio executed at a net advantage to VWAP. Thus, reducing on-market exposure eliminates some of these 'benefits'. We also note that securities in deciles 4 and 5 cause the greatest trade offset impact losses (-9.97 and -12.74 basis points respectively with an open price benchmark and -6.66 and -8.75 basis points with a VWAP benchmark). The 8^{th} decile also exhibits a statistically significant offset impact.

Across all stock size-based portfolios, timing costs have the greatest influence on overall emulation fund performance. We find that the small stock portfolios, particularly in the bottom 3 size deciles, incur much larger opportunity costs when their trade signals are delayed than do large and medium stocks. This is consistent with previous research indicating that active managers have greater skill trading smaller stocks in the Australian market (e.g. see Chen et al., 2010).

Overall, there is a distinct trend for portfolios of smaller size deciles to underperform more significantly than the larger size groups. From a practical perspective, this may encourage prospective emulation fund providers to selectively emulate trade signals on securities with greater market capitalisation, subject to risk diversification constraints.

[INSERT TABLE 4 HERE]

Style characteristics

As in the previous section, we construct 10 portfolios based on the price-to-earnings ratio rankings of the underlying securities. These are rebalanced on an annual basis. Figure 4 reports the offset ratio observed in each of these portfolios. We find that the offset ratios peak in deciles 3 and 4 (stocks with a moderate growth tilt) and in deciles 7 and 9 (stocks with moderate value tilt). These humps may reflect fund managers pursuing their stated investment styles while avoiding higher risk stocks with extreme P/E ratios.

[INSERT FIGURE 4 HERE]

Table 5 reports the decomposed performance drivers in each of the 10 portfolios. We find incremental price impact effects in select portfolios. The large standard deviations within each decile group, in conjunction with the lack of robustness between the two benchmark methods, suggests that the style dimension has a minimal degree of influence on price impact reductions in the emulation fund.

[INSERT TABLE 5]

Commission savings are greatest in the 5th decile, despite the dip in the offset ratio for this group relative to adjacent deciles. This implies that the average brokerage cost relative to trade value is higher for style neutral stocks than others. The general trend is convex with respect to stock style: brokerage reduction is greater for trades in securities with moderate P/E ratios compared to either extreme. This reflects the lower offset ratio for securities with extremely high or extremely low P/E ratios (i.e. those ranked closer to the 1st or 10th deciles).

We find that more P/E partitioned portfolios report opportunity costs related to internal offsetting when measured with an open price benchmark compared to a VWAP benchmark; this may be related to the aggregation bias mentioned earlier inherent in using this benchmark. The opportunity cost associated with delayed execution of trade signals produces a more definite trend. We find strong negative timing impacts in portfolios of stocks with high P/E ratios (i.e. growth oriented stocks) with both the open price and VWAP benchmarks. This may be explained by the principle that growth stocks tend to be bought as their prices increase -- a delay in execution would result in some of the gain being foregone. On the other hand, value stocks are bought with a longer-term investment horizon and so are less affected by short-term execution lags. However, the open price benchmark does show some timing costs in stocks with relatively low P/E ratios (i.e. value oriented stocks) as well. Portfolios of relatively style-neutral stocks exhibit the least timing-related cost.

Overall, using the open price benchmark we find that emulation has a statistically significant negative impact across portfolios of growth-oriented stocks (deciles 1 to 4), as well as stocks with moderate value tilts (those with relatively low price-to-earnings ratios in deciles 7 to 9). In contrast, trade signals on style neutral stocks in deciles 5 and 6 were not subjected to statistically different performance outcomes in the emulation fund compared to the target fund. The VWAP benchmark produces weaker results – significance is only found for negative performance impact in high P/E stock portfolios 1, 2 and 4.

Short-term market movement

We use two sensitivity measures to determine the effectiveness of emulation under varying market conditions. In this first part, we partition trade signal events by the underlying market movement in the five days after the initial trade signal arrives. In the next section we take a wider, longitudinal view of emulation performance across semi-annual periods.

Using net movement of the S&P/ASX 200 index between the start and end of each event lag window, we rank trades by the underlying market movement, and divide these into deciles. Table 4 reports the percentage offset trades in market condition deciles and shows that a larger degree of offsetting occurs when index movement is greatest, in decile 1 (greatest upsurge) and decile 10 (greatest down-surge). This reflects increased trade activity during periods of greater market volatility and hence, greater potential for internal crossing.

[INSERT FIGURE 5 HERE]

Table 6 reports the overall emulation performance by its constituent factors. We find no strong statistical significance[7] in price impact reduction across the different event study groups by either benchmark measure. The result also confirms our prior observations that brokerage savings in the emulation fund are largely proportional to the offset ratio. In this context, greater reductions are observed during periods of large market index movement when a greater proportion of trades can also be offset. The offset impact of emulation produced more mixed results. Agreement between the two benchmark methods only in the lower groups (market correction periods) suggests that emulation has a significant negative impact of around 10 to 12 basis points in the third of offset events that occur in times of market decline. The effect is unclear in other market conditions.

[INSERT TABLE 6 HERE]

Despite these factors, the direction and magnitude of emulation performance against the target fund is driven primarily by the effect of the delay lag on execution. With respect to both open price and VWAP benchmarked measures, we find statistically significant positive effects only in the first decile, while results between the third and ninth deciles (inclusive) are significantly negative. This suggests that managers mistimed when the market index rose sharply by selling too early compared to their tendency to buy prior to the increase. However in most other market growth states, fund managers exhibit significant ability in the net timing of their trades within a five-day window; the delay lag removes this and hence is detrimental. This result confirms to the short-lived informed trading discussed in Bernhardt and Miao (2004).

[7] No significance was found at the 1% level using either the open price or VWAP benchmarks. The 9th decile had significant positive effects (a reduction in price impact cost) with respect to the open price at a significance level of less than 5%.

We find positive total emulation performance over the target fund in the decile of trade packages that occurred during the largest market upsurges in decile 1. Open price benchmarked outperformance in this category was 49.71 basis points, while VWAP benchmarked outperformance was a more modest but nevertheless significant 40.89 basis points. Overall, emulation seems to have the poorest performance when market activity is relatively neutral or in a recessionary phase.

Longer-term market conditions

In this section, we partition our results based on trade dates using six-month trade intervals. Figure 6 reports the amounts of trade offset in each decile and shows a strong upward trend in the value weighted offset ratio from period to period, ranging from 20.4% in the first half of 2005 to 35.8% in the first half of 2009. This is symptomatic of the increased fund turnover within this period, leading to greater trade concentration. In line with this, we find that commission savings in the emulation fund relative to the target fund also increase over time.

[INSERT FIGURE 6 HERE]

Table 7 reports the individual impact factors over semi-annual periods.

[INSERT TABLE 7 HERE]

There is no definite consensus between price impact reduction in the emulation fund between the open price and VWAP benchmarked measures of performance. Where the figures are statistically significant, their economic significance is quite low, accounting for less than 5 basis points of total traded value. Commission savings are more substantial, especially in more recent periods due to the upward trend in offset ratios.

Relative to an open price benchmark, we find significant opportunity costs associated with offsetting in 2005, the first half of 2007 and in 2008. The trend suggests a link with the index return during each of these periods. In fact, we find a correlation of 74.0%[8] between aggregated offset costs and log market

[8] With an open price benchmark, the t-statistic is 3.11. Correlation between log index returns and VWAP benchmarked offset impact by simulated emulation was 76.6% with a t-statistic of 3.37.

returns over the 10 6-month periods in our sample. Conversely, the timing delay aspect of emulation displays the opposite effect. Here, the correlation between timing impact and log index return is -57.6%[9]. The performance impact caused by timing is also significantly greater in magnitude than that incurred by internal offsetting: during the pre-GFC growth period, emulation underperformance peaked at -72.59 basis points of traded value in the first half of 2006, and averaged 33.3 basis points over the two-and-a-half years from the start of 2005. During the GFC, the nominal performance figures were not found to be significant, but during the post-GFC recovery period of 2009, underperformance once again rose to around 50 basis points across the two benchmark measures. In conjunction with our results from earlier in this section (*Overall effectiveness)*, we infer that the relatively neutral timing performance during the GFC can be explained through market volatility. That is, the significant timing gains during short-term market surges (which were greatest during the high volatility duration of the GFC) balanced out the timing losses of the short-term corrections – hence high standard errors and low statistical significance.

While the offsetting impact and timing impact are negatively correlated, the latter is the significantly more dominant factor in determining overall performance impact. Hence, we find that emulation funds operate most ineffectively during periods of market growth and recovery, while not incurring as much loss (if any) during high volatility recessionary periods.

Multivariate tests

In this section, we use regression analysis to determine the degree of influence that the various trade signal, security and market characteristics have on the performance drivers of the emulation fund. Our regression specification is

$$Component = \alpha + \beta_1 isBuy + \beta_2 mr_{6m} + \beta_3 mr_{5d} + \beta_4 Val + \beta_5 \sigma_{20} + \beta_6 log(Cap) + \beta_7 P/E + \beta_8 PR1YR + \varepsilon \quad (5)$$

Each data point represents an initiating trade signal and subsequent trade signals against which it can be offset. The $Component$ indicates the specific performance driver (i.e. offset ratio, price impact, commission savings, offset impact, timing impact, and the net sum of these) realised in each data point.

[9] With an open price benchmark, the t-statistic is 1.99. This correlation is -44.6% under VWAP benchmarked price movement, which is not statistically significant (t-statistic is 1.41).

We also run this regression with the *offset ratio* and the *total* outcome. $isBuy$ is a dummy variable taking the value 1 if the offset event was initiated by a buy-side trade signal, and 0 otherwise. mr_{6m} is the market return over the six months prior to the offset event, and reflects the general, longer-term market state. mr_{5d} is the market movement in the five days subsequent to the initiating trade signal in the offset event. Val is the trade value of the initiating trade signal in dollars. σ_{20} is the historic price volatility of the underlying security in the 20 days prior to the initiating trade signal. $log(Cap)$ is the natural log of the stock's most recent monthly reported market capitalisation. P/E is the price-to-earnings ratio since the last financial reporting date of the underlying security. $PR1YR$ is the prior 1-year return on the security.We report the coefficient estimates in Table 8 Panel A for the open price benchmark and Table 8 Panel B for the VWAP benchmark.

[INSERT TABLE 8 HERE]

We find that the offset ratio (the proportion of trade signal volume that can be internally offset) has a strong positive correlation (<1% significance) with the market capitalisation of the underlying security, and strong negative correlations with the trade signal value and the prior 1-year return. The first two factors are easy to rationalise: larger stocks tend to be more densely traded, thus there is more opportunity for offsetting signals to occur within the delay period; however, larger trade packages are less likely to be fully offset as that requires subsequent offsetting signals to be of larger volumes as well. It is less clear why securities with higher prior 1-year returns tend to experience lower offset ratios in the emulation fund. It may be a residual characteristic related to security size, which is correlated with both higher returns and lower offset ratios.

None of the factors seemed to affect the proportion of price impact saved at the 1% level, though the market capitalisation had a positive effect on the open price benchmarked price impact reduction (at 5% significance). As expected, the factors that influenced offset ratio also directly affected the magnitude of commissions saved, since the relation between these components is approximately linear.

There appears to be a strong negative link between the offset cost and underlying market movement when measured with both price benchmarks. During market rallies, the offsetting of trades is less detrimental than during market corrections, implying that managers display greater timing ability when the market index is falling. Further, using the VWAP benchmark, the offset cost is also negatively correlated to the trade signal value. This may be a result of lower offset ratios associated with higher trade signal value.

Finally, the incremental timing cost associated with emulation is significantly and positively related to the prior 6-month market return and the trade signal value. The former observation confirms our finding that emulation strategies are less successful in generally favourable market conditions. The latter reflects the fact that timing costs are proportionally greater for trade signals with larger volume; this is a consequence of the lower offset ratio on these trade signals – hence a larger proportion of the volume is executed at an unfavourable delayed market price. However, the timing cost is significantly and negatively correlated with the short-term market movement across the offset event period. This suggests fund managers make better short-term timing decisions during market corrections. Additionally, smaller stocks and (in an open price benchmarked context) those with a lower market to book ratio (i.e. value stocks) perform less favourably from a trade timing aspect under emulation.

Overall, the multivariate analysis gives quite a clear picture of the factors that affect emulation performance on a trade-by-trade basis. In terms of underlying market conditions, our emulation fund fared least well during periods of general market growth. However, it is the offsetting events that occur during short-term market corrections that were most detrimental. We also find that trade signals of larger package volume attract greater underperformance in the emulation fund, though larger stocks are generally more favourable for inclusion in emulation than smaller stocks. We also find some significance favouring stocks with higher price-to-earnings ratios (i.e. growth oriented stocks) when we apply an open price benchmark, though this contradicts our findings when we partitioned our results according to price-to-earnings deciles. This is likely due to the fact that we used a value-weighted mean in the deciles calculation whereas the multivariate analysis weights all the data points equally.

Conclusions

While our findings support claims that emulation funds operate with reduced transaction costs relative to the target fund, we reveal the hidden costs of internal offsetting and delayed execution - foregone profit crystallisation from on-market trading and loss of trade timing ability on short-lived information. Overall, empirical results of simulating emulation using trade signals from an actual pension fund show a statistically significant loss of 37.8 basis points of total traded value using a 5-day offset when we benchmark against open prices for price impact and inter-day price movement (a VWAP benchmark results in a 22.3 basis points loss). We find that increasing the lag period increases the internal offset ratio, which in turn decreases implicit and explicit transaction costs. However, internally offsetting trades introduces an opportunity cost of foregone crystallised gains from on-market trading; thus there was a greater offset cost associated with longer lag windows.

We find that emulation produces a statistically significant positive effect only during short-term market surges that tend to occur during recessionary phases (e.g. during the GFC) but is insignificant or negative during other market periods. Hence, we find that the hypothetical emulation fund underperforms its target fund most significantly during the growth period prior to the GFC and the recovery period after. The simulation also shows that emulation performs worse on medium stocks than large stocks, and worse still on small stocks when compared to medium stocks. None of these groups exhibits significant positive net effects. With respect to style, we find that style neutral stocks were least adversely affected in the emulation fund, compared to stocks with either a growth or value tilt.

Overall, these results show there is little evidence that a straightforward emulation strategy will improve performance before fees. While some gains may be made through the reduction of implicit and explicit transaction costs, the delay in trade timing has a negative and significant impact on fund performance, which outweighs any of the formerly mentioned benefits. A secondary outcome of this study suggests that active fund managers have some skill in the inter-day timing of their trades. We note however that fees paid to active fund managers may be substantial, and emulation funds may in fact generate positive incremental cash flows on an after-fees basis compared to their funds.

We recognise that our study is constrained in terms of sample representativeness. While we have demonstrated that within our particular multi-manager fund, offsetting trades is not beneficial overall, extending this method would add greater weight to our findings. We have deliberately avoided any analysis on the treatment of tax savings from trade offsetting, since this area tends to be idiosyncratic to individual funds, and is difficult to estimate in a generalised context. Accordingly we leave the tax issue to future research. Further, we have not investigated the implementation of an emulation fund, for example the liquidity of small stocks and cash flow management. These are important issues that are topics for further research.

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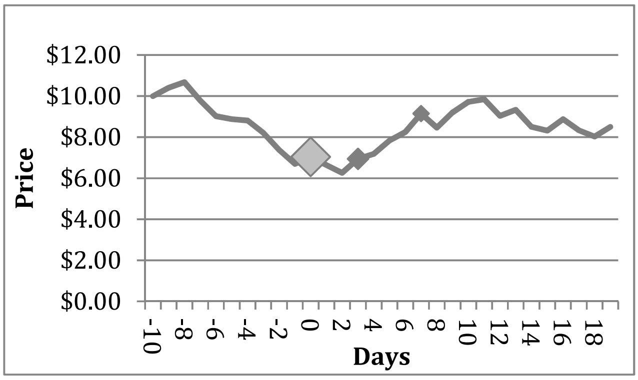
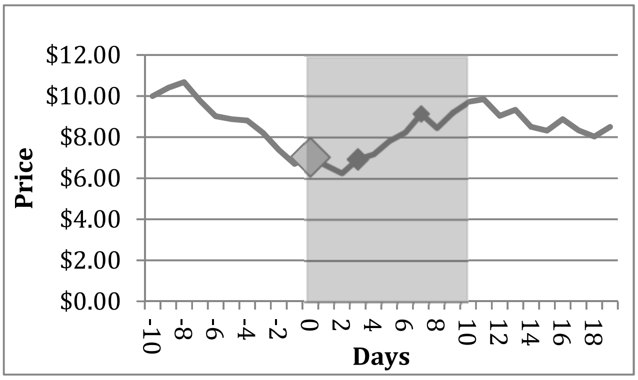
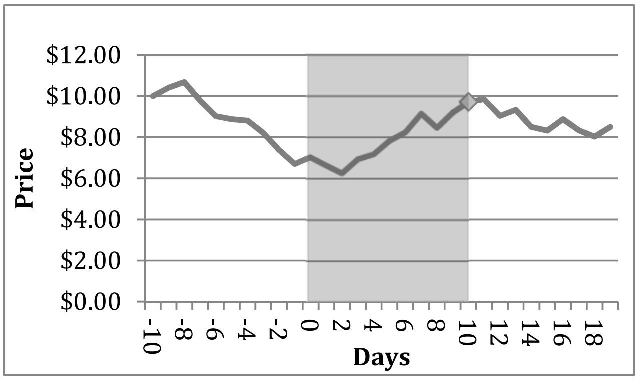
Figure 1. Example of the internal crossing process.



(a) Assume the following trade sequence:
1. Manager X issues buy signal for 100 shares on day 0
2. Manager Y issues sell signal for 30 shares on day3
3. Manager Z issues sell signal for 20 shares on day 7



(b) Offset subsequent sell signals (for 30 and 20 shares) against the initial buy signal, which in this case is lagged for 10 days.



(c) Execute residual buy volume on-market at the end of the lag delay period (50 shares).

Figure 2. Proportion of total trade value offset within different offset window periods. The size of the lag window was varied between five and 20 trading days, and represents the period of time a trade is delayed in order to offset against subsequent trades on the opposite market side. The percentage represents the total value of buys and sells offset against each other divided by the original total value of buys and sells traded by the multi-manager on market. Data is sourced from the transactions records of our sample multi-manager after aggregation of trades into trade packages and covers the period 2005 to 2009 inclusive.

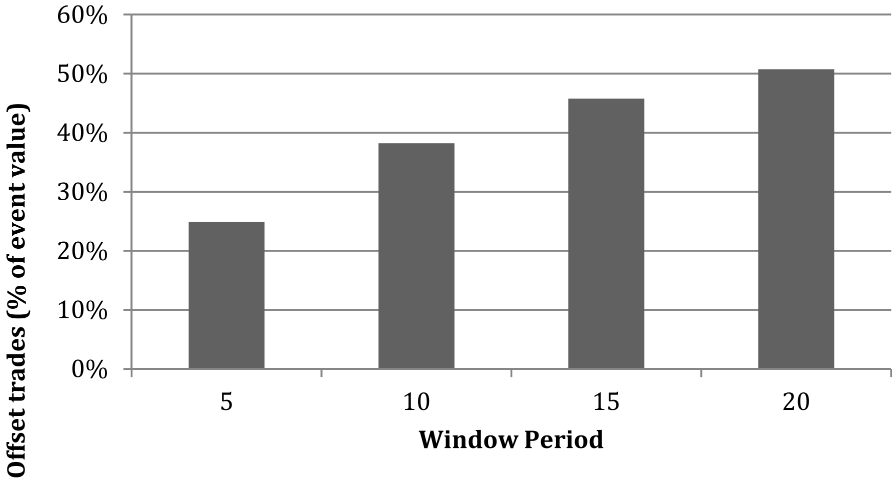


Figure 3. Proportion of total trade value offset with respect to stock size using a 5 day offset window. Trade packages were ranked by the monthly reported market capitalisation of the traded security (sourced from the SIRCA SPPR database). These were then partitioned into monthly deciles, and these deciles were then aggregated across months.

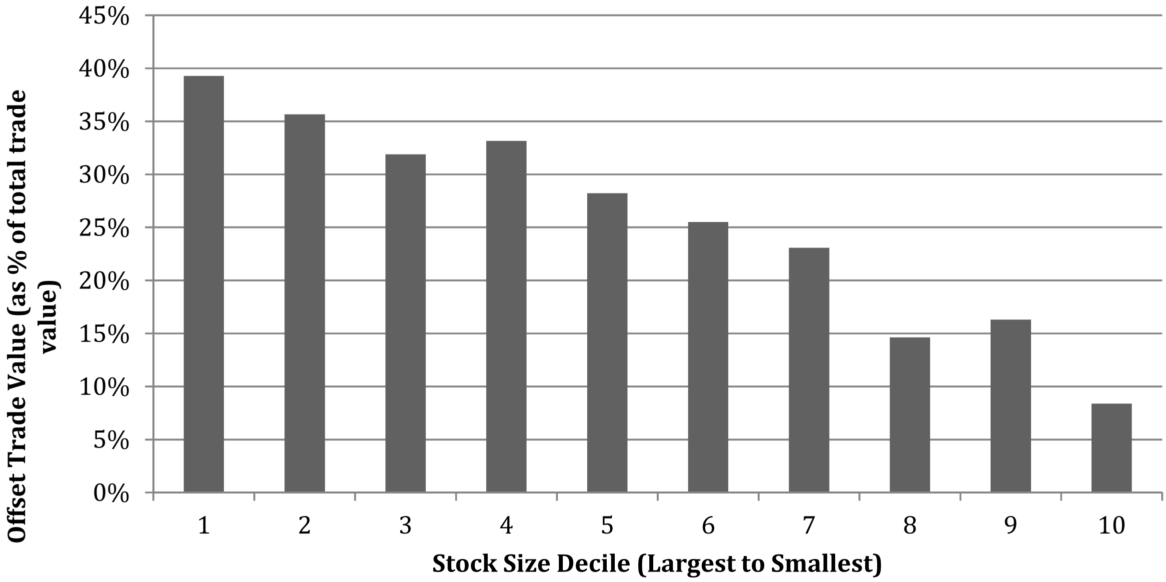


Figure 4. Proportion of total trade value offset with respect to stock P/E Ratio using a 5 day offset window. Trade packages were ranked by the annual reported earnings and mean share price of the traded security (sourced from the SPPR database). These were then partitioned into annual deciles, and these deciles were then aggregated across years.

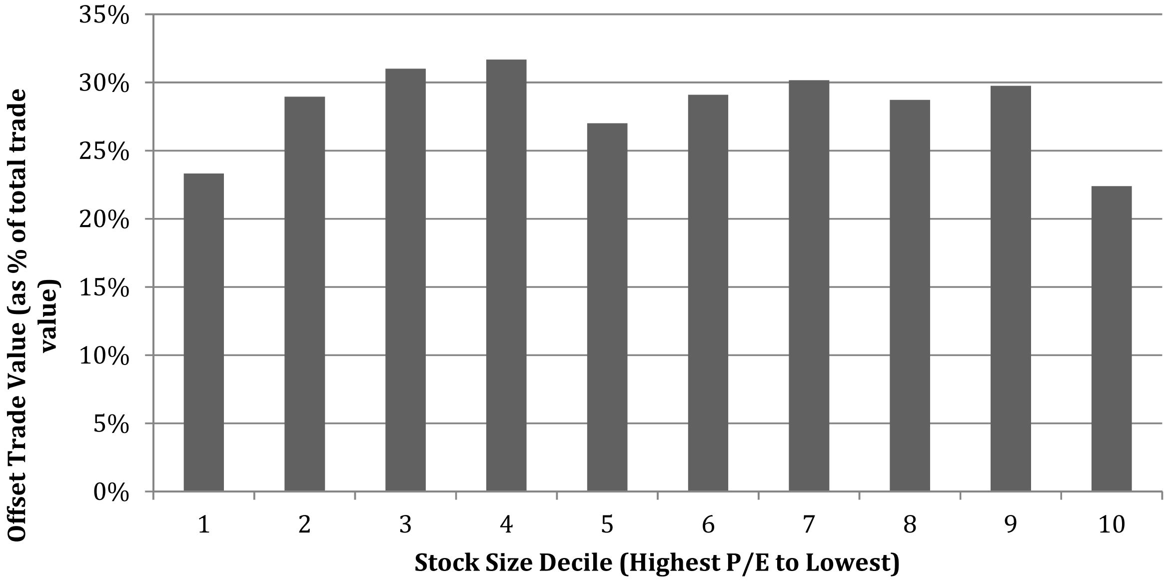


Figure 5. Proportion of total trade value offset under different short-term market conditions using a 5 day offset window. Trade packages were ranked by the underlying market growth (proxied by the S&P/ASX200) in the five days subsequent to the initial trade within each package. These were then partitioned into deciles.

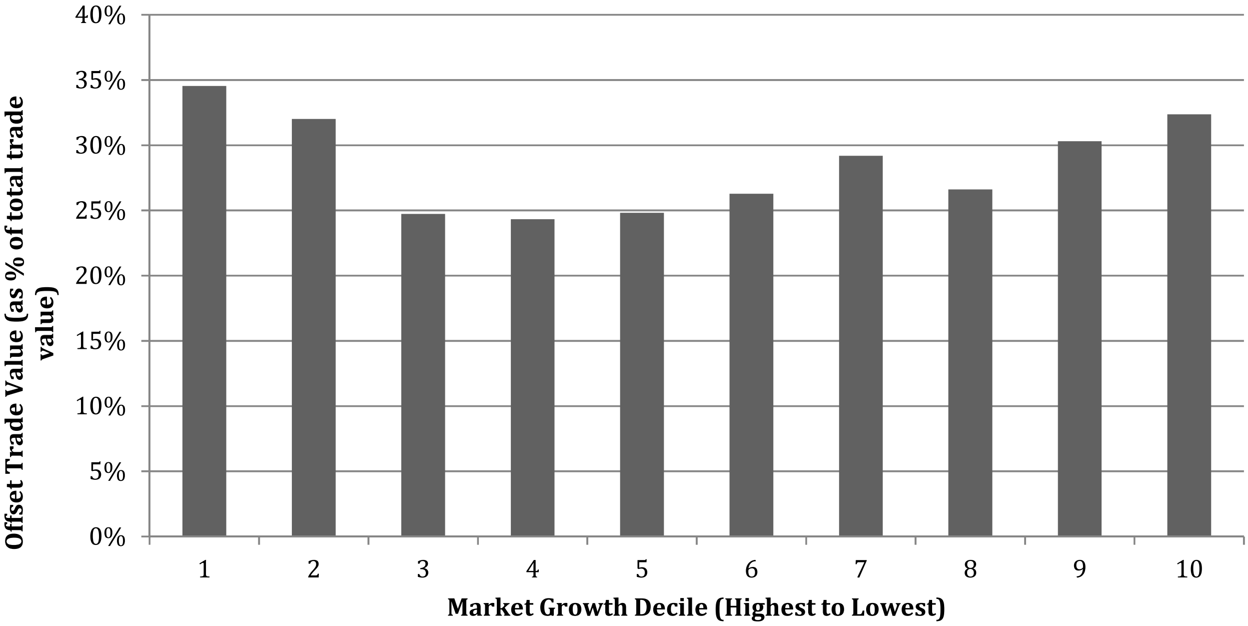


Figure 6. Proportion of total trade value offset across semi-annual time periods using a 5 day offset window. Trade packages were partitioned into semi-annual time periods.

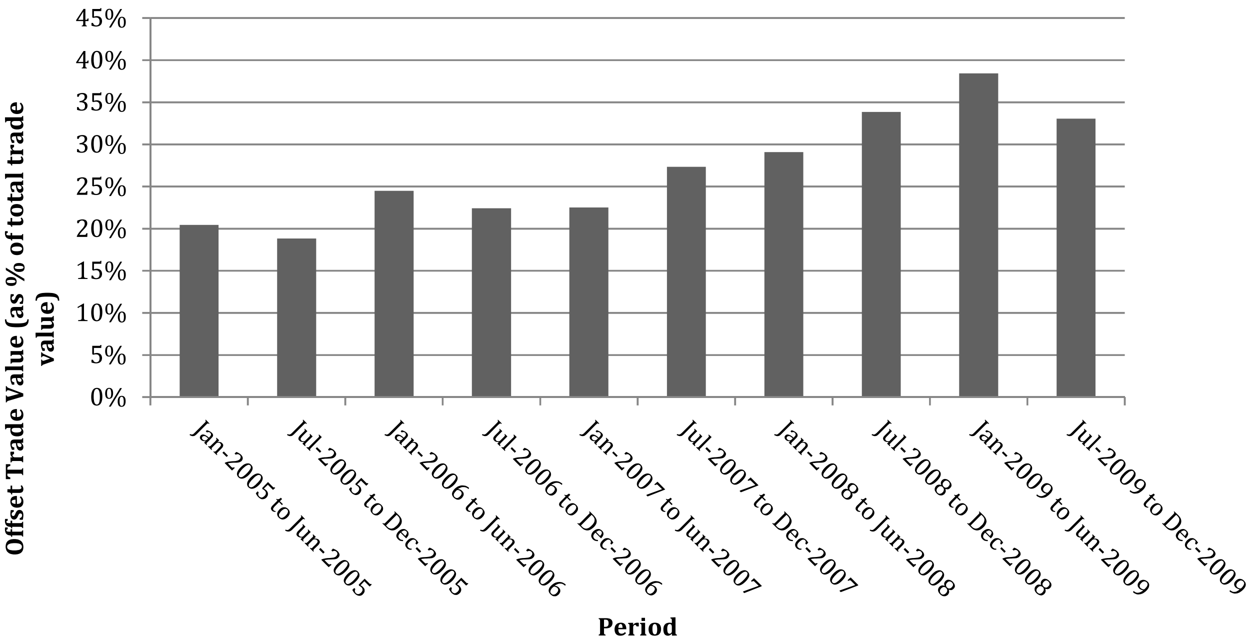


Table 1. Descriptive statistics of the dataset. Trade packages are determined from individual trades by aggregating successive trades executed by a single manager on one side of the market, and unbroken by a trade by that manager on the opposite market side or a trading gap of more than five days. Data for this table is entirely sourced from our sample multi-manager.

	2005	*2006*	*2007*	*2008*	*2009*	*All Years*
Multi-manager Composition						
Enhanced Passive	4	4	4	4	4	4
Growth	1	1	1	2	2	2
Long/Short	1	1	1	2	2	2
Style-Neutral	1	1	2	3	3	3
Value	3	3	4	5	5	5
Total	**10**	**10**	**12**	**16**	**16**	16
Total trades						
Buy	4,137	5,669	5,746	8,272	9,097	32,921
Sell	3,640	4,892	6,112	7,630	8,650	30,924
Total trade packages						
Buy (% in parentheses)	1,392	1,980	2089	2691	3073	11,225
Sell (% in parentheses)	1,431	1,753	2188	3048	3528	11,948
Total Fund Value ($m)	6,782.2	8,153.4	9,084.3	8,010.7	8,351.7	-
Annual Turnover (%)	37.88	41.14	38.58	50.83	46.71	-
Unique Securities Traded	155	165	215	220	248	332

Table 2. Price impact against open price and VWAP benchmarks. We use two methodologies to calculate price impact. These are based on those used by Comerton-Forde et al. (2005), Chiyachantana et al. (2004) and Keim and Madhavan (1996). The open price benchmarked measure extrapolates the weighted mean price differential between the execution price of each trade within the package and the open price on the initial day of package trading, adjusted for market movements over that period:

$$PI_{open} = \sum_{i}^{N} w_i \left(\frac{P_i - OP_1}{OP_1} - \frac{M_i - M_1}{M_1}\right)$$

Here, trade packages have been deconstructed into their N constituent trades. w_i is the volume weighting of each trade in the package, P_i is the trade price of trade i in the package, OP_1 is the opening on the first day of the trade package, and M_i is the value of the market index on the day of trade i. The VWAP benchmark, following Chiyachantana et al.'s (2004) methodology, measures the weighted price differential between constituent trades of a package and its respective trade day VWAP ($VWAP_i$):

$$PI_{VWAP} = \sum_{i}^{N} w_i \left(\frac{P_i - VWAP_i}{VWAP_i}\right)$$

The trading day open price and VWAP of a security are used as benchmark prices. Price impacts are based on approximately 23,000 trade packages across five years of data. Means and standard deviations reported are value weighted.

Benchmark		*Mean (bp)*	*SD (bp)*
Open	Buy	7.31***	196.35
	Sell	12.21***	181.50
VWAP	Buy	-4.91***	88.96
	Sell	0.72	64.28

*** 1% significance ** 5% significance * 10% significance

Table 3. Trade value weighted breakdown of costs and savings associated with emulation across varying lag windows. Each component is calculated as the basis point saving/cost of trade value. Results in Panel A use an open price benchmark for calculating price impact, offset impact and timing impact. Results in Panel B use the VWAP to benchmark these effects. Positive (negative) values represent savings (costs) of the emulation fund over the target fund. *PI (Price Impact)* is calculated as the relative, value weighted difference between the trade price and the day's benchmark price, as described in equations (1) and (2), scaled linearly with the proportion of volume offset. Similarly *COM (Commission Reduction)* represents commissions saved through the reduction of on-market traded volume. *OFFSET (Offset Impact)* is the value-weighted opportunity cost of foregone crystallised gains or losses realised by internally crossing buy and sell orders. Finally, *TIMING (Timing Impact)* represents the opportunity cost associated with adverse price movement between the benchmark price on the original trade date in the target fund and the respective benchmark price on the hypothetical execution date in the simulated emulation fund. Note that positive values represent costs and have a negative effect on the total. The *TOTAL* (*Total Impact)* column sums the price impact and brokerage commission savings and subtracts the offset and timing costs. For the simulation, we used the sample multi-manager's transactions data (2005 to 2009 inclusive) merged with daily prices (opening price and VWAP) from the SIRCA Australian Equities Tick History database, and incorporated market capitalisation and dividend payment data from the SPPR database.

Panel A. Open Price Benchmark

Lag (days)	*PI (bp)*	*COM (bp)*	*OFFSET (bp)*	*TIMING (bp)*	*TOTAL (bp)*
5	0.81	6.79***	4.67***	40.71***	-37.78***
10	2.09***	10.95***	8.79***	35.44***	-31.20***
15	3.73***	14.00***	11.30***	25.93***	-19.50***
20	4.17***	16.71***	9.90***	27.07***	-16.10***

Panel B> VWAP Benchmark

Lag (days)	*PI (bp)*	*COM (bp)*	*OFFSET (bp)*	*TIMING (bp)*	*TOTAL (bp)*
5	-0.97**	6.79***	1.26*	26.81***	-22.25***
10	-1.20**	10.95***	3.81***	22.17***	-16.23***
15	-1.06**	14.00***	4.68***	17.48***	-9.22**
20	-0.98**	16.71***	2.65	17.59***	-4.51

*** 1% significance ** 5% significance * 10% significance

Table 4. Trade value weighted breakdown of costs and savings associated with emulation across varying stock sizes. Each component is calculated as the basis point saving/cost of trade value. Results in Panel A use an open price benchmark for calculating price impact, offset impact and timing impact. Results in Panel B use the VWAP to benchmark these effects. Positive (negative) values represent savings (costs) of the emulation fund over the target fund. *PI (Price Impact)* is calculated as the relative, value weighted difference between the trade price and the day's benchmark price, as described in equations (1) and (2), scaled linearly with the proportion of volume offset. Similarly *COM (Commission Reduction)* represents commissions saved through the reduction of on-market traded volume. *OFFSET (Offset Impact)* is the value-weighted opportunity cost of foregone crystallised gains or losses realised by internally crossing buy and sell orders. Finally, *TIMING (Timing Impact)* represents the opportunity cost associated with adverse price movement between the benchmark price on the original trade date in the target fund and the respective benchmark price on the hypothetical execution date in the simulated emulation fund. Note that positive values represent costs and have a negative effect on the total. The *TOTAL* (*Total Impact)* column sums the price impact and brokerage commission savings and subtracts the offset and timing costs. For the simulation, we used the sample multi-manager's transactions data (2005 to 2009 inclusive) merged with daily prices (opening price and VWAP) from the SIRCA Australian Equities Tick History database, and incorporated market capitalisation and dividend payment data from the SPPR database.

Panel A. Open Price Benchmark

Decile	*PI (bp)*	*COM (bp)*	*OFFSET (bp)*	*TIMING (bp)*	*TOTAL (bp)*
1 (Largest)	5.06**	10.13***	0.91	35.30***	-21.01**
2	-0.02	8.42***	4.22*	14.80*	-10.62
3	0.65	9.69***	3.89*	20.49**	-14.04
4	1.73	7.22***	9.97***	36.58***	-37.60***
5	-0.11	6.32***	12.74***	17.04*	-23.56**
6	-3.17	6.14***	3.51	37.95***	-38.49***
7	2.55	5.09***	-1.01	18.64*	-10.00
8	-0.15	3.24***	7.92***	84.27***	-89.11***
9	3.09*	3.12***	3.99	62.19***	-59.97***
10 (Smallest)	-0.11	1.78***	2.23	90.02***	-90.58***

Panel B. VWAP Benchmark

Decile	*PI (bp)*	*COM (bp)*	*OFFSET (bp)*	*TIMING (bp)*	*TOTAL (bp)*
1 (Largest)	2.19***	10.13***	-2.04	29.54***	-15.17*
2	-0.20	8.42***	1.57	4.92	1.74
3	-2.83	9.69***	-1.48	12.25	-3.91
4	-1.26	7.22***	6.66***	19.72**	-20.42**
5	-0.74	6.32***	8.75***	4.96	-8.12
6	-5.60	6.14***	1.56	19.34**	-20.36**
7	-1.47**	5.09***	-6.59**	11.10	-0.89
8	-0.59	3.24***	4.84**	48.66***	-50.86***
9	-0.61	3.12***	-1.69	44.72***	-40.53***
10 (Smallest)	-1.01	1.78***	-0.85	59.58***	-57.95***

*** 1% significance ** 5% significance * 10% significance

Table 5. Trade value weighted breakdown of costs and savings associated with emulation across varying stock P/E Ratios. Each component is calculated as the basis point saving/cost of trade value. Results in Panel A use an open price benchmark for calculating price impact, offset impact and timing impact. Results in Panel B use the VWAP to benchmark these effects. Positive (negative) values represent savings (costs) of the emulation fund over the target fund. *PI (Price Impact)* is calculated as the relative, value weighted difference between the trade price and the day's benchmark price, as described in equations (1) and (2), scaled linearly with the proportion of volume offset. Similarly *COM (Commission Reduction)* represents commissions saved through the reduction of on-market traded volume. *OFFSET (Offset Impact)* is the value-weighted opportunity cost of foregone crystallised gains or losses realised by internally crossing buy and sell orders. Finally, *TIMING (Timing Impact)* represents the opportunity cost associated with adverse price movement between the benchmark price on the original trade date in the target fund and the respective benchmark price on the hypothetical execution date in the simulated emulation fund. Note that positive values represent costs and have a negative effect on the total. The *TOTAL* (*Total Impact)* column sums the price impact and brokerage commission savings and subtracts the offset and timing costs. For the simulation, we used the sample multi-manager's transactions data (2005 to 2009 inclusive) merged with daily prices (opening price and VWAP) from the SIRCA Australian Equities Tick History database, and incorporated market capitalisation and dividend payment data from the SPPR database.

Panel A. Open Price Benchmark

Decile	*PI (bp)*	*COM (bp)*	*OFFSET (bp)*	*TIMING (bp)*	*TOTAL (bp)*
1 (Highest P/E Ratio)	-0.56	4.73***	10.33***	64.73***	-70.89***
2	1.69	6.42***	4.78**	51.60***	-48.26***
3	-1.59	7.89***	6.69***	31.82***	-32.21***
4	6.17***	7.54***	-0.60	58.48***	-44.17***
5	0.80	8.67***	6.43***	7.37	-4.33
6	9.52***	7.44***	-1.95	19.89**	-0.98
7	3.57*	6.69***	10.72***	32.54***	-33.00***
8	-1.67	6.33***	4.87**	33.51***	-33.72***
9	-6.09**	7.29***	10.71***	31.52**	-41.03***
10 (Lowest P/E Ratio)	-3.48	5.57***	-2.40	31.13**	-26.63*

Panel B. VWAP Benchmark

Decile	*PI (bp)*	*COM (bp)*	*OFFSET (bp)*	*TIMING (bp)*	*TOTAL (bp)*
1 (Highest P/E Ratio)	-0.54	4.73***	5.89**	37.18***	-38.88***
2	-2.39**	6.42***	0.73	27.85***	-24.54**
3	-0.18	7.89***	2.69	19.32**	-14.30
4	-0.30	7.54***	-6.94***	52.87***	-38.70***
5	-4.39*	8.67***	1.02	-1.57	4.84
6	1.71***	7.44***	3.81	10.93	2.03
7	0.88	6.69***	2.43	13.35	-8.21
8	-0.66	6.33***	3.82**	20.93*	-19.08*
9	-0.94	7.29***	10.38***	16.36	-20.40
10 (Lowest P/E Ratio)	-5.39	5.57***	-3.63	21.58*	-17.76

*** 1% significance ** 5% significance * 10% significance

Table 6. Trade value weighted breakdown of costs and savings associated with emulation across market movement deciles. Each component is calculated as the basis point saving/cost of trade value. Results in Panel A use an open price benchmark for calculating price impact, offset impact and timing impact. Results in Panel B use the VWAP to benchmark these effects. Positive (negative) values represent savings (costs) of the emulation fund over the target fund. *PI (Price Impact)* is calculated as the relative, value weighted difference between the trade price and the day's benchmark price, as described in equations (1) and (2), scaled linearly with the proportion of volume offset. Similarly *COM (Commission Reduction)* represents commissions saved through the reduction of on-market traded volume. *OFFSET (Offset Impact)* is the value-weighted opportunity cost of foregone crystallised gains or losses realised by internally crossing buy and sell orders. Finally, *TIMING (Timing Impact)* represents the opportunity cost associated with adverse price movement between the benchmark price on the original trade date in the target fund and the respective benchmark price on the hypothetical execution date in the simulated emulation fund. Note that positive values represent costs and have a negative effect on the total. The *TOTAL* (*Total Impact)* column sums the price impact and brokerage commission savings and subtracts the offset and timing costs. For the simulation, we used the sample multi-manager's transactions data (2005 to 2009 inclusive) merged with daily prices (opening price and VWAP) from the SIRCA Australian Equities Tick History database, and incorporated market capitalisation and dividend payment data from the SPPR database.

Panel A: Open Price Benchmark

	PI (bp)	*COM (bp)*	*OFFSET (bp)*	*TIMING (bp)*	*TOTAL (bp)*
1 (Greatest upsurge)	4.31	9.37***	8.91**	-44.94***	49.71***
2	-0.87	7.46***	-1.32	14.56*	-6.65
3	-2.95	8.36***	2.21	33.00***	-29.80***
4	1.84*	5.30***	3.96***	47.5***	-44.32***
5	2.54	5.46***	2.71	56.69***	-51.38***
6	0.70	6.24***	-2.62	50.94***	-41.39***
7	2.97	6.75***	5.90***	46.79***	-42.98***
8	-1.00	5.87***	7.60***	68.19***	-70.92***
9	4.48**	6.80***	12.34***	35.30***	-36.35***
10 (Greatest down-surge)	-0.04	7.84***	11.03***	24.75	-27.98

Panel B: VWAP Benchmark

Decile	*PI (bp)*	*COM (bp)*	*OFFSET (bp)*	*TIMING (bp)*	*TOTAL (bp)*
1 (Greatest upsurge)	-3.52	9.37***	-0.21	-34.84**	40.89**
2	-0.54	7.46***	-4.80**	-7.69	19.41**
3	-3.20	8.36***	-2.38	18.34**	-10.80
4	0.09	5.30***	0.88	25.90***	-21.38***
5	-0.80	5.46***	0.38	40.50***	-36.21***
6	0.07	6.24***	-5.22*	30.70***	-19.17**
7	-1.57	6.75***	0.20	30.54***	-25.56***
8	-0.51	5.87***	3.64**	58.23***	-56.51***
9	-0.53	6.80***	10.33***	21.84**	-25.91**
10 (Greatest down-surge)	-1.29*	7.84***	9.86***	11.70	-15.01

*** 1% significance ** 5% significance * 10% significance

Table 7. Trade value weighted breakdown of costs and savings associated with emulation across semi-annual time periods. Each component is calculated as the basis point saving/cost of trade value. Results in Panel A use an open price benchmark for calculating price impact, offset impact and timing impact. Results in Panel B use the VWAP to benchmark these effects. Positive (negative) values represent savings (costs) of the emulation fund over the target fund. *PI (Price Impact)* is calculated as the relative, value weighted difference between the trade price and the day's benchmark price, as described in equations (1) and (2), scaled linearly with the proportion of volume offset. Similarly *COM (Commission Reduction)* represents commissions saved through the reduction of on-market traded volume. *OFFSET (Offset Impact)* is the value-weighted opportunity cost of foregone crystallised gains or losses realised by internally crossing buy and sell orders. Finally, *TIMING (Timing Impact)* represents the opportunity cost associated with adverse price movement between the benchmark price on the original trade date in the target fund and the respective benchmark price on the hypothetical execution date in the simulated emulation fund. Note that positive values represent costs and have a negative effect on the total. The *TOTAL* (*Total Impact)* column sums the price impact and brokerage commission savings and subtracts the offset and timing costs. For the simulation, we used the sample multi-manager's transactions data (2005 to 2009 inclusive) merged with daily prices (opening price and VWAP) from the SIRCA Australian Equities Tick History database, and incorporated market capitalisation and dividend payment data from the SPPR database.

Panel A. Open Price Benchmark

Period	*PI (bp)*	*COM (bp)*	*OFFSET (bp)*	*TIMING (bp)*	*TOTAL (bp)*
2005 Jan - Jun	2.82***	3.92***	7.84***	36.77***	-37.87***
2005 Jul - Dec	2.01**	3.56***	2.20*	57.94***	-54.57***
2006 Jan - Jun	2.08*	5.15***	1.44	84.90***	-79.11***
2006 Jul - Dec	2.78***	4.18***	0.35	35.90***	-29.28***
2007 Jan - Jun	-3.27	7.45***	2.19**	41.26***	-39.28***
2007 Jul - Dec	0.26	5.87***	0.66	23.95***	-18.48**
2008 Jan - Jun	4.26**	7.19***	10.96***	13.21	-12.72
2008 Jul - Dec	1.80	8.72***	10.05***	20.52	-20.06
2009 Jan - Jun	-5.01	10.13***	4.60	55.94***	-55.42***
2009 Jul - Dec	1.09	7.27***	2.24	57.08***	-50.95***

Panel B. VWAP Benchmark

Decile	*PI (bp)*	*COM (bp)*	*OFFSET (bp)*	*TIMING (bp)*	*TOTAL (bp)*
2005 Jan - Jun	0.43*	3.92***	3.44***	19.14**	-18.23**
2005 Jul - Dec	0.51	3.56***	0.98	37.07***	-33.98***
2006 Jan - Jun	-0.54	5.15***	-1.99*	72.59***	-65.99***
2006 Jul - Dec	-0.16	4.18***	-4.28***	18.81***	-10.51
2007 Jan - Jun	-3.12	7.45***	0.03	18.92***	-14.62**
2007 Jul - Dec	-0.31	5.87***	-3.08*	11.05	-2.42
2008 Jan - Jun	0.36	7.19***	4.48**	-8.49	11.56
2008 Jul - Dec	-1.54**	8.72***	8.54***	14.31	-15.68
2009 Jan - Jun	-5.06	10.13***	1.38	47.89***	-44.19***
2009 Jul - Dec	0.14	7.27***	-0.54	46.85***	-38.90***

*** 1% significance ** 5% significance * 10% significance

Table 8. Regression of impact components against partitioning variables. The regression formula is given by

$$Component = \alpha + \beta_1 isBuy + \beta_2 mr_{6m} + \beta_3 mr_{5d} + \beta_4 Val + \beta_5 \sigma_{20} + \beta_6 log(Cap) + \beta_7 P/E + \beta_8 PR1YR + \varepsilon$$

Each data point represents an initiating trade signal and subsequent trade signals against which it can be offset. The $Component$ indicates the specific performance driver (i.e. offset ratio, price impact, commission savings, offset impact, timing impact, and the net sum of these) realised in each data point. We also run this regression with the *offset ratio* and the *total* outcome. $isBuy$ is a dummy variable taking the value 1 if the offset event was initiated by a buy-side trade signal, and 0 otherwise. mr_{6m} is the market return over the six months prior to the offset event, and reflects the general, longer-term market state. mr_{5d} is the market movement in the five days subsequent to the initiating trade signal in the offset event. Val is the trade value of the initiating trade signal in dollars. σ_{20} is the historic price volatility of the underlying security in the 20 days prior to the initiating trade signal. $log(Cap)$ is the natural log of the stock's most recent monthly reported market capitalisation. PE is the stock's most recent annually reported P/E ratio. P/E is the price-to-earnings ratio since the last financial reporting date of the underlying security. $PR1YR$ is the prior 1-year return on the security. Panel A explains simulation results when the open price benchmark method is used; Panel B explains VWAP benchmarked results. Positive (negative) values represent savings (costs) of the emulation fund over the target fund. The *Offset Ratio* is the proportion of signal volume in the initiating trade this is internally offset by subsequent crossed trade signals. *Price Impact* is calculated as the relative, value weighted difference between the trade price and the day's benchmark price, as described in equations (1) and (2), scaled linearly with the proportion of volume offset. Similarly *Commission* represents commissions saved through the reduction of on-market traded volume. *Offset Cost* is the value-weighted impact of foregone crystallised gains or losses realised by internally crossing buy and sell orders. Finally, *timing cost* represents the effects of price movement between the benchmark price on the original trade date in the target fund and the respective benchmark price on the hypothetical execution date in the simulated emulation fund. The *total* aggregates these components. We used 2005 to 2009 transactions data from our sample multi-manager merged with daily prices (opening price and VWAP) from the SIRCA Australian Equities Tick History database. Market capitalisation and dividend payment data was sourced from the SPPR database, while market volatility data, proxied by the S&P/ASX 200, was accessed online from the S&P website.

Panel A. Open Price Benchmark

	F Value	*R-squared*	*Parameter*	*Estimate*	*Std Error*
Offset Ratio	351.3	0.132	Intercept	-2.618***	0.060
			isBuy	0.004	0.006
			mr_{6m}	-0.027	0.019
			m_{r5d}	-0.284**	0.126
			Val	-0.000***	0.000
			σ_{20}	0.003*	0.002
			log(Cap)	0.112***	0.002
			P/E	0.000	0.001
			PR1YR	-0.040***	0.006
Price Impact	1.65	0.001	Intercept	-6095.465**	2841.050
			isBuy	-151.630	296.353
			mr_{6m}	-1161.494	897.477
			m_{r5d}	5060.458	6002.242
			Val	0.000	0.000
			σ_{20}	126.342*	72.455
			log(Cap)	231.075**	105.579
			P/E	8.769	34.668
			PR1YR	194.628	267.703
Commission	407.15	0.150	Intercept	-4461.927***	166.594

			ìsBuy	12.359	17.378
			mr_{6m}	-123.274**	52.626
			m_{r5d}	642.646*	351.961
			Val	0.000***	0.000
			σ_{20}	-1.040	4.249
			log(Cap)	176.386***	6.191
			P/E	-0.916	2.033
			PR1YR	-81.110***	15.698
Offset Cost	1.99	0.001	Intercept	-4402.901	4322.494
			ìsBuy	460.304	450.884
			mr_{6m}	-878.189	1365.460
			m_{r5d}	-24000.766***	9132.066
			Val	-0.000*	0.000
			σ_{20}	121.088	110.237
			log(Cap)	179.920	160.632
			P/E	-35.133	52.746
			PR1YR	430.807	407.294
Timing Cost	24.25	0.010	Intercept	53219.303***	20629.174
			ìsBuy	-498.450	2151.850
			mr_{6m}	19454.984***	6516.680
			m_{r5d}	-99703.026**	43582.936
			Val	0.007***	0.001
			σ_{20}	857.324	526.107
			log(Cap)	-2085.628***	766.618
			P/E	-513.257**	251.731
			PR1YR	-364.703	1943.818
Total	20.67	0.009	Intercept	-59373.793***	21509.261
			ìsBuy	-101.125	2243.652
			mr_{6m}	-19861.564***	6794.697
			m_{r5d}	129406.896***	45442.281
			Val	-0.007***	0.001
			σ_{20}	-853.110	548.552
			log(Cap)	2313.170***	799.323
			P/E	556.242**	262.470
			PR1YR	47.414	2026.746

Panel B. VWAP Benchmark

	F Value	*R-squared*	*Parameter*	*Estimate*	*Std Error*
Offset Ratio	351.3	0.132	Intercept	-2.618***	0.060
			ìsBuy	0.004	0.006
			mr_{6m}	-0.027	0.019
			m_{r5d}	-0.284**	0.126
			Val	0.000***	0.000

			σ_{20}	0.003*	0.002
			log(Cap)	0.112***	0.002
			P/E	0.000	0.001
			PR1YR	-0.040***	0.006
Price Impact	0.75	0.000	Intercept	447.827	2769.095
			ìsBuy	532.025*	288.847
			mr_{6m}	-1001.699	874.747
			m_{r5d}	1470.983	5850.223
			Val	0.000	0.000
			σ_{20}	-11.367	70.620
			log(Cap)	-30.296	102.905
			P/E	7.282	33.790
			PR1YR	212.756	260.923
Commission	407.15	0.150	Intercept	-4461.927***	166.594
			ìsBuy	12.359	17.378
			mr_{6m}	-123.274**	52.626
			m_{r5d}	642.646*	351.961
			Val	0.000***	0.000
			σ_{20}	-1.040	4.249
			log(Cap)	176.386***	6.191
			P/E	-0.916	2.033
			PR1YR	-81.110***	15.698
Offset Cost	6.81	0.003	Intercept	3177.160	4519.011
			ìsBuy	921.049*	471.382
			mr_{6m}	-1583.469	1427.539
			m_{r5d}	-27560.968***	9547.244
			Val	-0.001***	0.000
			σ_{20}	-8.816	115.249
			log(Cap)	-112.306	167.935
			P/E	-8.284	55.144
			PR1YR	505.934	425.811
Timing Cost	35.95	0.015	Intercept	52138.254**	20359.611
			ìsBuy	622.710	2123.731
			mr_{6m}	14164.414**	6431.526
			m_{r5d}	-127947.796***	43013.434
			Val	0.009***	0.001
			σ_{20}	984.377*	519.232
			log(Cap)	-2174.556***	756.600
			P/E	-367.752	248.441
			PR1YR	-1759.869	1918.418
Total	27.59	0.012	Intercept	-59329.514***	21343.303
			ìsBuy	-999.375	2226.341
			mr_{6m}	-13705.918**	6742.271

		m_{r5d}	157622.394***	45091.665
		Val	-0.008***	0.001
		σ_{20}	-987.969*	544.319
		log(Cap)	2432.952***	793.156
		P/E	382.402	260.445
		PR1YR	1385.581	2011.108

*** 1% significance ** 5% significance * 10% significance