12 November 2010 | 40 pages

Under the Microscope

Measuring Systemic Risk – The Absorption Ratio

- **Different Perspective** —Our 'Under the Microscope' series, introducing topical academic research, aims to gain additional insight from the research and to investigate the empirical implications we think would be of most interest to market practitioners.
- **Standing out from the Crowd**— With stock returns becoming increasingly synchronous within Europe, diversification opportunities are increasingly hard to identify in equities, and monitoring systemic risk has become a central component of the investment process.
- **Measuring Systemic Risk** — We examine a measure of implied systemic risk, the Absorption Ratio - the proportion of total variability explained by a set number of principal components. A high Absorption Ratio implies a more codependent market and, consequently, a higher level of systemic risk.
- **Our Approach** — One part of the original research was the application of the Absorption Ratio as a market timing model in the US (Principal Components as a Measure of Systemic Risk; Kritzman, Li, Page & Rigobon - 2010) we present empirical findings for market timing using the Absorption Ratio in European (and other) markets and investigate other pragmatic areas of implementation for the methodology.
- **Extending the Analysis** — Our findings suggest that the Absorption Ratio certainly has some merit as a market timing signal in Europe and we see it as a useful tool for identifying market fragility/systemic risk. Additionally, we extend the application of the Absorption Ratio to sector timing/rotation. Using the methodology within sector at the stock level, we find that Absorption Ratio could be used successfully in timing sector rotation.

Chris Montagu
+44-20-7986-3958
chris.montagu@citi.com

Helen H Krause, CFA
+44-20-7986-8653
helen.krause@citi.com

Matthew J Burgess
+44-20-7986-8325
matt.burgess@citi.com

Rahul Jalan
+44-20-7986-4075
rahul.jalan@citi.com

Lingjuan Ma
+44-20-7986-4104
lingjuan.ma@citi.com

See Appendix A-1 for Analyst Certification, Important Disclosures and non-US research analyst disclosures.

Contents

Introduction	**3**
The View from Academia: Market Timing & Sector Selection	**4**
The Absorption Ratio	**6**
Does the Absorption Ratio Work?	**8**
Market Timing using the Absorption Ratio	9
Absorption Ratio Signal Decay	13
Can the Absorption Ratio be used for Sector Selection?	**14**
Can the Absorption Ratio Signals be used on a Monthly Basis?	**20**
Combining the Market Timing and Sector Selection Signals	**21**
Conclusion	**22**
Appendix - ARMT in Other Regions	**24**
Appendix – PCA and Absorption Ratio Example	**26**
Appendix – References	**30**
Appendix A-1	**37**

Introduction

The 'Under the Microscope' report aims to shed light on the potential benefits of ideas that have only very recently been presented in academic papers. In the second edition of our series, we examine a recent working paper from Kritzman, Li, Page, and Rigobon (2010) which we discussed in our July 2010 ARD publication. The title of the paper is:

"Principal Components as a Measure of Systemic Risk"[1]

The Absorption Ratio – a measure of implied systemic risk

The research introduces a measure of implied systemic risk, termed the "absorption ratio", which equals the fraction of total variance of a set of asset returns explained or "absorbed" by a fixed number of principal components. The authors argue that an increase in this ratio indicates an increase in the importance of common risk/return driver(s), i.e. a set of common – latent – factors explains a larger proportion of total variability, and hence points to an increase in systemic risk. An increase in systemic risk in turn suggests that the entire market becomes more fragile, in the sense that negative shocks propagate more quickly and broadly. To the extent that the latter conjecture is true, the absorption ratio can be used as a market timing signal. This is tested in one of the main experiments undertaken by Kritzman, Li, Page, and Rigobon (2010).

Market Timing in the European Markets

Our analysis focuses on this empirical question too. We examine where the absorption ratio can be used as a market timing signal in Europe. We carry out a number of additional tests relative to Kritzman, Li, Page, and Rigobon (2010) to test the robustness of the signal. While our base analysis focuses on 24 industry groups as a representation of the entire market, we are also interested in alternative representations, i.e. 16 countries, 10 sectors. Given the aggressive nature of the signal we also investigate its decay and whether an aggressive rebalance approach can still be effective.

Extending the application of the Absorption Ratio to sector timing

Moreover we extend the analysis to investigate whether the absorption ratio concept can be used from an industry selection perspective. We hypothesize that tightly coupled stocks - with the same industry participation - are more vulnerable to negative shocks within their industry. Hence an increase in the absorption ratio calculated within industry groups may be an effective industry rotation signal. We investigate several angles of this hypothesis in a research framework that best suits the typical equity portfolio manager.

The results of our analysis can be summarized as follows:

- The Absorption Ratio Market Timing (ARMT) signal is an effective market timing model producing nearly double the return of bonds with comparable risk adjusted returns.
- The decay of the ARMT signal is fairly slow. Lagging the signal or extending the holding period still significantly outperforms both holding either equities or bonds, offering attractive risk adjusted returns. This also allows for effective monthly implementation of the market timing model.
- Using the Industry Group ARMT signals for sector selection is also fruitful. Both suggested implementation models consistently outperform the benchmark.
- Combining the ARMT signal with the sector selection model further improves returns. Although the majority of returns for this combined model appear to be driven by the ARMT market timing aspect, it is good to see that overlaying the sector selection model provides incremental value.

[1] The full paper is available from the SSRN Electronic Paper Collection

The View from Academia: Market Timing & Sector Selection

Rising systemic risk as a result of increased connections and integration as well as similarities in risk exposures

The Global Financial Crisis of 2007-2009 has created renewed interest in the study of the varying correlations of financial assets. Billio et al. (2010) argue that increasing correlations, i.e. increased connections and integration as well as similarities in risk exposures, contribute to the increase of systemic risk and hence to the vulnerability of financial markets to negative shocks. They propose a number of measures designed to capture changes in correlation and causality among financial institutions (the focus of their study). One of their approaches uses Principal Component Analysis (PCA hereafter) and examines the time variation in the magnitudes of the eigenvalues of financial institution returns' covariance matrix. They conjecture that increases in eigenvalues indicate increases in systemic risk. They conclude that their PCA approach provides a broad view of connections and is "…indeed capable of picking up periods of market dislocation and distress, and may be used as early warning signal…"

Using PCA to gain insight into market linkages

Kritzman et al. (2010) extend this idea to the entire equity market and study whether a modified PCA approach can capture the extent to which groups of stocks are unified or tightly coupled. In the former case their analysis would suggest that the entire market loads heavily on a common risk factor, hence it is more fragile in the sense that negative shocks propagate more quickly and broadly. The latter would suggest the contrary. One straightforward empirical implication would be to use their measure, termed Absorption Ratio, as a market timing signal. A natural extension however in our view would be to examine whether the notion of financial fragility also applies within industries. The question we posit is what happens when stocks within industries are tightly coupled, hence more vulnerable to negative price shocks and how the Absorption Ratio concept can be used from an industry rotation perspective. Before we develop the relevant hypotheses and predictive models, we present in the following paragraphs a brief review of the current stand of academic literature in these two areas, i.e. market-timing and sector rotation.

The academic literature in market-timing is dominated by studies that aim to predict the return of the market on the basis of a regression model with past period variables as predictors. Predictors that have been proposed over the years include a) technical variables, e.g. lagged returns, b) valuation factors, e.g. dividend yield, earnings yield, c) macro related variables, e.g. short rate, term spread, inflation, d) risk factors, e.g. default spread, options implied volatility, and e) sentiment variables, e.g. volume of shares traded[2]. The fit of models of this kind is generally moderate to poor[3]. However it has been argued that even this level of fit is supportive of pursuing market timing strategies based on predictive regression models[4].

[2] See: Keim and Stambaugh (1986), Campbell (1987), Chen et al. (1986), Campbell and Shiller (1988), Fama and French (1989), Ferson (1990), Ferson and Harvey (1991a,b), Ferson and Harvey (1993), Whitelaw (1994), Pesaran and Timmermann (1995), Kandel and Stambaugh (1996), Pontiff and Schall (1998), Bossaerts and Hillion (1999), Lynch and Balduzzi (2000), Barberis (2000), Pastor (2000), Pastor and Stambaugh (2000), Xia (2001), Ait-Sahalia and Brandt (2001), Avramov (2002), Cremers (2002), Avramov (2004), Avramov and Chordia (2006), Ang and Bekaert (2007), Pastor and Stambaugh (2008).

[3] Campbell (1991) highlights that in predictive regressions of the excess stock market return using monthly data, fairly typical values of R2 are in the magnitude of 2.5%

[4] Clarke et al. (1989) find that a model that predicts monthly stock returns with an R2 of 0.09 can be expected to give a market timer a 5.9 per cent annual return advantage over an investor who buys and holds stocks.

The implications of Kritzman et al. (2010) for market timing - while original to our knowledge in terms of motivation - fall in a separate class of studies that propose less-structured frameworks for the prediction of future equity returns. Shen (2003), for example, advocates a profitability-based market timing strategy that uses the spread between the E/P ratio of the stock market index and the yield of three-month Treasury bills and the spread between the E/P ratio and the yield on ten-year Treasury notes. Faber (2007) applies a price-based rule, i.e. signals are based on the spread between short and long-term moving averages, and argues that the strategy results in equity-like returns with bond-like volatility and drawdowns. Guo and Higbee (2007) propose a risk-based trading strategy that builds on mean-variance and idiosyncratic-variance and find that it outperforms a buy-and-hold strategy, and that the difference is important economically.

Whilst the models in the former category may be more fundamentally sound relative to those in the latter, they are more data intensive and technically advanced; typically impose substantial structure to the predictive relationship hence increasing the impact of estimation and model risk; and are not de facto providing incremental utility for market timers.

The literature on sector rotation very much resembles the setup we highlighted above. A number of studies have highlighted that certain economic variables can be predictive of a sector's future return. Salsman (1997), for example, finds that past changes in short-term interest rates (a signal of the future business cycle), precious metal prices (a signal of inflation), and dividend yield (a signal for valuation) are the most powerful explanatory factors predicting the relative performance of market sectors. Beller, Kling, and Levinson (1998) use macroeconomic variables such as the default premium, maturity premium, and aggregate dividend yield. Fletcher (1998) uses lagged market excess returns, return on the risk-free asset, lagged dividend yield of the aggregate market and a January dummy variable. Conover et al. (2008) use announced Fed policy changes as indicators of when to shift a portfolio to a more aggressive or defensive posture.

Industry-specific fundamental factors and industry return momentum have, however, been the dominant factors in industry return predictability and industry rotation literature. Sorensen and Burke (1986) find that industry-specific stock price movements tend to persist for at least two quarters and advocate a sector rotation strategy based on buying and holding the best performing industry group. Moskowitz and Grinbalt (1999) find that industry momentum investment strategies, which buy stocks from past winning industries and sell stocks from past losing industries, appear highly profitable. O'Neil applies the principle of industry momentum with Sector Mutual Funds. Loudon and Okunev (2006) integrate value, momentum and growth in a global sector rotation strategy while Cavaglia and Moroz (2002) advocate a sector rotation strategy based on industry profitability, valuation and momentum. Other factors that have been proposed include analysts' forecasts (Boni and Womack, 2006, Kadan et al., 2009) and flow information (Froot and Teo, 2008, Beber et al., 2008).

In summary, the literature on sector return predictability and sector rotation strategies has thus far concluded that industry returns can be predicted effectively either through macro variables or through industry momentum, valuation, profitability and other factors. In this report we will investigate whether a new factor based on the principle of financial fragility can add value to sector return predictability and sector rotation.

The Absorption Ratio

Regulators have been motivated to develop tools to monitor and measure systemic risk in financial markets

As discussed in the previous section, the motivation of the research is by Kritzman et.al and is to examine the use of principal components as a measure or implied measure of systemic risk. To recap, they argue that as result of the market turmoil of the past couple of years, regulators have been motivated to develop tools to monitor and measure systemic risk in financial markets. However, due to the sophistication and, as a result, complexity of markets, it can at times be difficult to directly observe the potentially many linkages of financial institutions. Thus, the authors argue that their measure of systemic risk – the absorption ratio – can capture the extent to which markets are tightly coupled. In this context, a more tightly coupled or fragile market could lead to a faster propagation of a negative shock.

We present below an outline of the methodology used to calculate the AR signals. We hope to provide sufficient information on the methodology to allow the reader to understand our analysis but, for more information, please see the original paper by Kritzman, Li, Page & Rigobon (2010) for a more complete guide to the process.

Principal Component Analysis – Quick Explanation of Use

At the heart of the methodology is Principal Components Analysis

Given that Principal Component Analysis (PCA) is at the heart of this research, we thought it worthwhile to provide a high-level discussion on the technique[5]. PCA involves a mathematical procedure that transforms a number of possibly correlated variables into a smaller number of uncorrelated variables called principal components. The first principal component accounts for as much of the variability in the data as possible, and each succeeding principal component (eigenvector/eigenvalue) accounts for as much of the *remaining* variability as possible.

Without getting too technical, eigenvectors and eigenvalues help in PCA because of their mathematical properties. For eigenvectors, each eigenvector of a matrix is orthogonal to each other regardless of the dimensions of the matrix. For PCA this is important because data can be expressed in terms of the orthogonal eigenvectors instead of expressing them in terms of the x and y axis.

In reference to the eigenvalues (which correspond to a respective principal component), the one with the highest value corresponds to the eigenvector that has the most significant relationship between the original data points. Therefore, ordering the eigenvectors by their respective eigenvalues gives you the principal components in order of significance. That is, the first principal component is the combination of variables that explains the greatest amount of variation. The second principal component defines the next largest amount of variation and is independent to the first principal component.

[5] For more information on PCA and working example, please see Appendix.

How PCA relates to the Absorption Ratio

A measure of the extent to which sources of risk are becoming more or less compact

As briefly discussed on the previous page, the AR aims to 'measure the extent to which sources of risk are becoming more or less compact' by looking at the proportion of the total variability explained by a set number of principal components/eigenvectors. Formally, the risk statistic is calculated as:

$$AR = \frac{\sum_{i=1}^{n} \sigma_{Ei}^2}{\sum_{j=1}^{N} \sigma_{Aj}^2}$$

Where,

AR: Absorption Ratio

N: Number of assets

n: number I of eigenvectors used to calculate AR

σ_{Ei}^2 : variance of he i-th eigenvector

σ_{Aj}^2 : variance of the j-th asset

In order to estimate the AR, the authors use a 500 day window to estimate the covariance matrix and eigenvectors and set the number of eigenvectors used in the analysis to 20% of the number of assets in the sample. The variances/eigenvalues in the above equation are calculated with an exponential weighting with a half life set to half of the window, or 250 days.

Raw AR signal is coincidental; another measure ΔAR is used as a leading signal

As the authors note, the AR has exhibited a strong inverse relationship with the US stock market, however, the relationship is coincidental which limits its use as a leading signal of an impending market shock. To this end another signal has been created based on the raw AR to transform the signal such that it has an application as a leading signal – the 'Standardized Shift in the Absorption ratio' (ΔAR).The signal is calculated as the one-year moving average of the AR subtracted from the 15 day moving average of the AR. The difference is then divided by the standard deviation of the one-year absorption ratio to give ΔAR. This is then used as the input for the market timing model.

$$\Delta AR = \frac{(AR_{15Day} - AR_{1Yr)})}{\sigma}$$

Where:

ΔAR : standardized shift in AR

AR_{15Day} : 15 day AR moving average

AR_{1Yr} : 1 year AR moving average

σ : standard deviation 1 year AR

Does the Absorption Ratio Work?

The first question we aim to answer is whether the AR works in European markets as a market timing model. Kritzman et.al. provide compelling evidence to suggest that the AR market timing strategy works well in the US and we aim to replicate this performance using a different market universe. Additionally, we extend the analysis and consider the methodology using different "assets" within markets such as different levels of sector grouping and at the country level.

Data & Coverage

MSCI Europe is the base universe and the GICS 24 Industry Groups are the "assets"

The original research by Kritzman, Li, P age & Rigobon (2010) focused on daily signals generated by the standardized change in Absorption ratio (ΔAR) for the MSCI US Universe at an Industry level (51 Industries). We focus our attention on MSCI Europe and replicate the methodology using daily prices for the 24 MSCI Europe GICS Industry Groups to calculate the AR. We would have preferred to have used the same breadth of sectors as Kritzman et.al. but felt that the within sector breadth at this granular level was too low and may promote noise in the actual signal.

We also replace the T-Bonds used in the original analysis with a suitable European alternative – 10 year German Bunds – for when the model signals a switch out of equities.

As previously defined, in order to calculate the AR we require 500 trading days of price history for each of the 24 GICS Industry Groups to generate the AR signal. We then use 250 days of the AR signal to calculate the (longer) one-year moving average used in the ΔAR calculation.

Empirical analysis starts 2001 to 2010

Our backtest period consequently covers January 2001 to September 2010 inclusive – January 2001 being the earliest date for which we have at least the required 3 years returns for the underlying GIC Industry Groups in addition to MSCI Europe daily total returns data (in local currency). Clearly it's a relatively short period with which to conduct our empirical analysis, especially as we are dealing with a market timing model. In order to address the limitations that we have with the daily data, we further support our analysis by conducting the same analysis but on a monthly basis where our data access is less restricted. We argue that if we see similar results on a monthly basis over a longer time period to what we see on a daily basis over a shorter period, we can assume that we would get similar results for the daily analysis over the longer period.

Methodology & Assumptions

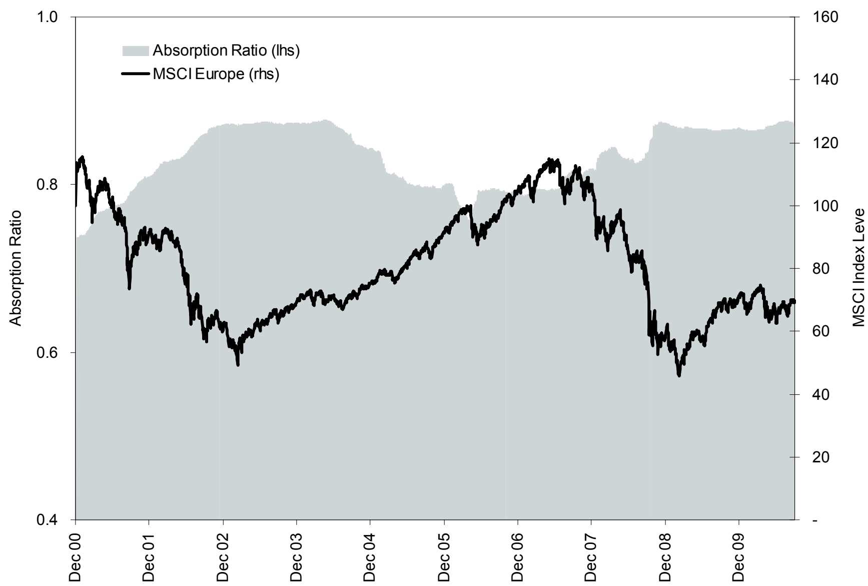
To comply with the original methodology and for implementation purposes signals are lagged by one trading day – we therefore start to realize returns *the day following a signal* and assume that we are able to execute trades at the close price *on the day of the signal*. Additionally, we have measured the performance of the strategy(s) using index levels but we recognize that the implementation would be done using ETFs/Futures etc – therefore we would have preferred to use the historical prices of these instruments. But, once again due to data limitations we were unable to do so. However, we don't see this as major factor that could influence the results of our analysis and with the original market timing model generating an average of 1.7 signals per year, the difference in pricing/returns using the underlying over the instrument is minimal.

Market Timing using the Absorption Ratio

Analysis finds inverse relationship between Absorption Ratio and MSCI Europe

Given the caveats on the data and methodology our first set of analysis is to replicate the market timing strategy for the European market. Figure 1, shows a historical time series of the raw AR, together with the performance of the MSCI Europe. At a glance, the inverse relationship between the two series is apparent.

Figure 1. Absorption Ratio (MSCI Europe Industries) and MSCI Europe Stock Prices



Source: Citi Investment Research and Analysis

Delving a little deeper, we consider the data a little closer. As Figure 2 shows, a sizable proportion of the most significant drawdowns within MSCI Europe were lead by a one standard deviation spike in the AR.

Whilst a high AR implies market fragility, it may not imply a significant drawdown

Figure 2. Proportion of drawdowns preceded by 1 standard deviation spike in AR, MSCI Europe

	1% Worst	2% Worst	5% Worst
1 Day	80.0%	80.0%	68.8%
1 Week	84.0%	84.0%	76.0%
20 Day	44.0%	62.0%	71.0%

Source: Citi Investment Research and Analysis

Increase (decrease) equity exposure when AR falls (rises)

Results are impressive but somewhat inferior to those portrayed for the US market. One anomaly for the European data is that the hit rate for monthly drawdowns *increases* as the percentage threshold is relaxed, whereas daily and weekly equivalents follow the same pattern the authors found for the US.

It should be noted that the authors conclude '*that a spike in the AR reliably leads to a significant drawdown in stock prices'* but that one would be *'correct to conclude that a spike in the AR is a near necessary condition for a significant drawdown, just not a sufficient condition.'*

Figure 3. Annualised return after +/- 1 standard deviation spike in AR

	1 StDev Increase	1 StDev Decrease	Difference
1 Day	-14.6%	20.5%	35.0%
1 Week	-13.1%	19.0%	32.1%
20 Day	-14.0%	18.4%	32.4%

Source: Citi Investment Research and Analysis

As in the original paper, on average, significant increases (decreases) in the AR are followed by significant stock market losses (gains) implying it would perhaps be prudent to increase (decrease) exposure to equities when the AR falls (rises).

Trading the Signal – Making Money

The trading strategy is simply based on three rules which switch between equities, cash, and a balanced holding of the two

Kritzman et.al. present a straightforward trading strategy that uses the ΔAR signal and shows impressive results for the signal in the US. We replicate this trading strategy and show similar results for the European market. The trading strategy is simply based on three rules which switch between equities, cash and a balanced holding of the two:

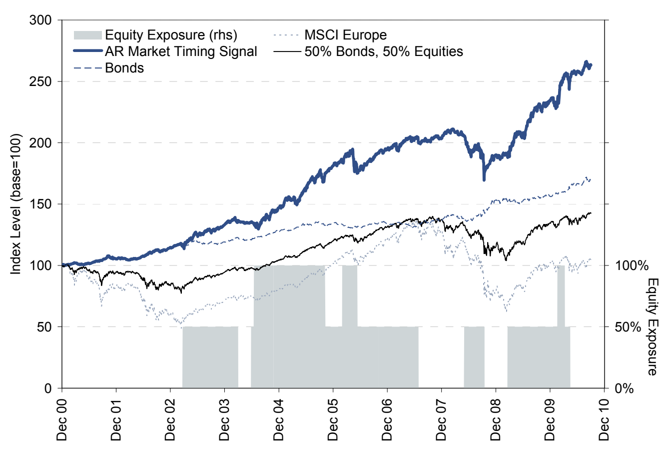
$-1\sigma \leq \Delta\mathrm{AR} \leq +1\sigma$: 50% Equities, 50% Bonds

$\Delta AR > +1\sigma$: 100% Bonds

$\Delta AR < -1\sigma$: 100% Equities

For our analysis trades are lagged by one trading day following the day of the signal and returns are calculated using MSCI Europe daily total returns and 10 year German Bund daily returns. Figure 4 & Figure 5 show the results of our empirical analysis.

Figure 4. ARMT Signal, Historical Performance & Equity Exposure



Source: Citi Investment Research and Analysis

Figure 5. Performance Statistics

	ARMT	50/50	MSCI Europe	Bonds
Annualised Return	10.2%	3.6%	0.4%	5.4%
Annualised Volatility	7.7%	10.0%	21.3%	3.7%
Information Ratio	1.3	0.4	0.0	1.5
Overall Hit Rate	57.4%			
% Positive Market Days Up	75.5%			
% Negative Market Days Up	37.4%			
Henricksson & Merton Test[6]	0.11 (4.36)			
T-Stat (vs 50/50 model)[7]	2.0			

Source: Citi Investment Research and Analysis

[6] Henriksson and Merton test is a statistical evaluation of the directional accuracy of factor model forecasts. For more information on test see Henriksson and Merton (1981).

[7] The null hypothesis in this test is that the ARMT returns are the same as the 50/50 model.

As seen by the results, dynamically rotating equity exposure according to the AR Market Timing (ARMT) signal produces a significantly more attractive profile than a pure equity or equally weighted equity/bond strategy for both absolute and risk adjusted returns.

Double the return of bonds…

The ARMT approach produces enhanced returns (10.2%) in comparison to both pure equities (0.4 %%) and equally weighted blend of equities and bonds (3.6%) strategies, with nearly double the returns of bonds.

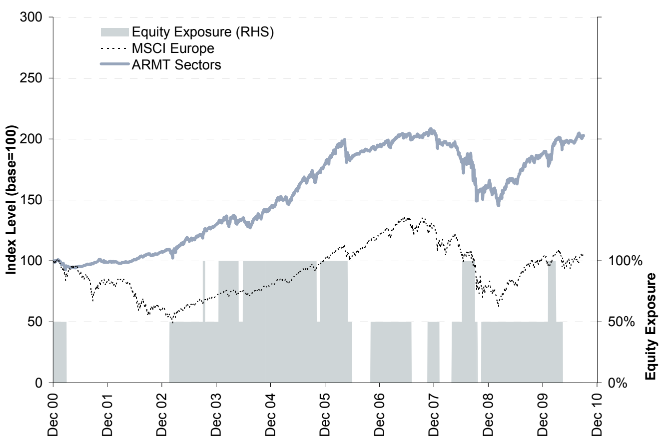
…1/3rd of the volatility of pure equities

Volatility is around a third of that of pure equities, producing an Information Ratio (IR) of 1.3 - a more attractive result and only just shy of the IR associated with holding bonds (1.5).

The obvious downside of this strategy would be the possible inability of the average institutional investor to switch so aggressively between equities and bonds. However, we don't suggest, and we are sure the authors of the original research would not advocate, this trading strategy as something that the typical institutional manager would undertake. We see the strategy as an example of the potential market timing ability of the AR signal.

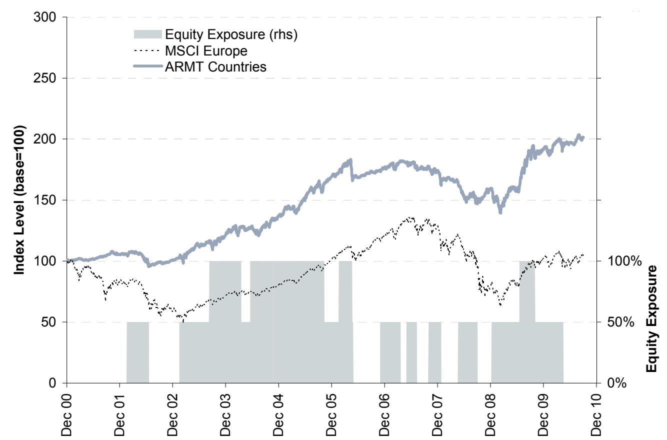
For reference, we also present returns for the ARMT model by using GICS sectors (10) and MSCI Europe countries (16) as the input into the underlying AR calculations.

Figure 6. ARMT Signal using (10) MSCI GICS Sectors



Source: Citi Investment Research and Analysis

Figure 7. ARMT Signal using (16) MSCI Europe Countries



Source: Citi Investment Research and Analysis

Regardless of whether we use sector, Industry Group or Country returns as the underlying data, the ARMT signal outperforms both the pure equity and equally weighted equity/bonds strategies.

It is, however, worth noting the almost linear relationship between the number of underlying assets used in the AMRT calculation and the resulting returns, volatility and risk adjusted returns.

Figure 8. ARMT using Industry Groups, Sectors and Countries

	Industry (24)	Country (16)	Sectors (10)
	10.2%	7.2%	7.3%
Annualised Volatility	7.7%	8.8%	10.3%
Information Ratio	1.3	0.8	0.7
Overall Hit Rate	57.4%	55.3%	55.9%
% Positive Markey Days Up	75.5%	79.1%	80.4%
% Negative Market Days Up	37.4%	29.0%	28.9%
Henricksson & Merton Test	0.11 (4.36)	0.05 (2.00)	0.06 (2.45)
T-Stat (vs 50/50 model)	2.0	1.2	1.3
Average Equity Exposure	38%	45%	47%

Source: Citi Investment Research and Analysis

More signal diversity – higher returns

As we decrease the number of assets used in the underlying ARMT signal calculations the volatility of the signal increases since the additional benefit of the marginal eigenvalue (i.e. the next eigenvalue or principal component) becomes more dominant within the model – *i.e. the signal becomes less diversified*!

One could theoretically repeat this exercise at the stock level to maximise the number of eigenvectors/values[8] used in the ARMT model but, with increasing stock return cross sectional correlation, the incremental value of the additional eigenvectors would be minimal, potentially rendering the exercise futile.

[8] That is, the proportion of the of the total variance explained by the top eigenvalues or principal components remains constant between using GICS sectors or industries as the underlying assets, but the actual number of principal components used increases with the higher breadth sector classification.

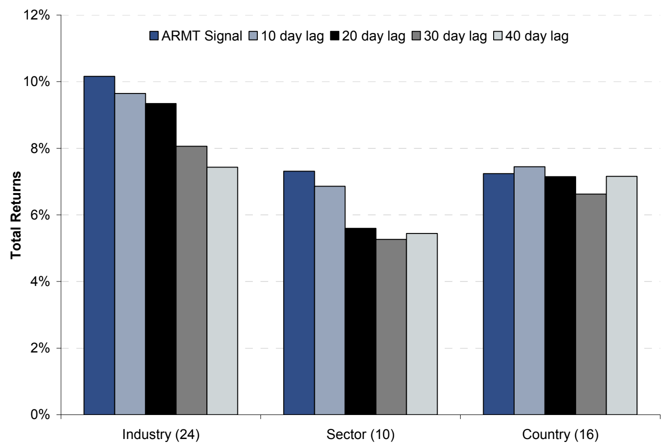
Absorption Ratio Signal Decay

Auto correlation of Absorption Ration signal is low

Implementation can be critical with any market timing strategy. Many strategies show excellent risk adjusted returns on paper but, in reality, the returns may be generated by very high turnover and therefore those excellent returns can not be fully harvested. One obvious concern with this strategy and the empirical results presented is that the strategy is based on a one-day investment horizon – the strategy is rebalanced daily. For many investment managers, a daily market timing model may not be feasible within their investment mandate. Consequently the slower the signal decay the more robust and investable this strategy could be. To this end we have investigated the serial correlation of the signal to establish the rate of signal decay.

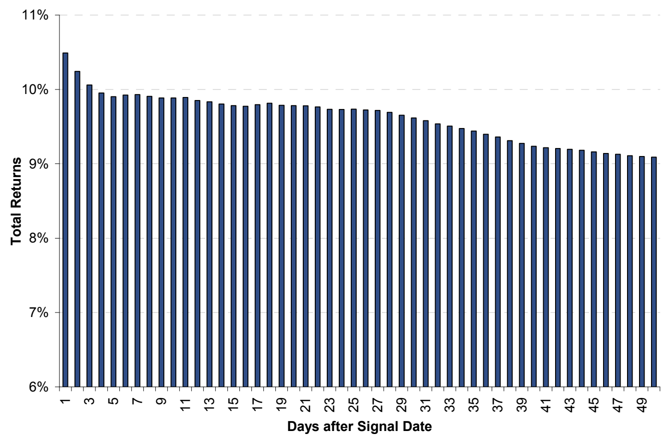
Below we illustrate the decay of the absolute annualized returns for the ARMT signal[9]. Focusing on Figure 9, although returns decrease fairly aggressively (and almost monotonically) with the length of the applied lag, applying even a 40 day lag to the signal results in substantial outperformance over both a pure equity and equally weighted equity/bonds model.

Figure 9. ARMT Signal Decay – Annualised Returns



Source: Citi Investment Research and Analysis

Figure 10. ARMT - Annualised Returns for Extended Holding Periods[10]



Source: Citi Investment Research and Analysis

This is further reinforced by the fact that, whilst there is some decay in returns, by extending the holding period following each signal (even up to 50 days) the ARMT model still yields 9% annualized returns. This gives us confidence that, as a market timing signal, ARMT is relatively robust and that the superior risk adjusted returns are not merely a result of excess turnover.

On a related issue, which we don't see as a major concern but for completeness we briefly discuss, when the model is either 100% equities or 100% cash there isn't an issue with rebalancing, per se, but when the position is 50/50% equities/cash, there will be turnover/transactions to maintain the 50/50% position.

[9] Volatility remains unchanged so the decay in risk adjusted returns is identical.

[10] Note that the 10 day lagged return is different in this chart relative to the chart in Figure 9 due to a difference in the calculation: Figure 9 is based on compound average returns over a certain period whereas the Figure 10 is based on average over each prior period to the period that we are considering.

Can the Absorption Ratio be used for Sector Selection?

AR at the stock level can indicate how tightly coupled or how fragile a sector is and therefore how exposed it is to negative shocks

Considering the efficacy of the AR when used as a market timing signal, it makes intuitive sense to further the analysis and investigate whether the AR can be incorporated into a sector selection model or, at least, a signal to aid in sector allocation. Our motivation is to see whether the AR metric or framework can be applied at the stock level within sector. That is, we answer the question as to whether the AR at the stock level can indicate how tightly coupled or how fragile a sector is and therefore how exposed it is to negative shocks. Put simply, can the AR be used a sector level to measure implicit "systemic" risk within a sector?

Within Sector Absorption Ratio

The logical start in which to analyse whether the AR can aid in sector rotation is to simply look at the performance of the AR within sector at the stock level. Using the same methodology as the previous analysis, we calculate 24 daily AR (one for each MSCI GICS Industry Group) using the relevant underlying stock constituents to create the co-variance matrices from which the AR's are derived.

ARMT improves returns for 22 of the 24 GICS Industry Groups

The simple test is conducted as a basic switching model. Like before the signal dictates whether we are in equities – in this case, the industry group which we are considering – or bonds. Additionally, to mitigate market exposure inherent in the industry, our industry returns are ex the market. In this sense we are attempting to disentangle the marketing timing from the industry timing[11]. Figure 11, following page, provides some evidence that the ARMT model does have value when applied at an Industry Group level. 22 of the 24 Industry Group classification returns are improved by integrating the ARMT mode with only Materials and Retailing offering negative relative returns using the ARMT model. Armed with this anecdotal evidence we are motivated to explore the industry timing potential of the absorption ratio.

For this study we present a simple empirical analysis for two alternative methods of using the AR as an input into a sector selection framework. As an additional test, we also consider the cross-sectional predictive power of the ΔAR signal. We stress that this analysis is not extensive but more an investigation on the potential application of the AR to other parts of an investment strategy. The three sector rotation strategies based on the AR are:

1. Equally Weighted Sector Overweight Signal

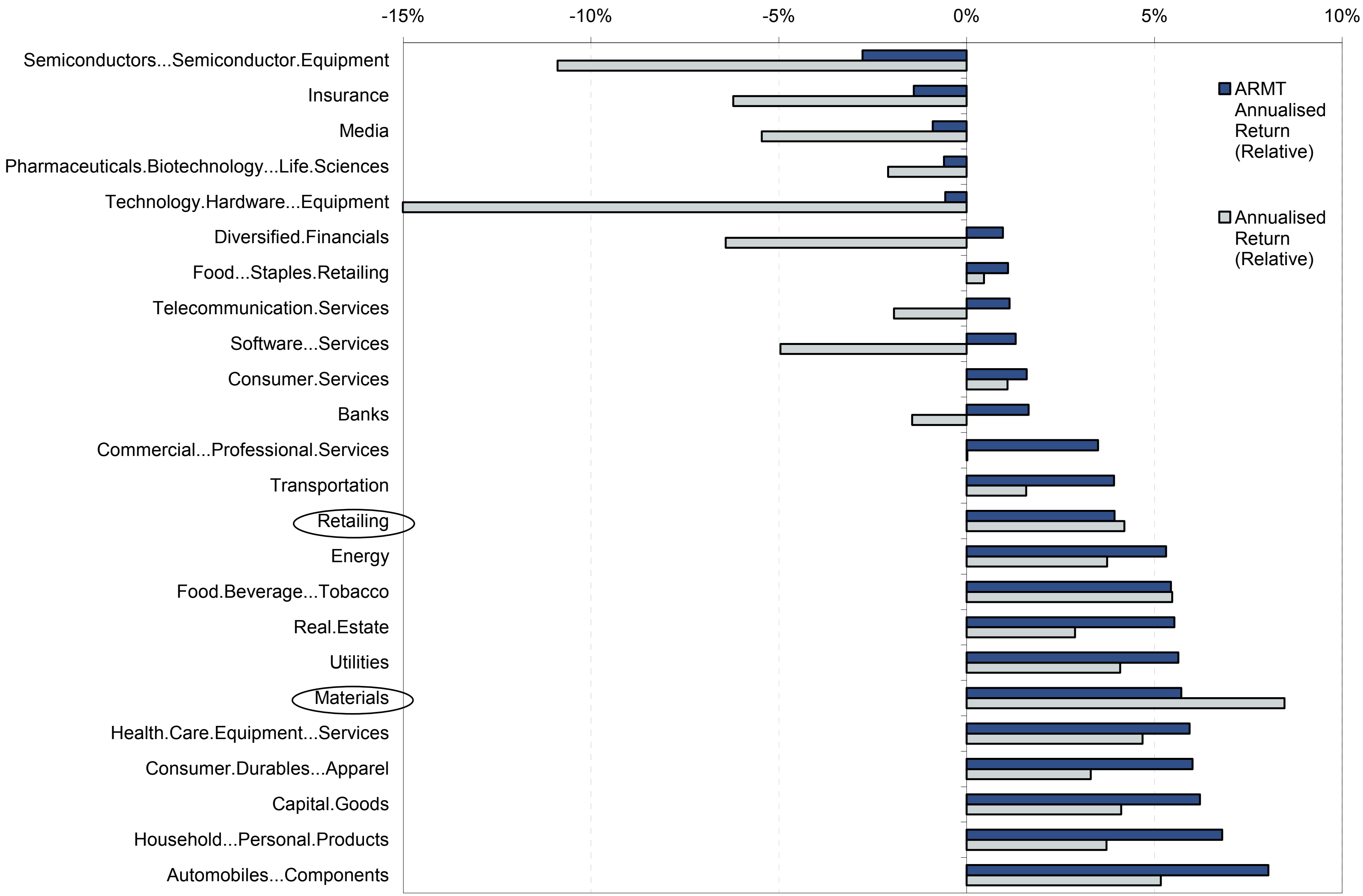
2. Dynamic Adjusted Sector Weights Signal

and,

Quintile Sector AR Ranking

[11] We formally address the combination of these two signals – market and industry timing – further on in this research and we note that this analysis has a potential bias as we are assuming each sector has a beta to the market of one.

Figure 11. MSCI Industry Groups vs. ARMT for MSCI Industry Group (Annualized Returns) – Industry's highlighted where the ARMT performance is less than the actual industry return.



Source: Citi Investment Research and Analysis

1. Equally Weighted Overweight Signal (EWOS)

Our first analysis into whether the AR can be used as a sector rotation signal is straightforward - the approach is to simply invest in all sectors when the AR (ΔAR < -1) signal is "long" with an equal weighting. To ensure the strategy is 100% invested at all times, if no overweight signals are generated at the Industry level, the model is simply long the market.

Whilst this approach to sector selection would in all probability not be investable from a risk perspective (the strategy is invested in 2 Industry Groups or less 37% of the time) it provides a useful indication of whether a more aggressive approach to sector re-weighting using the AR would be more fruitful.

2. Dynamic Adjusted Weights Signal (DAWS)

The second rotation strategy is more sophisticated than the first and aims to best replicate how an investment manager may implement explicit industry tilts within an investment strategy. The strategy is benchmark "anchored" and the approach uses a pragmatic and implementable methodology based on the overweight and underweight signals generated from the AR model in order to calculate an adjusted weight for each Industry on a given day.

Specifically:

$$w_{i(adj)} = w_i \left(I_{\{AR_i < -1\}} + \frac{I_{\{AR_i < (-1)\}} \sum w_i^{UW}}{\sum w_i^{OW}} \right)$$

Where:

$w_{i(adj)}$ - adjusted weight of i-th industry

n – number of industries

$\sum w_i^{UW} = \sum_{i=1}^{n} I_{\{AR_i > 1\}} w_i$ (sum of underweight industry signals)

$\sum w_i^{OW} = \sum_{i=1}^{n} I_{\{AR_i < (-1)\}} w_i$ (sum of overweight industry signals)

AR_i - ΔAR (standardized shift in Absorption Ratio) of i-th industry

$I_{\{.\}}$ - denotes indicator function, equal to 1 if argument is true

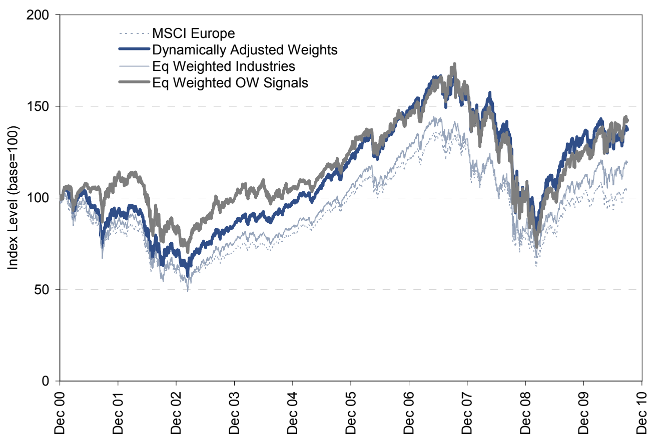
Put simply, we allocate the sum of the weight of all Industries generating an *underweight* (ΔAR >1) signal proportionately (by MSCI market cap) to those industries generating an *overweight* (ΔAR < -1) signal. All Industries generating a *neutral* signal (-1 < ΔAR <1) remain at market weight.

These daily adjusted Industry weights are then simply multiplied by the respective underlying daily Industry returns to calculate model performance. As before, we lag the AR signals by one day.

Results/Performance

For reference, for the two strategies discussed, we provide a comparison against both the market and an equally weighted approach across all Industries. Implementing a sector selection model based on either of the above approaches delivers improved returns in comparison to the benchmark.

Figure 12. Industry Selection using ARMT Signals



Source: Citi Investment Research and Analysis

Figure 13. Performance Statistics

	Dynamically Adjusted Weights	Equal Weighted OW AR Signals	Equal Weighted Indusrties	MSCI Europe
Annualised Return	3.2%	3.6%	1.8%	0.4%
Annualised Volatility	21.5%	21.7%	21.0%	21.3%
Information Ratio	0.15	0.17	0.08	0.02
Overall Hit Rate	53.0%	52.9%	52.8%	
% Positive Market Days Up	*96.4%*	*87.3%*	*95.3%*	
% Negative Market Days Up	*5.1%*	*14.9%*	*5.8%*	
T-Stat (vs MSCI Europe)	*2.3*	*1.1*	*1.2*	

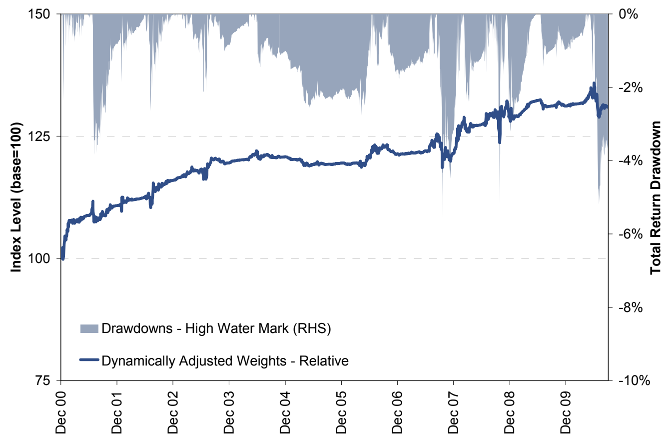
Source: Citi Investment Research and Analysis

Whilst volatility remains relatively unchanged in either case, annualized returns are improved significantly and to such an extent that risk adjusted returns as 8 times those of the benchmark, although this improvement heralds from a low base.

Consistent outperformance over benchmark with a 58% hit rate

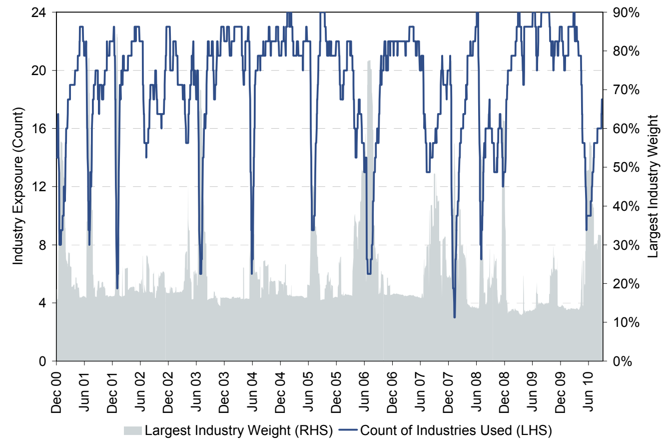
At first glance, both the Dynamically Adjusted Weights (DAWS) and Equally Weighted Overweight Signals (EWOS) seem to closely track the benchmark. Outperformance seems perhaps incidental and attributable to a few distinct periods. However, on closer inspection, outperformance of the DAWS approach is consistent over time and the strategy, relative to MSCI Europe, and has only been 5% off its ‘high water mark’ for 4 days (0.16% of the time – see Figure 14, next page) in the entire backtest period, setting new highs on 9% of all days with annualized returns of 2.7% and a low volatility (3.8%).The DAWS approach also outperforms the benchmark on 58% of days, (53% on an absolute basis).

Figure 14. Dynamically Adjusted Weights, Relative to Benchmark



Source: Citi Investment Research and Analysis

Figure 15. Number of Industries Held by Dynamically Adjusted Weights Model



Source: Citi Investment Research and Analysis

Whilst it is feasible for the DAWS model to be exposed to just a single Industry at a given point in time, we find the model holds 12 or more Industries (i.e. at least half of all industries) for 92% of the backtest period.

Model holds a minimum of 3 Industry Groups on any given day

Although at times the model is faced with significant sector tilts, these occurrences are few and far between. The model holds a minimum of 3 Industry Groups on any given day and holds less than 6 Industry Groups for, on average, only 1 day a year (Figure 15, above). This provides us with some confidence that the DAWS model is sufficiently diversified and not overtly exposed to persistent significant individual sector bias.

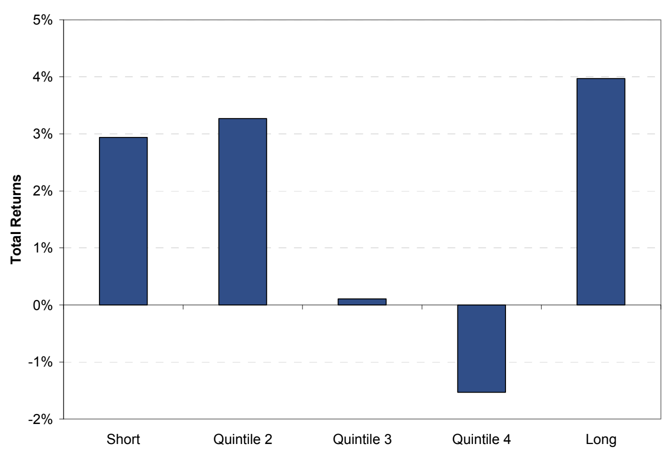
A 'Traditional' Quant Approach - Industries in Quintiles

An alternative way of utilizing the AR signals would be to incorporate them into a 'more traditional' Quant framework, allocating each Industry group to a performance 'bucket' according to the underlying AR signal (i.e. standard percentile bucketing/ranking).

With there being 24 MSCI GICS Industry Groups, we split the universe into quintiles, ranking the Industry Groups in *ascending* order according to their ΔAR score and allocating[12]:

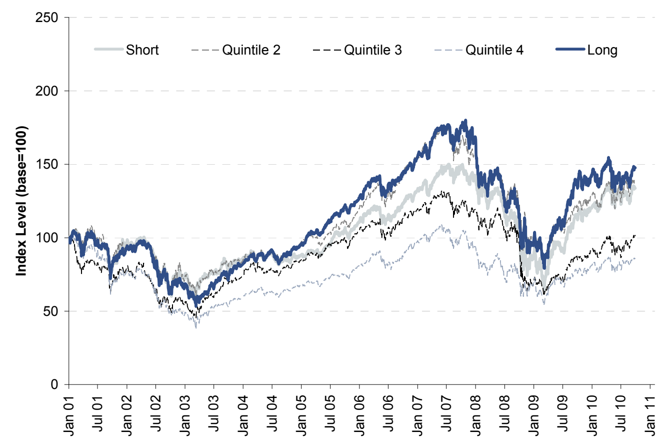
- ranks 1 to 5 in quintile 5 (our long portfolio)
- ranks 6 to 11 in quintile 4
- ranks 15 to 19 in portfolio 2
- ranks 20 to 24 in quintile 1 (our short portfolio)
- all remaining Industry Groups are allocated to quintile 3[13]

Figure 16. Quintile Total Return Spreads: Industry Group ΔAR Signals



Source: Citi Investment Research and Analysis

Figure 17. Cumulative Total Returns: Industry Group ΔAR Signals



Source: Citi Investment Research and Analysis

Although it is good to see the long quintile outperforming the short, the underperformance of quintiles 3 and 4 throw a sizable "spanner into the works" and make the distribution of quintile returns particularly non-monotonic. Having said, that if we consider the return spread between the top and bottom quintile, the total return is just over 1% and from a statistical perspective the returns are also significant at the 5% level.

The average Information Coefficient (IC) over time is a statistically insignificant 0.5%, i.e. a higher ΔAR implies higher returns, albeit marginally. It should however be noted that by grouping Industry Groups into quintiles in this manner we are removing the requirement for ΔAR to pass outside the previously defined one standard deviation bound to generate a signal and may consequently be diluting the power of the most extreme signals.

[12] Consequently, Industry Groups with the lowest ΔAR score will be in our long portfolio.

[13] Pre 2004 there are 23 Industry Groups. We follow the same logic but allocate ranks 19 to 23 to our short portfolio etc.

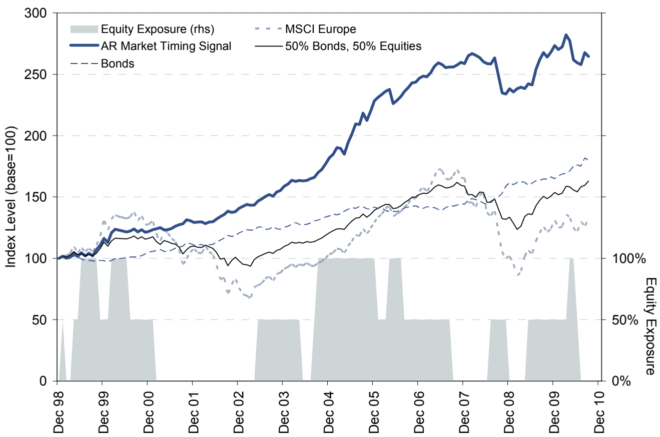
Can the Absorption Ratio Signals be used on a Monthly Basis?

There is scope for the AR signal to be used on a less frequent basis – not just daily

We previously illustrated on page 13 that the decay of the AR signal is relatively slow - even when it is lagged by 40 days. This suggests there is scope for the AR signal to be used on a less frequent basis. As a way of demonstrating the AR's usefulness and to extend the period of our analysis, we repeat the same analysis on a monthly basis. With the focus on daily data, we have been restricted by the time period with which we can undertake our analysis – daily total returns at an index level are limited pre 2000's. The monthly analysis allows a longer time period to test the signal and make inference on the daily analysis over the same period. Additionally, a rebalancing frequency other than daily is perhaps more aligned with many institutional investment managers.[14]

Using the same daily AR signals as before we take a snapshot at each month-end and then apply the same methodology to determine whether the model is 0%, 50% or 100% invested in equities over the subsequent monthly period.

Figure 18. ARMT Signal, Historical Performance & Equity Exposure



Source: Citi Investment Research and Analysis

Figure 19. Performance Statistics

	ARMT	50/50	MSCI Europe	Bonds
Annualised Return	8.6%	4.2%	2.5%	5.1%
Annualised Volatility	7.0%	7.8%	23.3%	3.6%
Information Ratio	1.2	0.5	0.1	0.5
Overall Hit Rate	67%	60%	56%	65%
% Positive Correct	*85%*	*90%*		
% Negative Correct	*44%*	*19%*		
Henricksson & Merton Test	0.23 (2.23)			
T-Stat (vs 50/50)	*1.9*			

Source: Citi Investment Research and Analysis

As with our previous findings using daily AR signals, a monthly implementation of the AR significantly outperforms a pure equity, bonds and an equally weighted mix of bonds and equities.

As expected, implementing the ARMT model on a monthly basis does indeed still provide strong returns. The ARMT model risk profile is similar to that associated with bonds yet is accompanied by a 70% increase in absolute returns and a hit rate approaching 70%. Volatility is more than halved in relation to the benchmark.

[14] Adjusting the rebalance frequency in this manner has the added benefit of extending our backtest period by 3 years to 1998 as we can utilize the additional history of MSCI total returns available on a monthly basis.

Combining the Market Timing and Sector Selection Signals

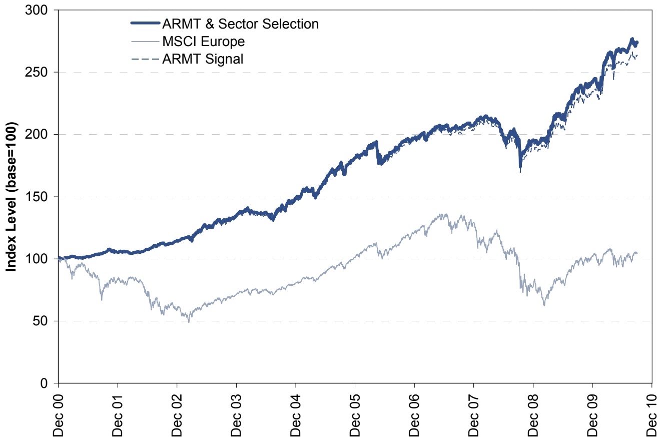
As a final step in our analysis, we combine the Absorption Ratio Market Timing model signal with a sector selection model. We recognize that the performance of the sector timing strategies that we have considered is partly driven by AR's efficacy as a market timing tool. Having presented analysis that the Dynamically Adjusted Weights approach for sector timing does outperform the benchmark, we overlay the AR market timing signal with this sector timing model.

Market Timing vs. Sector Timing – what drives the returns?

Again, the motivation of this research is not to provide a prescription for sector/market timing but merely to present enough analysis to indicate the AR signal's ability to aid in these investment pursuits. The strategy we have employed for this analysis is straight forward. Whenever the ARMT model implies an equity exposure we assume the 'equity' proportion is derived from the DAWS approach as opposed to being invested in the equity benchmark.

This analysis, when compared with the standard market timing signal, allows us to gauge the proportion of the sector signal that is market timing derived rather than a signal that is idiosyncratic to the specific sector/industry. Having said, it also must be recognized that the market timing signal may at times be driven by a specific sector – for example, the global financial crisis or TMT.

Figure 20. Combined ARMT and Sector Selection Signals



Source: Citi Investment Research and Analysis

Figure 21. Performance Statistics

	ARMT & Sector	ARMT	MSCI Europe
Annualized Return	10.6%	10.2%	0.4%
Annualized Volatility	7.7%	7.7%	21.3%
Risk Adjusted	1.4	1.3	0.0
Overall Hit Rate	58%	57%	53%
% Positive Correct	75.0%	75.5%	
% Negative Correct	38.8%	37.4%	
T-Stat (vs 50/50)	2.1	2.0	

Source: Citi Investment Research and Analysis

In terms of the performance over time of the signals derived using the AR, the results are very positive when compared to the benchmark equity index (See Figure 20). Focusing on the aggregate performance statistics, the improvement in performance is only incremental. We do, however, draw attention to the fact that both annualized (10.6% from 10.2%) and risk adjusted (1.4 from 1.3) returns are improved for a constant volatility. Whether the market timing signal is picking up something industry specific of vice versa, its impossible to tell from this analysis, however, it is clear that the market timing signal and the combination signal AR could be useful signals in potentially many investment strategies.

Conclusion

Equities are more codependent, systemic risk is a concern...

With the past few years offering a particularly unsympathetic equity market accompanied by significant spikes in volatility, timing – perhaps more than ever - has been paramount to the investment process and investors have, arguably, never been more concerned with systemic risk.

...macro has dominated; stock selection has had little added value above asset/style allocation.

Whether this has been market timing for asset allocation, sector selection or quantitative style rotation purposes, since the crisis (or should we say crises?) of 07/08, equities have become more codependent and stock selection has taken a back seat as macro factors have continued to dominate the markets – it hasn't really mattered what you have bought, the marginal contribution of effective stock selection has been minimal provided you have been invested in the right assets/styles.

With this in mind, the Absorption Ratio - a model used to measure the level of implied systemic risk in the market is of interest. Whilst the analysis is based on the findings from Kritzman, Li, Page & Rigobon (Principal Components as a Measure of Systemic Risk, 2010) for the US market, we have replicated the original analysis focusing on MSCI Europe and also extended the study to perform an empirical analysis on the use of the Absorption Ratio at an Industry Group level and as an input into a sector selection model.

To determine if the Industry Group level signals have any incremental value above just market timing, as a final step, we combined the Absorption Ratio Market Timing signals with a sector selection model (Dynamically Adjusted Weights Signal – DAWS).

The results of our analysis can be summarized as below:

The Absorption Ratio: an effective daily market timing signal...

- The Absorption Ratio Market Timing (ARMT) signal is an effective market timing model producing nearly double the return of bonds with comparable risk adjusted returns.
- The decay of the ARMT signal is fairly slow. Lagging the signal by up to 40 days still significantly outperforms both holding either equities or bonds, offering attractive risk adjusted returns.
- Extending the holding period beyond the original daily rebalance (even up to 50 days) returns in excess of 9% annualized. This gives us confidence that the ARMT is robust and that the superior risk adjusted returns are not just a result of excessive turnover.

...meaningful on a monthly basis and at an Industry Group level.

- Implementing the ARMT signal on a monthly basis consequently offers equally attractive returns, outperforming both equities and bonds.
- ARMT can also be used at a more granular level. 22 out of 24 MSCI Europe GICS Industry Groups returns are improved by integrating the ARMT signal. Only Retailing and Materials offer inferior returns.
- Using the Industry Group ARMT signals for sector selection is also fruitful. Both our Dynamic Adjusted Weights Signal (DAWS) and Equally Weighted Overweight Signal (EWOS) consistently outperform the benchmark.
- Allocating Industry Groups to quintiles according to their ARMT signals - a more typical quantitative approach - has some benefit. Long/short returns are statistically significant but are offset by a poor average Information Coefficient caused by, despite the long quintile outperforming the short, a strong non-monotonic distribution of quintile returns.

Overlaying the Absorption Ratio and a Sector Selection model further improves returns.

- Combining the ARMT model with the DAWS sector selection approach (i.e. implementing the DAWS model for any equity exposure implied by the ARMT signal) further improves returns. Although the majority of returns for this combined model appear to be driven by the ARMT market timing aspect, it is good to see that overlaying the DAWS sector selection approach does provide incremental value.

In summary, our findings suggest that the Absorption Ratio certainly has some merit as a market timing signal in Europe. Whilst we don't necessarily see this trading strategy as something a typical institutional manager would undertake, we do see it as a useful tool for identifying market fragility/systemic risk.

To avoid the pitfalls of such an aggressive style switch, our alternative method of implementation, using Absorption Ratios at the Industry Group level for input into a sector selection model, offers the potential for better returns than the benchmark with considerably smaller adjustments to the underlying Industry Group weightings.

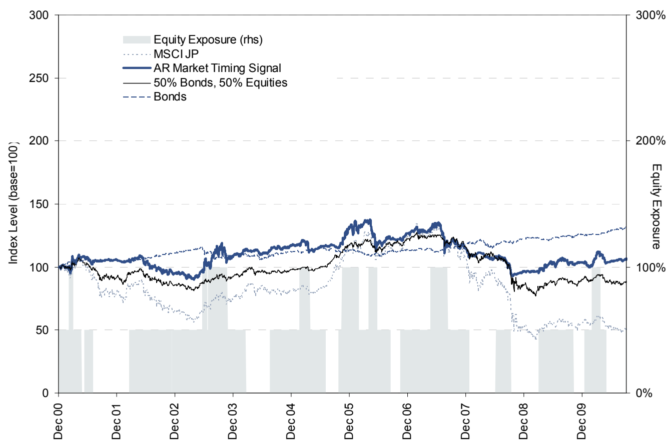
Considering the efficacy of the signal at both the market and Industry Group level, we see the Absorption Ratio as having use as both an alpha generating signal and, at the very least, as an additional risk metric for institutional managers to consider.

Appendix - ARMT in Other Regions

For completeness, we also consider our analysis from a regional perspective and below we present the base results for the ARMT model in each of:

- MSCI Japan, calculated from 24 GICS Industry Groups Indices
- MSCI United States, calculated from 24 GICS Industry Group Indices
- MSCI Asia ex Japan, calculated from 12 MSCI Asia ex JP Country Indices
- Whilst expanding the underlying indices from 12 Asia Pac ex Japan Countries to 24 Industry Groups may produce improved returns, we argue that the country bias remains more dominant in Asia Pac ex Japan and consequently present results using countries to more closely dovetail with the investment process of our Asia Pac ex Japan readership.

Figure 22. ARMT, MSCI Japan (Industry Groups)



Source: Citi Investment Research and Analysis

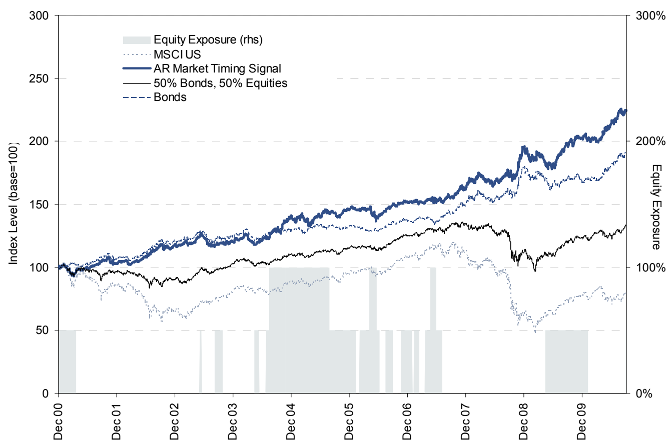
Figure 23. Performance Statistics

	ARMT	50/50	MSCI Japan	Bonds*
Annualised Return	0.6%	-1.4%	-6.7%	2.8%
Annualised Volatility	11.0%	11.1%	23.2%	3.7%
Risk Adjusted	0.0	(0.1)	(0.3)	0.8
Overall Hit Rate	53%	49%	48%	56%
% Positive Correct	79%			
% Negative Correct	29%			
Henricksson & Merton Test	0.08 (2.99)			
T-Stat (vs 50/50)	0.6			

** JGB 10 Year (total returns)*

Source: Citi Investment Research and Analysis

Figure 24. ARMT, MSCI United States (Industry Groups)



Source: Citi Investment Research and Analysis

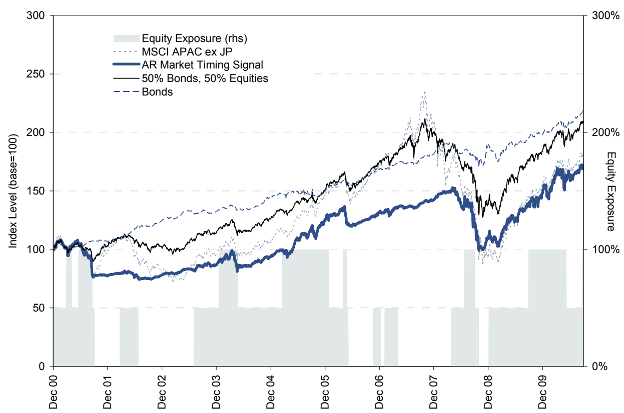
Figure 25. Performance Statistics

	ARMT	50/50	MSCI US	Bonds*
Annualised Return	8.4%	2.9%	-2.3%	6.7%
Annualised Volatility	8.1%	10.0%	21.8%	7.1%
Risk Adjusted	1.0	0.3	(0.1)	0.9
Overall Hit Rate	55%	53%	52%	54%
% Positive Correct	63%			
% Negative Correct	47%			
Henricksson & Merton Test	0.09 (3.72)			
T-Stat (vs 50/50)	1.4			

**US 10 Year (total returns)*

Source: Citi Investment Research and Analysis

Figure 26. MSCI Asia Pac ex Japan (Countries)



Source: Citi Investment Research and Analysis

Figure 27. Performance Statistics

	ARMT	50/50	MSCI APAC ex JP	Bonds*
Annualised Return	5.4%	7.6%	6.0%	8.2%
Annualised Volatility	12.6%	11.6%	21.3%	4.7%
Risk Adjusted	0.4	0.7	0.3	1.8
Overall Hit Rate	56%	55%	54%	58%
% Positive Correct	87%			
% Negative Correct	19%			
Henricksson & Merton Test	0.08 (2.69)			
T-Stat (vs 50/50)	(0.8)			

**Due to limited data availability, we use the iBoxx Asia Government Bond Index (Total Return, unhedged) as a proxy for Asia Pac ex Japan Bonds.*

Source: Citi Investment Research and Analysis

What we find

MSCI Japan: With Japan being a highly mean reverting market, it comes as no surprise that the ARMT model struggles to identify sufficient trends for effective market timing, given the 500day estimation window of the AR. That said, ARMT at least provides positive returns (0.6%) – a significant improvement to a pure equity based approach (-6.7%).

ARMT does however underperform bonds in Japan, and has a significantly higher volatility, making it the least attractive of the regions analysed from a market timing perspective.

MSCI United States: We concur with Kritzman et al and, although we use 24 Industry Groups as out input vs. their 51 industries, we find a significant improvement in both returns (8.4% annualized from -2.3%) and volatility (8.1% from 21.8%).

Risk adjusted returns are improved relative to *both* equities *and* bonds.

MSCI Asia Pacific ex Japan: Results are less attractive for Asia Pacific ex Japan, with the AMRT model underperforming both the underlying equity index and bonds. One should however take into account the fact that 1) Bond returns are perhaps inflated as they are Asian Government bonds and do not take Australia/New Zealand into account and 2) as above, we calculate the AR using 12 countries as opposed to 24 Industry Groups.

Appendix – PCA and Absorption Ratio Example

In this section we will provide a basic example of how to perform principal components analysis and follow-up with a more mathematical description of how the analysis is conducted.

A Two Asset Example

We provide a basic example on how to conduct Principal Components Analysis (PCA) which will show the concept of the analysis. For this example, we will be working within 2 dimensions, but the theory scales up to N dimensions based on the same principles. We have two stocks, BHP and RIO, and we have time series of weekly prices (Figure 14). We start off by calculating the weekly returns and then by subtracting the mean from these vectors of returns – this produces two dimensions or vectors that have means of zero.

Figure 28. Data Example

	Price		Weekly Price Return		De-meaned Return	
Date	**Asset 1**	**Asset 2**	**Asset 1**	**Asset 2**	**Asset 1**	**Asset 2**
13-Jan-10	2373	7050	1.60%	2.40%	0.60%	1.70%
20-Jan-10	2466	7400	3.80%	4.80%	2.80%	4.10%
27-Jan-10	2605	7610	5.50%	2.80%	4.50%	2.00%
03-Feb-10	2553	7475	-2.00%	-1.80%	-3.00%	-2.60%
10-Feb-10	2475	7440	-3.10%	-0.50%	-4.10%	-1.20%
17-Feb-10	2388	7165	-3.60%	-3.80%	-4.60%	-4.50%
24-Feb-10	2455	7220	2.80%	0.80%	1.80%	0.00%
03-Mar-10	2434	7035	-0.90%	-2.60%	-1.90%	-3.40%
10-Mar-10	2337	6750	-4.10%	-4.10%	-5.10%	-4.90%
17-Mar-10	2470	7125	5.50%	5.40%	4.50%	4.60%
24-Mar-10	2592	7523	4.80%	5.40%	3.80%	4.70%
31-Mar-10	2800	7885	7.70%	4.70%	6.70%	3.90%
07-Apr-10	2950	8370	5.20%	6.00%	4.20%	5.20%
14-Apr-10	2975	8232	0.80%	-1.70%	-0.20%	-2.40%
21-Apr-10	3010	8080	1.20%	-1.90%	0.20%	-2.60%
28-Apr-10	2930	7865	-2.70%	-2.70%	-3.70%	-3.50%
05-May-10	3030	8275	3.40%	5.10%	2.40%	4.30%
12-May-10	3172	8797	4.60%	6.10%	3.60%	5.30%
19-May-10	2874	7830	-9.90%	-11.60%	-10.90%	-12.40%
26-May-10	2855	8041	-0.70%	2.70%	-1.70%	1.90%
		Mean	1.00%	0.80%	0.00%	0.00%

Source: Citi Investment Research and Analysis

We then can calculate a covariance matrix using the two vectors, above, that have been mean-adjusted:

$$\text{Cov} = \begin{bmatrix} 0.00189 & 0.00174 \\ 0.00174 & 0.00212 \end{bmatrix}$$

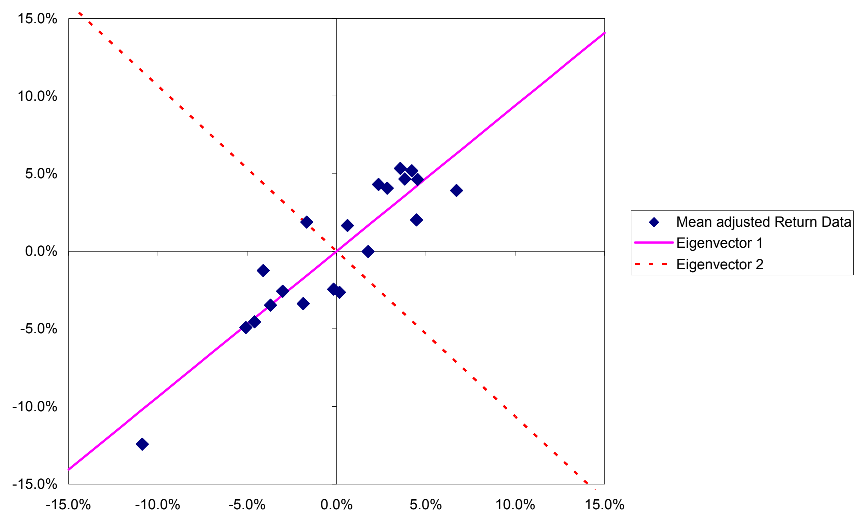
The next part is probably the most difficult part. As we have a square covariance matrix, we are able to calculate the eigenvalues and their respective eigenvectors for this matrix. Rather going into the mathematics of calculating eigenvalues/vectors, we provide them for our above covariance matrix[15]. Based on the covariance matix the resulting eigenvalues/vectors are:

Eigenvalues = $\begin{bmatrix} 0.00384 & 0.00017 \end{bmatrix}$

Eigenvectors = $\begin{bmatrix} 0.6842 & 0.7293 \\ 0.7293 & -0.6842 \end{bmatrix}$

What are eigenvalues/vectors? Without getting too technical, eigenvectors and eigenvalues help in PCA because of their mathematical properties. For eigenvectors, each eigenvector of a matrix is orthogonal to each other regardless of the dimensions of the matrix. For PCA this is important because data can be expressed in terms of the orthogonal eigenvectors instead of expressing them in terms of the x and y axis - Figure 29 illustrates this. In the chart below we plot the mean-adjusted data points from the weekly return series for Asset 1 and Asset 2. Drawn over this plot are the eigenvectors. Note that eigenvector 1, is similar to a line of best fit between of the plotted points while, eigenvector 2 is orthogonal to eigenvector 1. The first eigenvector shows us how the data is related along this line, while the second eigenvector shows us the next pattern in the data which is less important than the first. So in this regard we are able to extract lines that best characterise the original data.

Figure 29. Graphic example of mean adjusted data and the plots of the Eigenvectors



Source: Citi Investment Research and Analysis

[15] There is vast amount of literature on this subject and most statistical/mathematical packages have the capacity to calculate eigenvalues/vectors

In reference to the eigenvalues, the one with the highest value corresponds to the eigenvector that has the most significant relationship between the original data points. Therefore, ordering the eigenvectors by their respective eigenvalues gives you the principal components in order of significance. That is, the first principal component is the combination of variables that explains the greatest amount of variation. The second principal component defines the next largest amount of variation and is independent to the first principal component. We can also express this in terms of contribution to the overall variability of the data.

Figure 30. Statistics from Principal Components Analysis

Importance of Principal Components:

	PC1	PC2
Eigenvalue	0.0038	0.0002
Std Dev	0.0619	0.0131
% of Variance	0.957	0.043

Loadings:

	PC1	PC2
Eigenvector1	0.6842	0.7293
Eigenvector2	0.7293	-0.6842

Source: Citi Investment Research and Analysis

Relating this example to the Absorption Ratio, and in a rather extreme way, the total variance of this portfolio is sum of the Eigenvalues (e.g. 0.0038 + 0.0002 = 0.004). Principal Component 1 explains 95.7% of the total variance of the portfolio. The number of "assets" that are used in the analysis is the same number of the PCs that are output. In this example, two assets equals 2 principal components and PC1 suggests there is very dominant factor in explaining the return variability of this portfolio, and in the contact of the AR, this could be an indicator of some high level of systemic risk.

From a Technical/Mathematical Perspective

Consider a pool of N securities. We assume that the vector of historical returns for each security in the universe is known and denoted $\hat{r}^{(i)} = \left\{\hat{r}_t^{(i)}\right\}$ where *(i)* stands for the number of a stock in the universe. We can now evaluate a correlation matrix for securities returns $\hat{C}$ as $C_{i,j} = \mathrm{cov}(\hat{r}^{(i)}, \hat{r}^{(j)}) \big/ \sigma^{(i)}, \sigma^{(j)}$ where $\mathrm{cov}(\hat{r}^{(i)}, \hat{r}^{(j)})$ is a covariance of vectors (i) and (j) and $\sigma^{(i)}$ is the corresponding standard deviation.

In order to evaluate the principal components of the data set, we need to find eigenvalues λ_i and eigenvectors $\hat{e}_i$ of the correlation matrix, where are, by definition, solutions to the matrix equation:

$$\left(\hat{C} - \lambda_i \hat{I}\right)\hat{e}_i = 0$$

EQ-1

where $\hat{I} = \left[\delta_{ij}\right]$, with $\delta_{ij} = 1$ for *i=j* and 0 otherwise, is an identity matrix, and $i \in \left[1,2,\ldots,N\right]$.

After solving EQ-1, the matrix of principal components is then given as:

$$\hat{P} = \hat{T}\hat{R}$$

EQ-2

where $\hat{R}$ is a matrix of vectors $\hat{r}^{(i)}$ in the original time series, and $\hat{T}$ is the transformation matrix given by:

$$\hat{T} = \begin{bmatrix} e_{11} & \ldots & e_{1N} \\ \ldots & \ldots & \ldots \\ e_{N1} & \ldots & e_{NN} \end{bmatrix}$$

EQ-3

Principal components thus generated are uncorrelated and ordered by declining variance $\lambda_1 \geq \lambda_2 \geq \ldots \lambda_N$. The correlation matrix of the transformed data is diagonal matrix whose elements are made up of eigenvalues. The transformed points $\hat{P}$ are linear combinations of their original data value $\hat{R}$ weighted by the eigenvectors.

Appendix – References

Aït-Sahalia, Y. and M.W. Brandt, 2001, Variable selection for portfolio choice, Journal of Finance, 56, 1297-1351.

Ang, A., and G. Bekaert, 2006, Stock return predictability: Is it there?, Review of Financial Studies, 20, 3, 651-707.

Avramov, D., 2004, Stock return predictability and asset pricing models. Review of Financial Studies, 17, 699-738.

Avramov, D., 2002, Stock return predictability and model uncertainty, Journal of Financial Economics, 64, 423-458.

Avramov, D. and T. Chordia, 2006, Predicting stock returns, Journal of Financial Economics, 82, 387-415.

Barberis, N., 2000, Investing for the long run when returns are predictable, Journal of Finance, 55, 225-264.

Beber, A., M. W. Brandt, and K. A. Kavajecz, 2008, What Does Equity Sector Orderflow Tell Us About the Economy? Working Paper.

Beller, K. R., J. L. Kling, and M. J. Levinson, 1998, Are Industry Stock Returns Predictable?, Financial Analysts Journal, 54, September/October, 42-57.

Billio, M., M. Getmansky, A. W. Lo, and L. Pelizzon, 2010, Econometric Measures of Systemic Risk in the Finance and Insurance Sectors. NBER Working Paper Series

Boni, L. and K.L. Womack, 2006, Analysts, Industries, and Price Momentum, Journal of Financial and Quantitative Analysis, 41, 85-109.

Bossaerts, P., Hillion, P., 1999. Implementing statistical criteria to select return forecasting models: what do we learn? Review of Financial Studies 12, 405-428.

Campbell, J.Y., 1991, *A Variance Decomposition for Stock Returns,* Economic Journal, 101, 157-179.

Campbell, J.Y., 1987, Stock returns and the term structure, Journal of Financial Economics, 18, 373-399.

Campbell, J.Y. and R.J. Shiller, 1988, Stock prices, earnings, and expected dividends, Journal of Finance, 43, 661-676.

Cavaglia, S. and V. Moroz, 2002, Cross-Industry, Cross-Country Allocation, Financial Analysts Journal, November/December, 78-97.

Chen, N.-F., R. Roll, and S.A. Ross, 1986, Economic forces and the stock market, Journal of Business, 59, 3, 383-403.

Clarke, R.G. M.T. Fitzgerald, P. Berent, and M. Statman, 1989, Market Timing with imperfect Information, Financial Analysts Journal, November/December 1989, 27-36

Conover, C.M., G.R. Jensen, R.R. Johnson, and J.M. Mercer, 2008, Sector Rotation and Monetary Conditions, Journal of Investing, 17, 1, 34-46.

Cremers, M.K.J., 2002, Stock return predictability: A Bayesian model selection perspective, Review of Financial Studies, 15, 4, 1223-1249

Faber, M. T., 2007, A Quantitative Approach to Tactical Asset Allocation, Journal of Portfolio Management, Spring, 69-79.

Fama, E.F., French, K.R., 1989, Business conditions and expected returns on stocks and bonds, Journal of Financial Economics, 25, 23-49.

Ferson, W.E., 1990, Are the latent variables in time-varying expected returns compensation for consumption risk?, Journal of Finance, 45, 397-429.

Ferson, W.E., and C.R. Harvey, 1993, The risk and predictability of international equity returns, Review of Financial Studies, 6, 527-566.

Ferson, W.E., and C.R. Harvey, 1991a, The variation in economic risk premia, Journal of Political Economy, 99, 385-415.

Ferson, W.E., and C.R. Harvey, 1991b, Sources of predictability in portfolio returns, Financial Analysts Journal, May-June, 49-56.

Fletcher, J., 1997, An investigation of alternative estimators of expected returns in mean-variance analysis, Journal of Financial Research, 20, 1, 129-143.

Froot, K. A. and M. Teo. 2008, Equity Style Returns and Institutional Investor Flows, Journal of Financial and Quantitative Analysis, 43, 4, 883-906.

Guo, H. and J. Higbee, 2007, Market Timing with Aggregate and Idiosyncratic Stock Volatilities, Journal of Portfolio Management, Summer, 26-32

Henriksson, R.D. and R.C. Merton, 1981, On Market Timing and Investment Performance. II. Statistical Procedures for Evaluating Forecasting Skills, Journal of Business, Volume 54,October, Issue 4

Kadan, O., L. Madureira, R. Wang, and T. Zach, 2009, Do Industry Recommendations have Investment Value?, Working Paper.

Kandel, S. and R. Stambaugh, 1996, On the predictability of stock returns: An asset allocation perspective, Journal of Finance, 51, 385-424.

Keim, D. and R.F. Stambaugh, 1986, Predicting returns in the stock and the bond markets, Journal of Financial Economics, 17, 357-390.

Kritzman M., Y. Li, S. Page and R. Rigoban, 2010, Principal Components as a Measure of Systemic Risk, MIT Sloan Working Paper 4785-10.

Loudon, G. and J. Okunev, 2006, Generating Excess Returns through Global Industry Rotation, Working Paper.

Lynch, A.W. and P. Balduzzi, 2000, Predictability and transaction costs: The impact on rebalancing rules and behavior, Journal of Finance, 55, 2285-2309.

Pastor, L., 2000, Portfolio selection and asset pricing models, Journal of Finance 55, 179-223.

Moskowitz, T.J. and M. Grinblatt, 1999, Do Industries Explain Momentum?, Journal of Finance, 54, 4, 1249-1290.

O'Neil, E.S., 2000, Industry Momentum and Sector Mutual Funds, Financial Analysts Journal, July/August, 37-49.

Pastor, L. and R.F. Stambaugh, 2008, Predictive Systems: Living with Imperfect Predictors, CRSP Working Paper No. 617, Available at SSRN: http://ssrn.com/abstract=953272.

Pastor, L. and R.F. Stambaugh, 2000, Comparing asset pricing models: an investment perspective, Journal of Financial Economics, 56, 335-381.

Pesaran, M.H. and A. Timmermann, 1995, Predictability of stock returns: Robustness and economic significance, Journal of Finance, 50, 1201-1228.

Pontiff, J. and L.D. Schall, 1998, Book-to-market ratios as predictors of market returns, Journal of Financial Economics, 49, 141-160.

Salsman, R.M., 1997, Using Market Prices to Guide Sector Rotation, AIMR Conference Proceedings, 1997, 2, 48-57.

Shen, P., 2003, Market Timing Strategies That Worked, Journal of Portfolio Management, Winter, 57-68.

Sorensen, E. H. and T. Burke, 1986, Portfolio Returns from Active Industry Group Rotation, Financial Analysts Journal, 42, September/October, 43-50.

Whitelaw, R.F., 1994, Time variations and covariations in the expectation and volatility of stock market returns, Journal of Finance, 49, 515-541.

Xia, Y., 2001, Learning about predictability: The effects of parameter uncertainty on dynamic asset allocation, Journal of Finance, 56, 205-246.

Global Quantitative Research Team

Global Quantitative Research Director			
Keith L. Miller	New York	+1-212-816-2285	*keith.l.miller@citi.com*
Asia-Pacific			
Paul Chanin	Singapore	+65-6432-1153	*paul.chanin@citi.com*
Tan Si An	Singapore	+65-6432-1175	*si.an.tan@citi.com*
Nachiket Garde	Tokyo	+81 (3) 6270 -4888	*nachiket.garde@citi.com*
Tushar Mandal	Singapore	+65-6432-1154	*tushar.mandal@citi.com*
Nick Morton	Sydney	+61-2-8225-4895	*nick.morton@citi.com*
Puneet Singh	Singapore	+65-6432-1172	*puneet.singh@citi.com*
Aditya Shah	Mumbai	+91 (22) 6641-8959	*aditya.b.shah@citi.com*
Zee Yusuf	Sydney	+61-2-8225-4895	*zee.yusuf@citi.com*
Europe			
Chris Montagu	London	+44-20-7986-3958	*chris.montagu@citi.com*
Matt Burgess	London	+44-20-7986-8325	*matt.burgess@citi.com*
David Chew	London	+44-20-7986-7698	*david.chew@citi.com*
Helen Krause	London	+44-20-7986-8653	*helen.krause@citi.com*
Rahul Jalan	London	+44-20-7986-4075	*rahul.jalan@citi.com*
Lingjuan Ma	London	+44-20-7986-4404	*lingjuan.ma@citi.com*
North America			
Keith L. Miller	New York	+1-212-816-2285	*keith.l.miller@citi.com*
Emily Jing Jia	New York	+1-212-816-1867	*emily.jing.jia@citi.com*
Dading Li	New York	+1-212-816-1824	*dading.li@citi.com*
Hong Li	New York	+1-212-816-1844	*hong.li@citi.com*
John Rowe	New York	+1-212-816-6054	*john.rowe@citi.com*
Richard Schlatter	New York	+1-212-816 6279	*richard.w.schlatter@citi.com*
Aline Sun	New York	+1-212-816-7083	*aline.sun@citi.com*
Tiffany Zhou	New York	+1-212-816-4659	*tiffany.zhou@citi.com*
Peter Lo	New York	+1-212-816-0379	*peter.lo@citi.com*
Academic Consultant			
Daniel Giamouridis	London	+44-20-7986-3958	*gqrlondon@citi.com*

Notes

Notes

Notes

Appendix A-1

Analyst Certification

The research analyst(s) primarily responsible for the preparation and content of this research report are named in bold text in the author block at the front of the product except for those sections where an analyst's name appears in bold alongside content which is attributable to that analyst. Each of these analyst(s) certify, with respect to the section(s) of the report for which they are responsible, that the views expressed therein accurately reflect their personal views about each issuer and security referenced and that no part of their compensation was, is, or will be, directly or indirectly, related to the specific recommendation(s) or view(s) expressed by that research analyst in this report.

IMPORTANT DISCLOSURES

Analysts' compensation is determined based upon activities and services intended to benefit the investor clients of Citigroup Global Markets Inc. and its affiliates ("the Firm"). Like all Firm employees, analysts receive compensation that is impacted by overall firm profitability which includes investment banking revenues.

For important disclosures (including copies of historical disclosures) regarding the companies that are the subject of this Citi Investment Research & Analysis product ("the Product"), please contact Citi Investment Research & Analysis, 388 Greenwich Street, 28th Floor, New York, NY, 10013, Attention: Legal/Compliance. In addition, the same important disclosures, with the exception of the Valuation and Risk assessments and historical disclosures, are contained on the Firm's disclosure website at www.citigroupgeo.com. Valuation and Risk assessments can be found in the text of the most recent research note/report regarding the subject company. Historical disclosures (for up to the past three years) will be provided upon request.

Citi Investment Research & Analysis Ratings Distribution

Data current as of 30 Sep 2010	**Buy**	**Hold**	**Sell**
Citi Investment Research & Analysis Quantitative World Radar Screen Model Coverage	30%	40%	30%
% of companies in each rating category that are investment banking clients	21%	23%	21%
Citi Investment Research & Analysis Quantitative Decision Tree Model Coverage	48%	0%	52%
% of companies in each rating category that are investment banking clients	59%	0%	47%
Citi Investment Research & Analysis Quantitative European Value & Momentum Screen	30%	40%	30%
% of companies in each rating category that are investment banking clients	49%	52%	47%
Citi Investment Research & Analysis Asia Quantitative Radar Screen Model Coverage	20%	60%	20%
% of companies in each rating category that are investment banking clients	19%	20%	23%
Citi Investment Research & Analysis Australia Radar Model Coverage	50%	0%	50%
% of companies in each rating category that are investment banking clients	27%	0%	26%

Guide to Citi Investment Research & Analysis (CIRA) Quantitative Research Investment Ratings:

CIRA Quantitative Research World Radar Screen recommendations are based on a globally consistent framework to measure relative value and momentum for a large number of stocks across global developed and emerging markets. Relative value and momentum rankings are equally weighted to produce a global attractiveness score for each stock. The scores are then ranked and put into deciles. A stock with a decile rating of 1 denotes an attractiveness score in the top 10% of the universe (most attractive). A stock with a decile rating of 10 denotes an attractiveness score in the bottom 10% of the universe (least attractive).

CIRA Asia Quantitative Radar Screen model recommendations are based on a regionally consistent framework to measure relative value and momentum for a large number of stocks across regional developed and emerging markets. Relative value and momentum rankings are equally weighted to produce a global attractiveness score for each stock. The scores are then ranked and put into quintiles. A stock with a quintile rating of 1 denotes an attractiveness score in the top 20% of the universe (most attractive). A stock with a quintile rating of 5 denotes an attractiveness score in the bottom 20% of the universe (least attractive).

CIRA Australia Quantitative Radar Screen model recommendations are based on a robust framework to measure relative value and momentum for a large number of stocks across the Australian market. Stocks with a ranking of 1 denotes a stock that is above average in terms of both value and momentum relative to the stocks in the Australian market. A ranking of 10 denotes a stock that is below average in terms of both value and momentum relative to the stocks in the Australian market.

CIRA Quantitative Decision Tree model recommendations are based on a predetermined set of factors to rate the relative attractiveness of stocks. These factors are detailed in the text of the report. The Decision Tree model forecasts whether stocks are attractive or unattractive relative to other stocks in the same sector (based on the Russell 1000 sector classifications).

For purposes of NASD/NYSE ratings-distribution-disclosure rules, a Citi Investment Research & Analysis (CIRA) Quantitative World Radar Screen recommendation of (1), (2) or (3) most closely corresponds to a buy recommendation; a recommendation from this product group of (4), (5), (6) or (7) most closely corresponds to a hold recommendation; and a recommendation of (8), (9) or (10) most closely corresponds to a sell recommendation. An (NR) recommendation indicates that the stock is no longer in the screen.

For purposes of NASD/NYSE ratings distribution disclosure rules, a CIRA Asia Quantitative Radar Screen recommendation of (1) most closely corresponds to a buy recommendation; a CIRA Asia Quantitative Radar Screen recommendation of (2), (3), (4) most closely corresponds to a hold recommendation; and a recommendation of (5) most closely corresponds to a sell recommendation. An (NR) recommendation indicates that the stock is no longer in the screen.

For purposes of NASD/NYSE ratings-distribution-disclosure rules, a CIRA Quantitative Research Decision Tree model or Quantitative Research Australia Radar Screen recommendation of "attractive" (1) most closely corresponds to a buy recommendation. All other stocks in the sector are considered to be "unattractive" (10) which most closely corresponds to a sell recommendation. An (NR)/(0) recommendation indicates that the stock is no longer in the screen.

Recommendations are based on the relative attractiveness of a stock, thus can not be directly equated to buy, hold and sell categories. Accordingly, your decision to buy or sell a security should be based on your personal investment objectives and only after evaluating the stock's expected relative performance.

NON-US RESEARCH ANALYST DISCLOSURES

Non-US research analysts who have prepared this report (i.e., all research analysts listed below other than those identified as employed by Citigroup Global Markets Inc.) are not registered/qualified as research analysts with FINRA. Such research analysts may not be associated persons of the member organization and therefore may not be subject to the NYSE Rule 472 and NASD Rule 2711 restrictions on communications with a subject company, public appearances and trading securities held by a research analyst account. The legal entities employing the authors of this report are listed below:

Citigroup Global Markets Ltd	Chris Montagu; Helen H Krause, CFA; Matthew J Burgess; Rahul Jalan; Lingjuan Ma

OTHER DISCLOSURES

For securities recommended in the Product in which the Firm is not a market maker, the Firm is a liquidity provider in the issuers' financial instruments and may act as principal in connection with such transactions. The Firm is a regular issuer of traded financial instruments linked to securities that may have been recommended in the Product. The Firm regularly trades in the securities of the issuer(s) discussed in the Product. The Firm may engage in securities transactions in a manner inconsistent with the Product and, with respect to securities covered by the Product, will buy or sell from customers on a principal basis.

Securities recommended, offered, or sold by the Firm: (i) are not insured by the Federal Deposit Insurance Corporation; (ii) are not deposits or other obligations of any insured depository institution (including Citibank); and (iii) are subject to investment risks, including the possible loss of the principal amount invested. Although information has been obtained from and is based upon sources that the Firm believes to be reliable, we do not guarantee its accuracy and it may be incomplete and condensed. Note, however, that the Firm has taken all reasonable steps to determine the accuracy and completeness of the disclosures made in the Important Disclosures section of the Product. The Firm's research department has received assistance from the subject company(ies) referred to in this Product including, but not limited to, discussions with management of the subject company(ies). Firm policy prohibits research analysts from sending draft research to subject companies. However, it should be presumed that the author of the Product has had discussions with the subject company to ensure factual accuracy prior to publication. All opinions, projections and estimates constitute the judgment of the author as of the date of the Product and these, plus any other information contained in the Product, are subject to change without notice. Prices and availability of financial instruments also are subject to change without notice. Notwithstanding other departments within the Firm advising the companies discussed in this Product, information obtained in such role is not used in the preparation of the Product. Although Citi Investment Research & Analysis (CIRA) does not set a predetermined frequency for publication, if the Product is a fundamental research report, it is the intention of CIRA to provide research coverage of the/those issuer(s) mentioned therein, including in response to news affecting this issuer, subject to applicable quiet periods and capacity constraints. The Product is for informational purposes only and is not intended as an offer or solicitation for the purchase or sale of a security. Any decision to purchase securities mentioned in the Product must take into account existing public information on such security or any registered prospectus.

Investing in non-U.S. securities, including ADRs, may entail certain risks. The securities of non-U.S. issuers may not be registered with, nor be subject to the reporting requirements of the U.S. Securities and Exchange Commission. There may be limited information available on foreign securities. Foreign companies are generally not subject to uniform audit and reporting standards, practices and requirements comparable to those in the U.S. Securities of some foreign companies may be less liquid and their prices more volatile than securities of comparable U.S. companies. In addition, exchange rate movements may have an adverse effect on the value of an investment in a foreign stock and its corresponding dividend payment for U.S. investors. Net dividends to ADR investors are estimated, using withholding tax rates conventions, deemed accurate, but investors are urged to consult their tax advisor for exact dividend computations. Investors who have received the Product from the Firm may be prohibited in certain states or other jurisdictions from purchasing securities mentioned in the Product from the Firm. Please ask your Financial Consultant for additional details. Citigroup Global Markets Inc. takes responsibility for the Product in the United States. Any orders by US investors resulting from the information contained in the Product may be placed only through Citigroup Global Markets Inc.

Important Disclosures for Morgan Stanley Smith Barney LLC Customers: Morgan Stanley & Co. Incorporated (Morgan Stanley) research reports may be available about the companies that are the subject of this Citi Investment Research & Analysis (CIRA) research report. Ask your Financial Advisor or use smithbarney.com to view any available Morgan Stanley research reports in addition to CIRA research reports.
Important disclosure regarding the relationship between the companies that are the subject of this CIRA research report and Morgan Stanley Smith Barney LLC and its affiliates are available at the Morgan Stanley Smith Barney disclosure website at www.morganstanleysmithbarney.com/researchdisclosures.
The required disclosures provided by Morgan Stanley and Citigroup Global Markets, Inc. on Morgan Stanley and CIRA research relate in part to the separate businesses of Citigroup Global Markets, Inc. and Morgan Stanley that now form Morgan Stanley Smith Barney LLC, rather than to Morgan Stanley Smith Barney LLC in its entirety. For Morgan Stanley and Citigroup Global Markets, Inc. specific disclosures, you may refer to www.morganstanley.com/researchdisclosures and https://www.citigroupgeo.com/geopublic/Disclosures/index_a.html.
This CIRA research report has been reviewed and approved on behalf of Morgan Stanley Smith Barney LLC. This review and approval was conducted by the same person who reviewed this research report on behalf of CIRA. This could create a conflict of interest.

The Citigroup legal entity that takes responsibility for the production of the Product is the legal entity which the first named author is employed by. The Product is made available in Australia through Citigroup Global Markets Australia Pty Ltd. (ABN 64 003 114 832 and AFSL No. 240992), participant of the ASX Group and regulated by the Australian Securities & Investments Commission. Citigroup Centre, 2 Park Street, Sydney, NSW 2000. The Product is made available in Australia to Private Banking wholesale clients through Citigroup Pty Limited (ABN 88 004 325 080 and AFSL 238098). Citigroup Pty Limited provides all financial product advice to Australian Private Banking wholesale clients through bankers and relationship managers. If there is any doubt about the suitability of investments held in Citigroup Private Bank accounts, investors should contact the Citigroup Private Bank in Australia. Citigroup companies may compensate affiliates and their representatives for providing products and services to clients. The Product is made available in Brazil by Citigroup Global Markets Brasil - CCTVM SA, which is regulated by CVM - Comissão de Valores Mobiliários, BACEN - Brazilian Central Bank, APIMEC - Associação dos Analistas e Profissionais de Investimento do Mercado de Capitais and ANBID - Associação Nacional dos Bancos de Investimento. Av. Paulista, 1111 - 11º andar - CEP. 01311920 - São Paulo - SP. If the Product is being made available in certain provinces of Canada by Citigroup Global Markets (Canada) Inc. ("CGM Canada"), CGM Canada has approved the Product. Citigroup Place, 123 Front Street West, Suite 1100, Toronto, Ontario M5J 2M3. The Product is made available in France by Citigroup Global Markets Limited, which is authorised and regulated by Financial Services Authority. 1-5 Rue Paul Cézanne, 8ème, Paris, France. If the Product is made available in Hong Kong by, or on behalf of, Citigroup Global Markets Asia Ltd., it is attributable to Citigroup Global Markets Asia Ltd., Citibank Tower, Citibank Plaza, 3 Garden Road, Hong Kong. Citigroup Global Markets Asia Ltd. is regulated by Hong Kong Securities and Futures Commission. If the Product is made available in Hong Kong by The Citigroup Private Bank to its clients, it is attributable to Citibank N.A., Citibank Tower, Citibank Plaza, 3 Garden Road, Hong Kong. The Citigroup Private Bank and Citibank N.A. is regulated by the Hong Kong Monetary Authority. The Product is made available in India by Citigroup Global Markets India Private Limited, which is regulated by Securities and Exchange Board of India. Bakhtawar, Nariman Point, Mumbai 400-021. The Product is made available in Indonesia through PT Citigroup Securities Indonesia. 5/F, Citibank Tower, Bapindo Plaza, Jl. Jend. Sudirman Kav. 54-55, Jakarta 12190. Neither this Product nor any copy hereof may be distributed in Indonesia or to any Indonesian citizens wherever they are domiciled or to Indonesian residents except in compliance with applicable capital market laws and regulations. This Product is not an offer of securities in Indonesia. The securities referred to in this Product have not been registered with the Capital Market and Financial Institutions Supervisory Agency (BAPEPAM-LK) pursuant to relevant capital market laws and regulations, and may not be offered or sold within the territory of the Republic of Indonesia or to Indonesian citizens through a public offering or in circumstances which constitute an offer within the meaning of the Indonesian capital market laws and regulations. The Product is made available in Israel through Citibank NA, regulated by the Bank of Israel and the Israeli Securities Authority. Citibank, N.A, Platinum Building, 21 Ha'arba'ah St, Tel Aviv, Israel. The Product is made available in Italy by Citigroup Global Markets Limited, which is authorised and regulated by Financial Services Authority. Foro Buonaparte 16, Milan, 20121, Italy. The Product is made available in Japan by Citigroup Global Markets Japan Inc. ("CGMJ"), which is regulated by Financial Services Agency, Securities and Exchange Surveillance Commission, Japan Securities Dealers Association, Tokyo Stock Exchange

and Osaka Securities Exchange. Shin-Marunouchi Building, 1-5-1 Marunouchi, Chiyoda-ku, Tokyo 100-6520 Japan. If the Product was distributed by Nikko Cordial Securities Inc. it is being so distributed under license. In the event that an error is found in an CGMJ research report, a revised version will be posted on the Firm's Global Equities Online (GEO) website. If you have questions regarding GEO, please call (81 3) 6270-3019 for help. The Product is made available in Korea by Citigroup Global Markets Korea Securities Ltd., which is regulated by the Financial Services Commission, the Financial Supervisory Service and the Korea Financial Investment Association (KOFIA). Citibank Building, 39 Da-dong, Jung-gu, Seoul 110-180, Korea. KOFIA makes available registration information of research analysts on its website. Please visit the following website if you wish to find KOFIA registration information on research analysts of Citigroup Global Markets Korea Securities Ltd. http://dis.kofia.or.kr/fs/dis2/fundMgr/DISFundMgrAnalystPop.jsp?companyCd2=A03030&pageDiv=02. The Product is made available in Malaysia by Citigroup Global Markets Malaysia Sdn Bhd, which is regulated by Malaysia Securities Commission. Menara Citibank, 165 Jalan Ampang, Kuala Lumpur, 50450. The Product is made available in Mexico by Acciones y Valores Banamex, S.A. De C. V., Casa de Bolsa, Integrante del Grupo Financiero Banamex ("Accival") which is a wholly owned subsidiary of Citigroup Inc. and is regulated by Comision Nacional Bancaria y de Valores. Reforma 398, Col. Juarez, 06600 Mexico, D.F. In New Zealand the Product is made available through Citigroup Global Markets New Zealand Ltd. (Company Number 604457), a Participant of the New Zealand Exchange Limited and regulated by the New Zealand Securities Commission. Level 19, Mobile on the Park, 157 Lambton Quay, Wellington. The Product is made available in Pakistan by Citibank N.A. Pakistan branch, which is regulated by the State Bank of Pakistan and Securities Exchange Commission, Pakistan. AWT Plaza, 1.1. Chundrigar Road, P.O. Box 4889, Karachi-74200. The Product is made available in Poland by Dom Maklerski Banku Handlowego SA an indirect subsidiary of Citigroup Inc., which is regulated by Komisja Nadzoru Finansowego. Dom Maklerski Banku Handlowego S.A. ul. Chalubinskiego 8, 00-630 Warszawa. The Product is made available in the Russian Federation through ZAO Citibank, which is licensed to carry out banking activities in the Russian Federation in accordance with the general banking license issued by the Central Bank of the Russian Federation and brokerage activities in accordance with the license issued by the Federal Service for Financial Markets. Neither the Product nor any information contained in the Product shall be considered as advertising the securities mentioned in this report within the territory of the Russian Federation or outside the Russian Federation. The Product does not constitute an appraisal within the meaning of the Federal Law of the Russian Federation of 29 July 1998 No. 135-FZ (as amended) On Appraisal Activities in the Russian Federation. 8-10 Gasheka Street, 125047 Moscow. The Product is made available in Singapore through Citigroup Global Markets Singapore Pte. Ltd., a Capital Markets Services Licence holder, and regulated by Monetary Authority of Singapore. 1 Temasek Avenue, #39-02 Millenia Tower, Singapore 039192. The Product is made available by The Citigroup Private Bank in Singapore through Citibank, N.A., Singapore branch, a licensed bank in Singapore that is regulated by Monetary Authority of Singapore. Citigroup Global Markets (Pty) Ltd. is incorporated in the Republic of South Africa (company registration number 2000/025866/07) and its registered office is at 145 West Street, Sandton, 2196, Saxonwold. Citigroup Global Markets (Pty) Ltd. is regulated by JSE Securities Exchange South Africa, South African Reserve Bank and the Financial Services Board. The investments and services contained herein are not available to private customers in South Africa. The Product is made available in Spain by Citigroup Global Markets Limited, which is authorised and regulated by Financial Services Authority. 29 Jose Ortega Y Gassef, 4th Floor, Madrid, 28006, Spain. The Product is made available in Taiwan through Citigroup Global Markets Taiwan Securities Company Ltd., which is regulated by Securities & Futures Bureau. No portion of the report may be reproduced or quoted in Taiwan by the press or any other person. No. 1, Songzhi Road, Taipei 110, Taiwan. The Product is made available in Thailand through Citicorp Securities (Thailand) Ltd., which is regulated by the Securities and Exchange Commission of Thailand. 18/F, 22/F and 29/F, 82 North Sathorn Road, Silom, Bangrak, Bangkok 10500, Thailand. The Product is made available in Turkey through Citibank AS which is regulated by Capital Markets Board. Tekfen Tower, Eski Buyukdere Caddesi # 209 Kat 2B, 23294 Levent, Istanbul, Turkey. In the U.A.E, these materials (the "Materials") are communicated by Citigroup Global Markets Limited, DIFC branch ("CGML"), an entity registered in the Dubai International Financial Center ("DIFC") and licensed and regulated by the Dubai Financial Services Authority ("DFSA" to Professional Clients and Market Counterparties only and should not be relied upon or distributed to Retail Clients. A distribution of the different CIRA ratings distribution, in percentage terms for Investments in each sector covered is made available on request. Financial products and/or services to which the Materials relate will only be made available to Professional Clients and Market Counterparties. The Product is made available in United Kingdom by Citigroup Global Markets Limited, which is authorised and regulated by Financial Services Authority. This material may relate to investments or services of a person outside of the UK or to other matters which are not regulated by the FSA and further details as to where this may be the case are available upon request in respect of this material. Citigroup Centre, Canada Square, Canary Wharf, London, E14 5LB. The Product is made available in United States by Citigroup Global Markets Inc, which is regulated by FINRA and the US Securities and Exchange Commission. 388 Greenwich Street, New York, NY 10013.

Unless specified to the contrary, within EU Member States, the Product is made available by Citigroup Global Markets Limited, which is regulated by Financial Services Authority.

Many European regulators require that a firm must establish, implement and make available a policy for managing conflicts of interest arising as a result of publication or distribution of investment research. The policy applicable to CIRA's Products can be found at www.citigroupgeo.com.

Compensation of equity research analysts is determined by equity research management and Citigroup's senior management and is not linked to specific transactions or recommendations.

The Product may have been distributed simultaneously, in multiple formats, to the Firm's worldwide institutional and retail customers. The Product is not to be construed as providing investment services in any jurisdiction where the provision of such services would not be permitted.

Subject to the nature and contents of the Product, the investments described therein are subject to fluctuations in price and/or value and investors may get back less than originally invested. Certain high-volatility investments can be subject to sudden and large falls in value that could equal or exceed the amount invested. Certain investments contained in the Product may have tax implications for private customers whereby levels and basis of taxation may be subject to change. If in doubt, investors should seek advice from a tax adviser. The Product does not purport to identify the nature of the specific market or other risks associated with a particular transaction. Advice in the Product is general and should not be construed as personal advice given it has been prepared without taking account of the objectives, financial situation or needs of any particular investor. Accordingly, investors should, before acting on the advice, consider the appropriateness of the advice, having regard to their objectives, financial situation and needs. Prior to acquiring any financial product, it is the client's responsibility to obtain the relevant offer document for the product and consider it before making a decision as to whether to purchase the product.

CIRA concurrently disseminates its research via proprietary and non-proprietary electronic distribution platforms. Periodically, individual analysts may also opt to circulate research to one or more clients by email. Such email distribution is discretionary and is done only after the research has been disseminated via the aforementioned distribution channels.