Currency Overlay Management
It’s All about Beliefs and Objectives

By Robert Colehan and Edward D. Baker

In Colehan and Baker (2011) we discussed how the globalization of the financial markets has brought about opportunities for wider asset diversification and greater potential returns through international investment. We highlighted that while investing across international asset markets does provide these benefits, it also introduces an unintended byproduct, namely currency risk, which can have a significant impact on investment returns.

As with all things in life, actions can lead to unintended consequences, and international investment is no different. This is because when pension funds have exposure to international assets (ideally to boost pension fund returns), changes in currency rates will directly impact the value of these assets. This may add significantly to the volatility of returns and indeed, in many instances, can dominate the volatility of the underlying asset.

Our earlier article provided a general overview of the foreign exchange markets, and this article expands on how the currency exposures of institutional clients such as pension funds can be managed.

In this article we address the following two areas:

- What is currency risk and how does it impact an investor who invests globally?
- How can an investor effectively manage foreign currency exposure?

**Currency Risk and Its Impact on Investors**

Over the past decade or so, the non-home-country exposure of pension funds in many countries has expanded as these funds continue to broaden their investment horizons. Sensible as this may be for diversification purposes, it also has incrementally increased the currency risks involved (whether through accident or design).

There is no consensus on the amount of risk attributable to currencies in a portfolio, but a reasonable approximation would be that 55 percent of the risk (i.e., volatility of returns) in international bond portfolio returns (perceived as a low-volatility asset) and 20 percent of the risk in international equity portfolios (perceived as a higher-volatility asset) is attributable to currency. These numbers depend on the sample period, asset mix, and base currency, but they provide some perspective on the potential impact that foreign exchange fluctuations can have on the risk/return profile of international investments.

Some argue that returns from currencies are awash in the long run and that investing in currencies is a zero-sum game. If this is true and if investors have very long-term horizons, managing currency exposures simply results in uncompensated costs.

This may be true in the extreme long term (10+ years), but few pension funds are likely to be willing to ride out the impact of large shorter-term currency movements. It is also important to note that large devaluations/revaluations can lead to very long-term unrecoverable losses after moving from levels that are unlikely ever to be seen again. The fact is that currency risk changes the overall risk profile of a portfolio and thus directly impacts portfolio returns and volatility. These impacts are most noticeable in the shorter term (zero to five years) and few pension funds can afford to wait out a whole investment cycle when they have to manage declining funding ratios and increased liability risks.

Before discussing the options available for managing currency exposures, we present a framework for evaluating how currencies fit into the overall management of a global portfolio.

**Base currency selection.** The base currency selected is typically the domestic currency of the investor or the currency used for accounting purposes. With the globalization of financial markets, this may require multi-currency overlay mandates (e.g., in the case of a defined benefit pension fund for a multinational company where the various pension funds are pooled to achieve economies of scale.)

**Benchmark selection.** This is the standard against which active risk is taken and performance is assessed. Myriad published indexes are available for use as a benchmark; it is important to use an appropriate one. The default option is typically MSCI World ex the home country.

**Hedge ratio.** The most fundamental question that an international investor must address is whether to hedge currency exposure and by how much. This leads to the concept of a hedge ratio, which is defined as the portion of a position targeted for protection by a hedge versus the overall position. Such hedges are routinely put in place through the use of forward foreign exchange (FX) contracts that involve the purchase of one currency against the sale of another for delivery on an agreed date in the future. Hedge ratios will vary between pension funds and depend on the investor’s risk objectives and factors such as risk appetite, asset mix, and the underlying benchmark. Often the investor...
also will specify a range for the hedge ratio. This will serve as a constraint when the hedge is actively managed. The default position is often a static 50-percent hedge ratio. Unlike the 100-percent or fully hedged position, a 50-percent hedge ratio allows the investor to benefit to some extent when foreign currencies appreciate relative to the base currency. Consequently, it is often referred to as “the hedge of least regret.” (For details, see “Determining the Hedge Ratio,” below.)

Tracking error. This is a measure of the divergence between the investor’s theoretical hedged benchmark and the implemented portfolio’s actual returns. It is characterized as a standard deviation percentage difference between the hedged benchmark’s performance and what is actually delivered. Tracking error has several causes; the most significant result from active management decisions made by the currency manager. Short-term movements also can lead to divergence; e.g., tracking error usually occurs when movements lag between underlying assets and the resulting FX positions causing slippage. If equity trades are executed in the morning and the FX trades aren’t transacted until late afternoon, this time lag will result in differences between portfolio and benchmark performance.

An Example

One approach utilized by pension funds to manage currency risk is to appoint a specialist currency overlay manager to provide a dedicated currency risk management service. This is not a new strategy (specialist currency managers have been around since at least the early 1980s), but it is increasingly being adopted by pension funds as they increase international exposures.

The advantage of employing a specialist firm is expertise. Investment managers who specialize in one asset class do not necessarily demonstrate decision-making skill in another asset class. In other words, would you put your money on Usain Bolt or the winner of the Olympic decathlon in the 100 meters?

To illustrate the value of a specialist currency program, consider the example in table 1 for an international equity portfolio under varying currency hedging strategies. In the example, the client has a US$100-million international equity investment that returns 10 percent (in foreign currency terms). At the same time, the home currency appreciates by 10 percent (i.e., the foreign currencies decline by 10 percent).

In the example, a 100-percent hedge ratio has bought the base currency at a forward date against selling the currencies of the assets in the international portfolio with the aim of selling out the hedge at a higher price. This hedge will generate a cash gain at the maturity of the FX forward contract that will offset the decline in the currency values of the assets in the international portfolio. With perfect foresight, the hedge ratio could then be reduced to 0 percent as the base currency declined. If only life were so simple.

Given the cyclical nature of currency movements, a key determinant of the success of a currency hedging program is the timing of implementation. Over- or under-hedging can have serious negative consequences if done at the wrong point in a currency cycle. Getting the timing right is particularly important when the base currency depreciates and large excess returns can be provided. Conversely, excess returns can be small or negative when a reducing/zero hedge is in place as the base currency rises. A specialist currency manager may be best-placed to advise on these matters.

Costs and Cash Flows

The added value of overlay hedging mandates is usually significantly small so that it is measured in basis points rather than percentage points. As a result, implementation costs and transaction costs can have a greater impact on performance than with other investment strategies. Management fees should not be considered in isolation but in comparison to what a hedging policy can do to reduce currency risk, etc. A low-cost passive hedge may seem more attractive than an expensive active program, but a passive hedge during a large adverse move would lead to a significant loss on the hedge and a corresponding large negative cash flow, which would require funding from internal reserves or the sale of underlying assets when the hedges have expired. An active hedge likely would cost a small fraction of this; that difference measured in transaction and opportunity costs can be enormous compared with the difference in management fees paid.

With the “free of charge” offer that often comes with custodian-bundled

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**TABLE 1: EXAMPLE—IMPACT OF HEDGING ON AN INTERNATIONAL PORTFOLIO**

<table>
<thead>
<tr>
<th></th>
<th>Unhedged Exposure</th>
<th>50-percent Hedged Exposure</th>
<th>100-percent Hedged Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equity Investment</td>
<td>$100 million</td>
<td>$100 million</td>
<td>$100 million</td>
</tr>
<tr>
<td>Equity Return (percent)</td>
<td>10 percent</td>
<td>10 percent</td>
<td>10 percent</td>
</tr>
<tr>
<td>Total Return ($)</td>
<td>$10 million</td>
<td>$10 million</td>
<td>$10 million</td>
</tr>
</tbody>
</table>

**Currency Impact**

<table>
<thead>
<tr>
<th>Hedged Currency Return ($)</th>
<th>−$10 million</th>
<th>−$5 million</th>
<th>$0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Portfolio Return</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Return (percent)</td>
<td>0 percent</td>
<td>5 percent</td>
<td>10 percent</td>
</tr>
<tr>
<td>Total Return ($)</td>
<td>$0</td>
<td>$5 million</td>
<td>$10 million</td>
</tr>
</tbody>
</table>

**Base currency appreciates by 10 percent (foreign currency declines)**

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packages, investors need to be aware that the fiduciary responsibility found in other elements of the custodial contract does not always apply to the currency trading part. Costs aside, a properly managed currency exposure may make the difference in achieving funding levels by making more efficient use of risk budgets. These potential additional returns come at a relatively low cost and can be gained without impacting the underlying asset allocation.

The cost impact on the overall portfolio from managing a currency hedging program can be decomposed into the following elements:

- Transaction costs incurred with hedge implementation
- Tracking error, which results from an imperfect hedge
- Opportunity costs created when hedge losses make demands on cash flow

Implementing and managing a currency overlay program is largely a matter of trading off these three categories of costs against one another.

Transaction Costs

With all overlay programs, the quality of execution that a manager provides varies widely and poor execution can have a significant impact on returns due to the size of the transaction slippage involved. Better-quality execution is more likely to occur with a manager whose interests are closely aligned with the investor’s. This is clearly illustrated by several well-documented lawsuits where, as part of an overall service, currency transactions have been offered for “free,” but the quality of execution with “in house” FX departments has led to fills at disadvantageous prices. This is a potential problem because currency markets are mainly over-the-counter and therefore lack the transparency of exchange-traded products.

An independent/noncaptive manager that specializes in foreign exchange will have intimate knowledge of the currency market and is more likely to provide superior execution than a generalist desk because the manager is not beholden to deal in-house and can go to multiple counterparties in the search for best price and liquidity. Furthermore, large liquidity providers generally view these types of managers as valued clients rather than price predators (that are quoted defensive prices). A skilled manager also will tend to leave a smaller footprint in the market, which can minimize transaction slippage.

Geographic location is another consideration. It is no coincidence that many currency managers are based in London, which straddles Asian, European, and American time zones and is where approximately 70 percent of global daily FX volume is transacted. In recent years, technological improvements in electronic dealing platforms and execution algorithms also have reduced transaction-related slippage.

Tracking Error and Rebalancing Frequency

Just as there is no ideal hedge ratio, there is no ideal frequency for rebalancing the hedge with changes in the underlying portfolio because each mandate is different. A monthly rebalancing is usually the default position. It is frequent enough to respond to changes in the underlying assets but not so frequent that it creates excessive transaction costs. The manager and investor must weigh the tradeoff between the tracking error that results from less-frequent rebalancing and the higher transaction costs that result from more-frequent adjustments.

Opportunity Costs and Cash-Flow Management

As noted above, currency hedging may result in negative cash flows to pay for losses when forward FX contracts mature. On expiry of the forward contract, profits and losses are crystallized and need to be settled if in debit. At this point, the value of the underlying assets is assessed, adjustments are made to the size of the hedge ratio, and new forward contracts are entered into. Cash flows on the expiry of a forward contract usually are met from internal reserves or from selling underlying assets. With extreme movements in base currencies, these amounts can be very large. One way of reducing the concentration effect of having all forward contracts mature at the same time is to spread the hedges across a period of time, e.g., a maturity ladder (see figure 1).

The primary advantage of this approach is that it smoothes out cash-flow requirements. Furthermore, it does not leave as big a transaction footprint in the market and the ongoing rolls are at the shorter, more-liquid part of the forward curve. If rebalancing is needed before the expiry of the forward contract, forward contracts can be sold or rolled prior to the original expiration date. As they are traded over-the-counter, any expiry date can be chosen, but keep in mind that spreads and liquidity decline the further out you move on the timescale. On the whole, besides some

![FIGURE 1: STAGGERED MATURITY LADDER OF FORWARD FX CONTRACTS](image-url)
One advantage of shorter-dated contracts is that, from a timing perspective, it is easier to keep the hedge more accurately in line with the desired hedge ratio.

Peripheral currencies, forward FX contracts are extremely liquid. The use of currency forwards defers gains and losses until the maturity date chosen. How far out should you have a maturity date? If the maturity date is very close, transaction costs are less in the short run per trade because there is more liquidity, but this is offset by the need to roll the hedges more frequently. One advantage of shorter-dated contracts is that, from a timing perspective, it is easier to keep the hedge more accurately in line with the desired hedge ratio. We see the optimal solution as splitting the hedge on implementation so that every month a portion of the hedge is rolled.

Effectively Managing Foreign Currency Exposure

There are three generally accepted approaches to managing currency risk: passive overlay, dynamic overlay, and active overlay. Which of these approaches is taken depends importantly on the investor’s beliefs about currency market efficiency and a corresponding belief about their risk/reward potential. But the choice also importantly depends on the investor’s investment objectives. In the context of currency management, objectives fall into three categories as characterized in Table 2.

Passive Currency Overlay

Passive overlay management is by far the simplest of currency hedging choices. It involves a static hedge with changes only made periodically when the value of the underlying assets has changed significantly. The advantages are that it usually costs only a few basis points to implement and it protects the investor from depreciation in foreign currency assets versus the base currency. It is the approach taken when the investor believes that currency markets are efficient and the investor’s objectives are focused on risk reduction and cost containment.

Under this approach, profits generated from the hedge can be used to offset declines in the values of the currencies to which the investor is exposed. However, downside risk arises when foreign currencies appreciate against the home currency: The hedge will lose money and the cost to maintain the hedge will have to be funded from either internal reserves or by selling assets. The corresponding opportunity cost can be potentially acute, particularly when a home currency is positively correlated with asset markets. Investors will be forced to raise cash to fund the hedging losses exactly when they want maximum risk exposure.

A static hedge ratio is aimed at reducing currency risk in a portfolio over the longer term. However, it may be inappropriate in the shorter term, especially in periods of high currency volatility or when currencies deviate significantly from long-term fair value. Further, the real and theoretical results of a passive hedge often diverge because of the potential for tracking error arising from the lag between valuation of the underlying assets and implementation or rebalancing of the hedge. Consequently, the portfolio always will be over- or under-hedged to some degree. Managers can adjust the hedge periodically, but it will never be perfect. The more frequently the hedge is rebalanced, the higher the transaction costs (but lower the tracking error). Less-frequent rebalancing leads to a risk of significant tracking error between the actual and target hedge ratio.

For many people, passive hedging is viewed as a commodity service (i.e., a best-execution service in return for a small fee). Alternatively, it can be viewed as a first step in the currency management paradigm. Therefore, selecting a provider with whom a long-term relationship can be built is important, and execution capability, operational efficiency, and transparency are important features to consider.

Dynamic Currency Overlay

Dynamic currency overlay can be seen as an extension to a passive overlay. Rather than merely making changes only to maintain a tracking error target, a dynamic currency overlay adjusts the underlying hedge ratio dynamically to earn excess returns or avoid losses. The adjustment can be undertaken either via an ongoing dialogue between the manager and the pension fund (to decide the appropriate ratio) or via a delegated fiduciary approach where the manager

**TABLE 2: CURRENCY INVESTING: MARKET BELIEFS AND INVESTMENT OBJECTIVES**

<table>
<thead>
<tr>
<th>Beliefs</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market Efficiency</td>
<td>Risk Objectives</td>
</tr>
<tr>
<td></td>
<td>• Return seeking</td>
</tr>
<tr>
<td></td>
<td>• Loss avoidance</td>
</tr>
<tr>
<td>Risk/Return Opportunities</td>
<td>Volatility containment</td>
</tr>
<tr>
<td></td>
<td>Cost containment</td>
</tr>
<tr>
<td></td>
<td>Cash-flow management</td>
</tr>
</tbody>
</table>
is responsible for the adjustments of the hedge ratio.

As discussed above, a passive hedge can be a double-edged sword. Consider the example in Table 1, where the investor’s base currency appreciates 10 percent, and the unhedged portfolio would underperform both the 50-percent hedged and 100-percent hedged portfolios. Conversely, if the base currency declined, having the portfolio hedged (to any degree) would have subtracted value. A dynamic currency overlay, however, would come into its own by being able to move the hedge ratio through time.

A dynamic overlay program will make sense for investors who believe that currency markets do offer active management potential; such investors will fall into one of the following two categories:

1. Investors who seek medium to longer-term gains by actively increasing or decreasing exposure to foreign currencies through active management of the hedge ratio
2. Investors who pursue loss avoidance by increasing the hedge when appropriate

For the latter class of investors, risk is not viewed symmetrically and downside risk containment is given highest priority. Investment approaches that are used for such investors often take the form of put option replication strategies. They operate like a form of portfolio insurance and attempt to put a floor on the potential losses coming from adverse currency moves.

We have developed a technique for managing the hedge ratio that focuses on reducing downside tail risk. Figure 2 shows that currency returns do not follow a normal distribution and demonstrate fat tail risk. Using extreme value theory methods, we are able to model this tail risk and monitor it over time. When the downside tail risk increases, we increase the hedge, thus reducing exposure to potential losses.

Active Currency Overlay

Currency markets have inherent characteristics that can be exploited to deliver returns. Unlike equities and fixed income, currency markets are characterized by a significant proportion of participants who are not profit-seeking (e.g., central bank intervention, corporate transactions, capital flows, etc.). An active currency overlay program can exploit these characteristics to add value over and above what can be achieved through managing the equities or fixed income by themselves.

An investor who chooses this approach must believe that currency markets are inefficient and seek to take on risk through implementation of an active strategy.

Depending on the scope of the mandate, active currency overlay can provide protection from the depreciating base currency (as per a dynamic overlay), with additional returns sought through the active management of individual currency pairs, which may include nonbenchmark currencies. Relative to other asset classes, active overlay is relatively cost-effective to implement, but like the other approaches, poor execution can add significantly to costs.

Active overlay has three objectives:

- Hedge exposures to depreciating currencies
- Increase exposure to appreciating currencies
- Moderate the size and frequency of cash flows

Returns from an active overlay program can be cyclical and episodic, and investors should not expect constant alpha returns. For example, there may be periods when the base currency is falling and the manager has reduced the hedge to the minimum agreed-upon ratio (unless allowed to go to zero). In this framework, the manager is unable to add additional value. Conversely, with a strengthening base currency, a similar situation occurs unless it is allowed to go to a 100-percent hedge.

Determining the Hedge Ratio

Once an investor has selected the approach to currency overlay management that is a best fit with beliefs and objectives, the investor is ready to move to the implementation stage. The first step in this effort is to pick an appropriate hedge ratio. A long and varied literature can guide investors in this effort, and the results derived vary from highly formal, quantitative techniques to subjective rules of thumb (e.g., Black 1989, Campbell et al. 2010, Gardner and Wuilloud 1995).
One of the most startling results was obtained by Fischer Black (1989), who showed that, under proper assumptions, in equilibrium all investors will have the same hedge ratio, and this is independent of their home currency. This universal hedge ratio, HR, is given by the following formula:

\[ HR = \frac{\mu_m - \sigma_m^2}{\mu_m - \frac{1}{2} \sigma_m^2} \]

\[ \mu_m = \text{average expected excess return of the world market portfolio} \]

\[ \sigma_m = \text{volatility of the world market portfolio} \]

\[ \sigma_e = \text{average exchange-rate volatility across all currency pairs} \]

The proper assumptions here are that all investors have the same risk preferences and the same estimates for expected currency returns, market volatility, and currency volatilities; and that there is no net foreign investment (i.e., no balance of payment imbalances).

This formula was developed principally for stock market investors. One problem with its application is in the estimation of the parameters. Black (1989) analyzes two distinct time periods, 1981–1985 and 1985–1994. He uses the historical data from these two periods to estimate the hedge ratio. He finds that for 1981–1985 the hedge ratio is 30 percent and for 1985–1994 it is 73 percent. Obviously, this is not particularly encouraging.

Black goes on to say that an investor can try to estimate these parameters using methods other than fitting historical data. But the fact remains that this hedge ratio is sensitive to the input parameters, which are difficult to estimate. As a consequence, Black’s universal hedge ratio is not particularly useful in the real world.

Recall that this formula was derived principally for investors in the international equity markets. For international bond portfolios, this approach leads to a 100-percent hedged position. The case for stocks and bonds combined involves a hybrid of the two hedge ratios, i.e., a hedge ratio somewhere between the universal hedge ratio for stocks and 100 percent.

Black (1989) does allow that his approach, which is essentially a mean-variance optimization, also can be employed by investors who have unique estimates of expected returns for currencies.

On the other hand one can just ignore the expected return issues and focus entirely on risk reduction. The market wisdom on this front is that the risk-minimizing hedge ratio is always a 100-percent hedge. Campbell et al. (2010) show that this is not always the case. The fact is that the contribution to risk depends on the correlation of the currencies with the equity markets. When this correlation is negative it is actually risk-reducing to maintain some foreign currency exposure. It turns out that in Campbell et al. (2010) several currencies were negatively correlated with world equity markets so that risk-minimizing currency position would be long these currencies and short the currencies that are positively correlated with the world equity markets. So, in fact the risk-minimizing position is not a hedge ratio at all.

It is the case, however, that under the assumption of zero correlation between currencies and equities the risk-minimizing hedge ratio is 100 percent. In this case all of the currency risk is hedged out. Now the problem becomes one of cash-flow management, because the higher the hedge ratio the greater the cash-flow risk. In fact, the 100-percent hedge ratio is the hedge ratio of greatest cash-flow risk. Cash-flow risk drops proportionately with the hedge ratio so that, everything else being equal, aversion to cash-flow risk will motivate investors to hold lower hedge ratios.

Gardner and Wuilloud (1995) studied the impact of the hedge ratio on an investor’s regret. Regret here is defined as a gain that you would have made in your currency positions had you not been hedged, but as a result of the hedge did not enjoy. Interestingly they were able to show that a 50-percent hedge ratio avoids extremes in regret and is superior to the mean-variance optimization in lowering expected regret, at least in the short term. The 50-percent hedge

**TABLE 3: CURRENCY MARKET BELIEFS AND OBJECTIVES: PORTFOLIO IMPLICATIONS**

<table>
<thead>
<tr>
<th>Currency Beliefs</th>
<th>Objectives</th>
<th>Actions</th>
<th>Hedge Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fully efficient</td>
<td>Risk seeking/comfortable with currency risk</td>
<td>Accept currency risk: unhedged portfolio</td>
<td>0 percent</td>
</tr>
<tr>
<td>Fully efficient</td>
<td>Risk averse/comfortable with cash-flow risk</td>
<td>Passively hedge currency risk</td>
<td>Risk minimizing (100 percent)</td>
</tr>
<tr>
<td>Fully efficient</td>
<td>Risk averse/cash-flow risk averse</td>
<td>Passively hedge currency risk</td>
<td>50 percent–100 percent</td>
</tr>
<tr>
<td>Efficient but medium term return potential</td>
<td>Risk averse (moderate)/comfortable with cash-flow risk</td>
<td>Passively hedge currency risk: partial hedged</td>
<td>25 percent–75 percent</td>
</tr>
<tr>
<td>Efficient but contribute to returns</td>
<td>Risk averse/loss aversion</td>
<td>Dynamic hedge: hedge increases as potential losses rise</td>
<td>25 percent–75 percent</td>
</tr>
<tr>
<td>Partially inefficient</td>
<td>Risk averse (moderate)/cash-flow risk averse</td>
<td>Dynamic hedge</td>
<td>50 percent</td>
</tr>
<tr>
<td>Offer superior return potential</td>
<td>Risk seeking/comfortable with currency risk</td>
<td>Full active implementation</td>
<td>0 percent–50 percent</td>
</tr>
</tbody>
</table>

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ratio, in this regard, is the hedge ratio of minimal regret.

As with the other aspects of currency overlay, choosing a hedge ratio depends on the investor’s investment objectives and beliefs about risk and return opportunities. Investors who are comfortable taking incremental risk and who believe that currencies can add alpha will want lower hedge ratios. Highly risk-averse investors will want high hedge ratios and investors who are averse to cash-flow risk will want lower hedge ratios.

Summary

With the current global environment unsettled, we see significant differences between regions and currencies, and hence the currency markets look set to become volatile and are demanding a flexible approach to currency exposure management. However, it is equally true that poor currency management can adversely impact a fund’s performance.

As a result, investors and consultants are reappraising their assessments of currency exposure and how it should be handled, and a gradual shift from simple passive hedges is apparent. That said, the fiduciary burden increases for pension funds adopting either dynamic or active currency overlay programs. For either of these options, the key risks will revolve around the skill of the investment manager selected to implement the program. For a passive program, the key risks center on efficient implementation, which in this case means low transaction costs and the effective maintenance of the tracking error target.

Table 3 summarizes how an investor’s beliefs and objectives can lead to suggested actions. No two investors are the same, but this decision framework provides guidance to help an investor identify the most-suitable process.

Endnote

1 For further reading on the applications of extreme value theory, see Strub and Baker (2011) and Strub and Udy (2010).

References


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