Foreign Exchange Rate Risk: Institutional Issues and Stochastic Modeling

Richard W. Gorvett, FCAS, MAAA, ARM, Ph.D.

Biography

Rick Gorvett is an Assistant Professor of Actuarial Science at the University of Illinois at Urbana-Champaign He received a BS in Mathematics from the University of Illinois at Chicago, an MBA in Finance and Econometrics from the University of Chicago, and a Ph D. in Finance and Insurance from the University of Illinois at Urbana-Champaign

At the University of Illinois, Rick teaches undergraduate and graduate courses in the theory of interest, actuarial modeling, and actuarial risk theory Prior to his current position, he was on the faculties of The College of Insurance and the Finance Department at the University of Illinois, where he taught insurance, risk management, finance, and financial risk management. Rick's background includes business experience as an actuary and consultant Specific research and consulting interests include dynamic financial analysis, insurance securitization, and the use of financial models in determining insurance rates

Rick is a Fellow of the Casualty Actuarial Society, a Member of the American Academy of Actuaries, and has the Associate in Risk Management designation

Abstract

The increasing globalization of the property-liability insurance industry has provided insurers with both opportunities and challenges. The opportunities involve new markets with profit potential and diversification possibilities. On the other hand, companies with multinational operations and/or investments are exposed to the risk that foreign exchange rates will change, possibly adversely, in the future. This paper examines the sources of foreign exchange risk, and discusses the institutional techniques – e.g , financial derivatives – available to companies to manage that risk. Some anecdotal evidence is provided to indicate how some insurers actually do manage foreign exchange risk. Finally, the paper briefly describes some possible approaches to the modeling of foreign exchange risk, for example in a dynamic financial analysis context When modeling, the interrelationships between exchange rates and other variables – e.g., interest rates and inflation rates in the relevant countries – must be considered and reflected

Section 1 – Introduction and Overview

The recent "globalization" of the property-liability insurance industry has occurred on several levels. U.S.-based insurers have expanded into foreign markets – with varying degrees of difficulty and success – in order to attempt to take advantage of perceived opportunities On the other hand, many large European insurance organizations now have significant presences in the United States. These various multinational efforts have often been achieved through merger and acquisition activity. Furthermore, with the maturation of the global financial markets (including the development of new derivative products) and a variety of technological advances, multinational operations have become increasingly feasible and efficient.

However, for insurers (as well as for other firms), the potential advantages of globalization are accompanied by additional operating risks Whenever an insurer operates in multiple countries with different currencies, the insurer is subject to foreign exchange (FX) risk. Essentially, this is the risk that the value relationship between the insurer's "home" currency and the currency of a foreign country in which the insurer operates or invests will change in the future Such changes have the potential to either adversely or favorably affect the economic and/or accounting cash flows and asset/liability values of a company. A company's ability to compete internationally will depend, at least in part, on its ability to appropriately and effectively manage the risks introduced from multinational operations.

This paper examines FX risk and its potential effect on property-liability insurers. Section 2 presents a description of the nature and characteristics of this risk Before proceeding with a discussion of how this risk can be addressed, Section 3 asks a basic question: is there any

"value" associated with the "hedging" process? Section 4 examines the risk management techniques, including financial derivatives, available to insurers to manage FX risk, and Section 5 provides some anecdotal information regarding the use of such techniques by property-liability insurers Section 6 briefly discusses some of the issues involved in stochastically modeling FX risks; such modeling has important actuarial applications, for example with regard to efforts to simulate FX risk within the framework of dynamic financial analysis. Section 7 provides a summary and conclusion

Section 2 – Foreign Exchange Rate Risk

A. What is an Exchange Rate?

When companies or individuals engage themselves in activities involving cash flows denominated in different currencies[1], the value relationship between those currencies becomes important. This relationship is expressed as a ***foreign exchange rate***, which for our purposes we will take to mean the number of foreign currency units that can be purchased with one U.S. dollar.[2] The rate at which currencies can be exchanged today (for "immediate delivery"[3]) is referred to as the ***spot*** rate of exchange, the rate, agreed upon today, at which currencies can be exchanged in the future (for "future delivery") is referred to as the ***forward*** rate of exchange.

[1] A "currency" can be backed by a commodity, or it can be unbacked The latter, used in industrialized countries, is often called a "fiat" currency

[2] This is known as an "indirect" quote Alternatively, exchange rates can be quoted as the reciprocal of this ratio – namely, dollars per foreign currency unit, this is called a "direct" quote In the financial press, exchange rates are often listed both ways

[3] Technically, a spot FX rate refers to a trade that settles in two business days

The table below gives sample spot and forward exchange rates as of November 7, 2000 [4]

Table 1

Exchange Rates as of November 7, 2000

(Quoted as Currency per U S Dollar)

	Spot	1-Month Forward	3-Month Forward	6-Month Forward
British Pound	0 6972	0 6968	0 6959	0.6948
French Franc	7 6225	7 6115	7.5908	7.5658
German Mark	2 2728	2 2695	2 2633	2.2559
Japanese Yen	106.99	106 40	105 33	103 77

Thus, a company wanting to convert 10,000,000 French francs into U.S. dollars on a spot basis would receive

$$FF10{,}000{,}000 - 7\ 6225 FF/\$ = \$1{,}311{,}905\ 54$$

Exchanging in the other direction, a company wanting to convert $5,000,000 to British pounds on a spot basis would generate

$$\$5{,}000{,}000 \times 0\ 6972\ £/\$ = £3{,}486{,}000$$

(Both of these examples ignore any transactions fees or other "expenses." The use of forward rates will be illustrated later)

B Forms of Exchange Rate Risk

As with many other sources of financial risk, such as interest rate and commodity price risk, the level of FX risk to which companies and individuals are subject has increased significantly

[4] Per The Wall Street Journal, Wednesday, November 8, 2000, page C21 The rates shown are New York foreign exchange mid-range rates, applicable to trading among banks, in amounts of $1 million or more

during the last few decades. Specifically with regard to foreign exchange rates, the breakdown of the Bretton Woods Agreement[5] in the early 1970s led to a more volatile environment in which different currencies often fluctuate – sometimes significantly – relative to one another Combined with increased volatility in other financial variables – e g , U S interest rates[6] – this increase in foreign exchange volatility has caused multinational operations and investments to be potentially quite risky

Charts of monthly time series for several foreign exchange rates are appended to the end of this paper.[7] These charts exhibit the volatility inherent in the foreign exchange relationship Recognizing and quantifying that volatility is important, as volatility is one possible measure of the level of risk

Exposure to foreign exchange risk can take several different forms.

- *Transaction exposure* arises from transactions involving future cash flows which are denominated in a currency different from the "home" currency This type of risk occurs when the relevant exchange rate changes between the date a transaction agreement is entered into and the date the transaction is financially consummated. Examples of such exposures might include:

[5] In July, 1944, representatives of 44 countries met in Bretton Woods, New Hampshire, where they reached an agreement to achieve relative currency stability by adopting a system of fixed exchange rates The system involved pegging foreign currencies to the U S dollar, which was in turn pegged to gold This lasted until the early 1970s

[6] U S interest rates became more volatile in 1979, when the Federal Reserve, under Chairman Paul Volcker, essentially switched from a policy involving stabilizing interest rates to one involving controlling inflation

[7] Data for these charts is taken from the Federal Reserve Bank of St Louis' Federal Reserve Economic Data (FRED) website www stls frb org/fred/

- Revenues and expenses associated with a U S. parent company's foreign subsidiary For example, if the dollar strengthened or appreciated relative to the foreign currency (i.e , if the U S dollar now bought more units of the foreign currency), foreign revenues would be depreciated on a dollar basis (the foreign revenues would be worth less when converted to U S dollars than they would have been had the dollar not strengthened)
- The purchase and financing of assets in another currency A classic example (mentioned in both Smithson (1998) and Campbell and Krakaw (1993)) involves the now-defunct Laker Airlines In the late 1970s, the U S dollar was weak relative to the British pound, and thus there was significant demand among the British for vacations in the U S In response to this demand, Laker Airlines purchased several additional planes, financing them in U S dollars When, in the next few years, the dollar strengthened relative to the pound, Laker Airlines had a double problem (1) its revenues were in pounds and its debt largely in dollars (a mismatch which, because of the strengthened dollar, affected the company adversely), and (2) the demand for U S vacations among the British fell (due to the no longer favorable exchange rate) The first problem resulted from a transaction exposure, the second resulted from an operating exposure (see below). Laker Airlines went bankrupt in 1982

- *Translation exposure* an accounting-based exposure resulting from a company's having to convert asset and/or liability items from one currency to another for financial statement purposes This can occur, for example, when a U S parent company must restate the (foreign-denominated) assets and liabilities of a foreign subsidiary in U S dollars for the

parent company's financial statements. The degree of this risk depends upon the specific accounting rules pertaining to the exchange rate movements and the financial items involved

- *Operating exposure*: an exposure associated with the potential impact of changes in exchange rates on the future cash flows of the company This can also be referred to as economic exposure, since the economic value of a company is a function of the firm's future cash flows The above-mentioned second problem experienced by Laker Airlines – the change in demand for vacations and the resulting diminished revenue stream due to the strengthened dollar – is an example of this type of exposure

Section 3 – Why Bother to Hedge?

Now that the sources of FX risk have been identified, it seems logical that techniques for managing that risk be considered, and it is conceivable that one reasonable technique may involve the "hedging" of such risks, for example via certain financial derivatives These tools will indeed be discussed below. However, a basic question may justifiably be asked before proceeding· why bother to hedge with derivatives at all? In other words, under what circumstances, if any, will hedging actually serve to "improve" the company?

To respond to this important issue, consider the financial risk management (FRM) process from a broad perspective Financial risk management can be considered to include the following steps

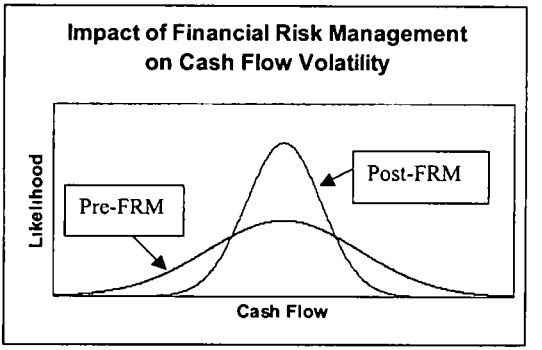
1) Determine the corporation's objectives (e g , solvency, profitability, liquidity)
2) Identify the risk exposure (e.g , FX risk, interest rate risk)
3) Quantify the risk exposure (e g., measure the volatility)
4) Assess the impact of the risk on the firm (e g., sensitivity analysis, dynamic financial analysis)
5) Examine alternative financial risk management tools (e g , derivatives)
6) Select an appropriate financial risk management technique
7) Implement the FRM technique
8) Monitor the FRM program for effectiveness

Step 5, some alternative tools and techniques available for managing FX risk, will be addressed below. However, an important question is this: can financial risk management techniques increase firm value? Given the prevalence and importance of such techniques – the derivatives market is immense – the anecdotal answer would seem to be "yes." However, this question is really a subset of a more general question as to whether or not the method of financing a company – equity versus debt, or the overall nature of the right-hand side of the balance sheet – can affect firm value. In 1958, Miller and Modigliani gave a qualified "no": under certain assumptions, a firm's financing is irrelevant to its value, because value is determined on the left-hand side of the balance sheet In other words, what is important is not *how* the company raises money, but rather what the company *does* with the money – e g., in terms of capital investment – after it's been raised Since financial risk management techniques essentially involve the financing of the company, the question can reasonably be asked as to whether managing financial risk is worthwhile

The key to this issue is to understand the assumptions that Modigliani and Miller made in developing their irrelevance proposition. They assumed no tax effects, no costs of financial distress, and a fixed investment policy Thus, if financial risk management techniques are to matter, it must be through the violation of one or more of those simplifying assumptions

- *Tax effects* If the tax function is convex (i e , if the marginal tax rate increases as income increases), financing policy might matter, because more volatile earnings can result in a greater average tax liability Financial risk management can thus add to company value by decreasing the volatility of its future earnings stream, and thereby potentially reducing expected taxes
- *Financial distress / bankruptcy costs* If a company is highly leveraged or somehow threatened by insolvency, it may behave in ways which are not optimal (e g , by favoring high-risk investments) Financial risk management can add value by encouraging better operational behavior through lowering the costs of financial distress
- *Future investment decisions* If a company experiences losses, sound investment opportunities might be "crowded out." If there are insufficient internal funds to finance sound investments, the company may have to raise more costly external capital if it still wishes to make those investments. By reducing the potential impact of losses through FRM, therefore, the company may be able to promote better capital investment behavior

Graphically, the effect of financial risk management techniques can be illustrated as a reduction in the variance (volatility) of future cash flows.



Thus, it does appear that FRM techniques can be beneficial to a firm, primarily by reducing the volatility of future results [8] A discussion of some of these FRM techniques follows in the next section

Section 4 – Techniques for Managing FX Risk

A variety of techniques can be used to manage foreign exchange rate risk. Descriptions of some of these techniques appear below In order to illustrate the differences between and characteristics of these techniques, a common example will be used throughout several of these descriptions· suppose that a U S insurance company must make a liability payment of DM10,000,000 in six months The company is exposed to FX risk because of the uncertainty associated with the relative value of Deutsche marks and U S dollars six months from now

A. Balance Sheet Hedges

If a company can take a position which offsets a foreign-denominated asset or liability on its financial statements, it is possible that the foreign exchange risk can be at least partially hedged When this is done, the company has performed an "on-balance sheet hedge." For example, if a company knows that it will need to make a future liability payment denominated in a foreign currency, it could take U S dollars, convert to the foreign currency at the spot exchange rate, and then invest in financial assets that are denominated in the foreign currency In the case of our Deutsche mark example, for this type of hedge the company would need (in dollar-denominated cash) the six-month present value of DM10,000,000 on a spot basis

$$\frac{DM10{,}000{,}000}{(1+r_{DM})^{0.5}} = 2.2728 DM/\$$$$

where r_{DM} is the German risk-free interest rate This dollar-denominated amount of cash could be converted, now, to DM, and then invested at r_{DM} so that, in six months, the DM10,000,000 liability payment would be covered

More directly, if the firm already has assets denominated in the foreign currency, it could "earmark" some of them for the upcoming liability payment Similarly, a U.S.-based company with a foreign subsidiary that does business in a foreign currency could use some of the subsidiary's foreign-denominated revenues to pay some of its subsidiary's foreign-denominated expenses, thus minimizing the amount of currency exchanging required

[8] It may also be advantageous for a company to engage in financial risk management activities to the extent that it

B FX Forward and Futures Contracts

Forwards are perhaps the most basic form of financial derivative A forward involves an obligatory agreement between two parties (often called *counterparties*) to enter into a transaction at some future date (the *expiration* or maturity date) The transaction involves either buying or selling an *underlying* asset. No payment is made until the maturity of the agreement, and then the transaction is consummated at the *delivery price*, either through physical delivery or a cash settlement (depending upon the type of asset involved and the agreement of the parties) The party agreeing to buy the underlying asset is referred to as taking the *long* position, and the party agreeing to sell the underlying asset is in the *short* position. Forwards can be tailor-made to fit the counterparties' particular situations

With respect to the DM10,000,000 liability payment example, the insurance company could hedge the FX risk inherent in the future liability payment transaction by entering, now, into a six-month forward contract This would be an agreement with a counterparty to purchase six months from now, at a pre-specified price, DM10,000,000 That pre-specified price would be the six-month DM/$ forward rate Thus, the insurance company would agree to pay, in six months,

$$DM10{,}000{,}000 - 2\ 2559 DM/\$ = \$4{,}432{,}820\ 60$$

in exchange for the DM10,000,000 it needs to make the liability payment By entering into a forward, the company has locked in the exchange rate six months from now, thus eliminating the potential FX volatility over the next six months Note that this may or may not end up having been a profitable transaction for the company, depending upon the actual spot exchange rate that emerges six months from now

---

can do so more efficiently and at lower cost than can individual stakeholders in the company

One issue associated with forwards is the ability of the counterparty to meet its contractual obligation when the transaction date arrives Forwards are sometimes called "pure credit instruments" since the only uncertainty with respect to the transaction is the ability of each party to perform up to its obligations These performance issues are addressed by a derivative that is closely related to the forward the future.

Futures contracts are similar to forward contracts, except that they are standardized[9] and traded on exchanges. The exchange provides a number of mechanisms to minimize the couterparty default risk: (1) daily settlement (or marking to market), in which the profit or loss resulting from the movement in the value of the underlying asset is recognized on the account of each party to the futures contract each day, (2) margins, which involve the posting of capital to help ensure performance, and (3) the exchange clearinghouse, which helps to further guaranty performance by interposing itself between the seller and buyer in futures transactions Currency futures are traded on major currencies, and are (as are other types of futures) identified according to the month during which they expire

C FX Options

An option is similar in some ways to a forward, although there are several critical distinctions The primary difference is that an option involves the *right*, not the obligation, to consummate a financial transaction As with other derivative instruments, two parties are involved in an option transaction one buys (is "long") the option, and one sells (is "short") the option The option

buyer – the party that holds the option – has the right to *exercise* the option, and will only do so if exercise is financially superior to non-exercise Depending upon the type of option, the holder has the right to either buy (a *call* option) or sell (a *put* option) the underlying asset at the exercise price Also depending upon the type, the option may be exercised either at any time before it expires (an *American* option), or only on the expiration date of the option (a *European* option)

The price initially paid for the option is typically referred to as the *premium*. This premium is a function of five parameters· the value of the underlying asset, the exercise price, the interest rate, the time until expiration of the option, and the volatility of the price of the underlying asset. In practice, there are several techniques (depending upon the specific characteristics of the option) for determining appropriate premium values for options, including the binomial method and the Black-Scholes pricing equation

Options can be used in combination with other financial items to provide "protection" on those items For example, owning an asset such as stock and also owning a put option on that stock (known as a "protective put" position) provides protection with respect to the downside potential of the stock ignoring the premium paid for the put, the combined stock-and-put portfolio value cannot fall below the exercise price of the put This is because the value of the put offsets the diminished value of the stock to the extent that the stock price falls below the exercise price Similarly, call options can be combined with liabilities to provide upside (ceiling) protection

[9] Standardization has advantages and disadvantages Expenses associated with a standardized product might be lower, but there is less flexibility available to tailor the instrument to a specific situation

With respect to FX options, calls and puts can be used to protect against undesired potential movements in the FX rate Consider our DM10,000,000 liability payment, due in six months The insurance company's fear is that the dollar will depreciate relative to the mark (or that the mark will strengthen relative to the dollar) over the next six months, meaning that the cost of the liability payment would be greater in the company's home currency (dollars) The current spot rate is, say, 2.2728 DM/$, or, equivalently, 0 4400 $/DM Thus, the company's fear is that the $/DM exchange rate will increase (On the other hand, the company will benefit if the $/DM rate falls) Perhaps the company is willing to take some FX risk – but wants to hedge the possibility, for example, that the exchange rate will be greater than 0 4600 $/DM six months from now The company could purchase an appropriate amount of foreign currency call options with an exercise price of 0 4600 $/DM, if the exchange rate rises above that level, the additional cost (in dollars) of the liability payment will be partially offset by the payoff of the call options

Note that the company could hedge even more of its FX risk by purchasing call options with a lower exercise price, say 0 4400 $/DM; however, the price of this hedge would be more costly, because the premium for the options would be greater (due to the lower exercise price) Thus, one of the issues in FX risk management – as with any form of insurance protection – involves the tradeoff between the price of the hedge (in this case, the options) and the amount of protection [10]

[10] Another alternative would be for the company to sacrifice some potential benefit in exchange for protection This can be done with a combination of puts and calls In this example, the company might protect itself by purchasing call options with an exercise price of, say, 0 4500 $/DM, but also give up some of the benefit if the $/DM exchange rate falls by selling put options with an exercise price of 0 4300 $/DM Note that by doing this, the company has

Options can also be used to hedge FX risk with respect to foreign-denominated assets and future cash inflows In this case, the company's fear is that the $/DM exchange rate will decline. Thus, the company would purchase FX puts with an appropriate exercise price, thus protecting the downside risk

D FX Swaps

A swap is an agreement between two counterparties to swap, or exchange, future cash flows With respect to currency swaps, according to Smithson (1998), "The evidence we have seen suggests that the dominant use of currency swaps is to modify the nature of a debt issue A firm will borrow in one currency and use a swap to transform the cash flows to another currency." A currency swap can also be used to hedge FX risk over a period of time, exchanging fixed cash flows in one currency for fixed cash flows in another A swap can thus involve three different types of cash flows an initial exchange of principal in the two different denominations, periodic interest payments denominated in different currencies passing between the parties, and finally the re-exchange of principal at the end of the swap Swaps can be tailor-made to fit a particular situation

Section 5 -- Some Evidence Regarding How Insurers Manage FX Risk

Sections 2, 3, and 4 of this paper have examined the nature of FX risk and some of the techniques available to manage that risk In this section, some evidence is provided regarding the manner in which property-liability insurance companies handle such risks in practice One

---

locked in an exchange rate range of 0 4300 to 0 4500 $/DM Note also that the company, by selling the puts, has

source of evidence is from a paper (Cummins, Phillips, and Smith (1997)) which provides a statistical analysis of financial derivatives activity for life and property-liability insurance companies during 1994 The other source of evidence provides anecdotal information for several companies from their December 31, 1999 Securities and Exchange Commission (SEC) 10-K filings

A Insurer Activity During 1994

Cummins, Phillips, and Smith (1997) used data from Schedule DB of the 1994 NAIC annual statements. They collected data at the group and company level, and their final sample included over 2,000 property-liability insurers (as well as over 1200 life insurers) They found that, with respect to 1994, approximately 7% of property-liability insurers used derivatives; this amounted to 142 insurers They also found that larger companies were more likely to use derivatives than smaller companies For property-liability insurers, the most often used contracts included foreign currency forwards and equity options.

In particular, the authors found that, among property-liability insurers, 19 companies opened positions in foreign currency forwards during 1994, and 5 opened foreign currency swap positions Four companies opened long positions in foreign currency futures, while 3 opened short futures positions during 1994 There was some, but not much, activity in foreign currency options during 1994. With regard to the relatively large number of companies involved in foreign currency forwards, the authors state that "To the extent that PC companies face

---

funded at least some of the cost of purchasing the call options.

substantial foreign exchange exposure due to foreign-based subsidiaries and/or the holding of foreign bonds or equities, this result is not unexpected "

B Anecdotal Evidence from Insurers' SEC 10-K Filings

The SEC requires an annual report, known as a Form 10-K, from, among others, every exchange-traded company. The report discloses certain financial information involving revenues, income, etc , and generally includes a fair amount of text explaining various financial items. Form 10-K is available as public information; one source of a company's 10-K is the SEC's *EDGAR* database of corporate information.[11]

Excerpts from a selection of five property-liability insurers are provided in Exhibit 1 These excerpts suggest, based on the companies' 10-K filings, the nature of their foreign exchange rate risk and how they manage that risk All 10-K filings referenced here were based upon the companies' December 31, 1999 financial statements The various excerpts specifically mention the use of forward contracts, swaps, and asset-liability matching as approaches employed for hedging FX risk

Section 6 -- Modeling Foreign Exchange Rates

Ultimately, insurers want to be able to model and quantify FX risks in order to assess alternative multinational financing and operating policies. There are any number of approaches to FX rate forecasting, including a variety of sophisticated macroeconomic models. Another interesting and

recent approach is documented in De Grauwe, et al (1993), in which the authors apply chaos theory to the task of modeling exchange rates (Chaos theory can be useful in modeling processes that exhibit complexities and non-linearities) However, all of these techniques are beyond the scope of this paper, several relevant citations are provided in the Reference section

In this section, the emergence of foreign exchange rates over time is considered from a modeling perspective, it may be useful to place this effort within a familiar actuarial context. dynamic financial analysis First, FX forecasting is briefly examined as an application of stochastic process theory Next, the difficulties of such an approach – revolving around the need to appropriately model certain correlations and relationships with other financial variables – are considered Finally, some other considerations regarding foreign exchange rate modeling are presented

A FX Rates as a Stochastic Process

Looking at the accompanying charts showing the time series of FX rates, one might recognize the general "pattern" essentially, these time series appear to have a "random walk" appearance that one often associates with stock price movements, interest rates, and some other financial and economic processes. A fair amount of effort has been expended in trying to model and forecast foreign exchange rates However, as mentioned in De Grauwe, et al (1993), "Since the inception of floating exchange rates in the beginning of the 1970s, economists have attempted to develop theories that explained what was going on, and that could be used to make predictions about future exchange rate movements After almost twenty years of frenetic research one is forced to

[11] All of the 10-K excerpts in this paper were derived from the EDGAR database, which is accessible from the

admit that success has been limited " Rosenberg (1996) comments that "the evidence suggests that at short- and medium-term horizons, a random walk characterizes exchange rate movements better than most conventional fundamental-based exchange rate models "

A significant trend in the property-liability insurance industry is the development and implementation, largely by actuaries, of dynamic financial analysis (DFA) models These models incorporate simulation techniques involving a variety of financial, economic, and insurance processes – e g , interest rates, equity market returns, insurance losses, etc If a company has significant multinational operations or investments and is exposed to FX risk, the DFA model should also include a foreign exchange process.

Expanding upon recent DFA-related work on stochastic interest rate modeling (and interest rates certainly have an important relationship to foreign exchange rates, as discussed below), FX rates can be viewed as a geometric Brownian motion process evolving over time

$$dS = \mu S\, dt + \sigma S\, dZ$$

where S is the spot rate of foreign exchange, μ is the rate of change (the "drift") in the spot rate, t is time, σ is the volatility factor associated with movements in the spot rate, and dZ is a Wiener (or simple random walk) process In this framework, instantaneous movements in the foreign exchange spot rate through time are a function of a deterministic drift component (which might be mean-reverting) and a stochastic volatility component that introduces variability to the

---

SEC's website at www sec gov

process This geometric Brownian motion specification of the spot rate would imply that future values of the spot rate have a lognormal distribution

Examples of mean-reverting financial models can be found in the interest rate modeling literature For instance, in D'Arcy, et al (1997 and 1998), the Cox-Ingersoll-Ross (1985) model (the CIR model) of stochastic interest rates is employed as the basis for the simulation of future interest rates Specifically, this model is characterized by the following equation

$$dr = \kappa(\theta - r)\,dt + \sigma r^{0.5}\,dZ$$

where r is the (short-term) interest rate, κ is the rate of mean reversion, and θ is the long-run mean value of r Thus, the CIR model is a mean-reverting model in which the volatility of the process is proportional to the square root of the interest rate level (meaning that there is greater volatility associated with higher interest rates, and vice versa) This mean-reverting framework could also be used for foreign exchange rates, if the data suggested that it was appropriate. On the other hand, the exponent on the r in the second term could be changed based on indications in the data – for example, if such volatility proportionality is not considered appropriate, the exponent could be changed to zero

Once alternative specifications for the FX rate process are considered and a particular model is selected, a discrete-time version can be developed which provides the basis for simulation. For example, suppose that the general geometric Brownian motion specification described above is

used for the spot exchange rate. A discrete-time version of the formula that could be used for simulation (see, for example, Hull (2000)) would be:

$$\Delta S = \mu S \Delta t + \sigma S \varepsilon (\Delta t)^{0.5}$$

where ε would be a randomly selected value from a standard normal distribution. Thus, in a DFA model, for example, future increments of time – e.g., months or years – would define the Δt term, and the discrete change in the spot rate over that period of time would be equal to the sum of a non-stochastic term and a stochastic term which would be simulated.

Conceptually, modeling FX rate emergence as a stochastic process as described above is straightforward. However, there are at least three challenging issues involved in this type of modeling. (1) determining the appropriate model specification (e.g., mean-reverting? proportional volatility?), (2) estimating the parameters of the model, and (3) recognizing the correlations and relationships with other financial and economic variables. The first two issues are statistical and econometric matters that are beyond the scope of this paper. The third issue is addressed in the following section.

B. Correlations and Relationships with Other Variables

Foreign exchange rates are potentially related to a variety of other financial and economic variables in the relevant countries. Any DFA-type modeling system, when forecasting possible future paths of exchange rates, will need to appropriately correlate FX rates with these other financial variables. In particular, there exists a series of hypothesized relationships involving

two countries' interest rates, inflation rates, and foreign exchange rates. (These relationships are generally critical in macroeconomic models of exchange rates)

The first relationship is referred to as *interest rate parity* The mathematical definition of interest rate parity is

$$\frac{1+r_F}{1+r_U} = \frac{f_{F/U}}{S_{F/U}}$$

or

$$S_{F/U}(1+r_F) = (1+r_U)f_{F/U}$$

where S is the spot exchange rate and f is forward exchange rate (both expressed as foreign currency units per U S dollar), F and U are subscripts denoting the foreign country and the U S., respectively, and r is the interest rate (in the country identified by the subscript). Interest rate parity thus requires that equal returns be generated in two different currencies when the expected change in the exchange rate is taken into account This may be clearest from the second formula above whether one converts to the foreign currency and then invests at the foreign interest rate, or invests in the U.S and later converts at the original forward rate, should not matter on an expected basis (to the extent that the forward rate represents an expectation regarding the future spot rate).

Another important relationship is referred to as *purchasing power parity* (sometimes called the "law of one price")

$$\frac{f_{F/U}}{S_{F/U}} = \frac{E[1+\iota_F]}{E[1+\iota_U]}$$

where ι is the inflation rate in the subscripted country. Thus, purchasing power parity says that expected changes in the exchange rate are a function of expected differences in the countries' inflation rates This implies that a good should cost the same regardless of the country in which it is bought (after adjustment, of course, for the exchange rate)

A third relationship is called the *international Fisher effect*.

$$\frac{1+r_F}{1+r_U} = \frac{E[1+\iota_F]}{E[1+\iota_U]}$$

The international Fisher effect states that differences in (nominal) interest rates are a function of differences in the countries' expected inflation rates This is an international version of the Fisher effect, which says that a nominal interest rate is a combination of a real interest rate and an inflation rate.

Anyone modeling exchange rates needs to decide the extent to which each of these relationships will be conditions incorporated into the model This may be a function of the time horizon involved in the model's forecasts (for example, and hypothetically, if it is believed that there can be short-term variations from one or more of these rules, but that the rules provide a reasonable approach to determining equilibrium in the longer-run) Incorporation of these relationships is important, but can be complicating For example, it would be conceptually straightforward to apply a Brownian motion process in the simulation of FX rates. However, in a broad-based (say,

DFA) model, the interest rates and inflation rates in the various countries might also be simulated separately, using similar stochastic process techniques. Care must be taken to properly introduce into the model the correlations between concurrent movements in all these processes. (See, for example, van Deventer and Imai (1997))

C Other FX Issues Relevant to Modeling

A stochastic foreign exchange rate model should also contemplate the different approaches to foreign exchange relationships that exist in different countries For example, the International Monetary Fund classifies countries' policies associated with exchange rates according to several alternative categories (see, for example, Shoup (1998) and Mange (2000)):

- *Pegged*: maintains a fixed value relationship, either with another single currency or with a composite currency.
- *Limited flexibility*: allows the rate to float within a relatively narrow range (either relative to a single currency or through a cooperative agreement)
- *Greater flexibility*: allows the rate to float within a relatively wide range.
- *Float independently*: allows the rate to float according to the market

A question associated with these exchange rate "regimes" involves how consistently and reliably a country applies its own policies. These issues should be considered when modeling foreign exchange rates.

Section 7 – Summary and Conclusion

As the property-liability insurance industry becomes increasingly global, companies with multinational operations and/or investments will potentially be exposed to significant foreign exchange rate risk This paper has examined the sources of such risk, discussed the institutional techniques available to companies to manage that risk, and provided evidence regarding the risk management techniques actually being utilized by the industry. The paper also briefly presented some possible approaches to modeling (for example, in a dynamic financial analysis framework) foreign exchange risk When modeling, the interrelationships between exchange rates and other variables – e g., interest rates and inflation rates in the relevant countries – must be considered and reflected.

References

Campbell and Kracaw, 1993, *Financial Risk Management Fixed Income and Foreign Exchange*, HarperCollins College Publishers, New York

Cox, Ingersoll, and Ross, 1985, "A Theory of the Term Structure of Interest Rates," *Econometrica*, 53 385-407

Cummins, Phillips, and Smith, 1997, "Corporate Hedging in the Insurance Industry The Use of Financial Derivatives by Insurers," *North American Actuarial Journal*, 1(1) 13-40

D'Arcy, Gorvett, Herbers, Hettinger, Lehmann, and Miller, 1997, "Building a Public Access PC-Based DFA Model," *Dynamic Financial Analysis Call Paper Program*, Casualty Actuarial Society, pp 1-40

D'Arcy, Gorvett, Hettinger, and Walling, 1998, "Using the Public-Access DFA Model A Case Study," *Dynamic Financial Analysis Call Paper Program*, Casualty Actuarial Society, pp 53-118

De Grauwe, Dewachter, and Embrechts, 1993, *Exchange Rate Theory Chaotic Models of Foreign Exchange Markets*, Blackwell Publishers, Oxford

Hull, 2000, *Options, Futures, and Other Derivatives*, Prentice Hall, Upper Saddle River, NJ

Kolb, 1996, *Financial Derivatives*, Blackwell Publishers, Inc , Cambridge, MA

Mange, 2000, "Measuring Foreign Exchange Risk in Insurance Transactions," *North American Actuarial Journal*, 4(2) 88-100

Rosenberg, 1996, *Currency Forecasting A Guide to Fundamental and Technical Models of Exchange Rate Determination*, Irwin Professional Publishing, Chicago, IL

Shoup, 1998, *The International Guide to Foreign Currency Management*, AMACOM, American Management Association, New York

Smithson, 1998, *Managing Financial Risk A Guide to Derivative Products, Financial Engineering, and Value Maximization*, McGraw-Hill, New York

Van Deventer and Imai, 1997, *Financial Risk Analytics: A Term Structure Model Approach for Banking, Insurance and Investment Management*, Irwin Professional Publishing, Chicago

Exhibit 1
Excerpts from SEC 10-K Filings

Source EDGAR Database, SEC website

(i) CNA Financial Corp

"Foreign exchange rate risk arises from the possibility that changes in foreign currency exchange rates will impact the value of financial instruments The Company has foreign exchange rate exposure when it buys or sells foreign currencies or financial instruments denominated in a foreign currency .. This exposure is mitigated by the Company's asset/liability matching strategy and through the use of forward contracts for those instruments that are not matched [a]"

(ii) CIGNA Corp

"CIGNA's investment strategy is to manage the characteristics of investment assets, such as liquidity, currency, yield and duration, to reflect the underlying characteristics of the related insurance and contract-holder liabilities, which vary among CIGNA's principal product lines In connection with this investment strategy, CIGNA uses derivative instruments through hedging applications to manage market risk. .

"Currency swaps are used to match the currency of individual investments to that of the associated liabilities

"Cash requirements arise as a result of CIGNA's derivative activities Under currency swaps, the parties generally exchange a principal amount in the two relevant currencies, agreeing to re-exchange principal amounts at a specified future date using an agreed-upon exchange rate, and agreeing to periodically exchange amounts equal to interest payments using the agreed-upon exchange rate "

(iii) The St Paul Companies, Inc

"Our exposure to market risk for changes in foreign exchange rates is concentrated in our invested assets denominated in foreign currencies Cash flows from our foreign operations are the primary source of funds for our purchase of these investments We purchase these investments primarily to hedge insurance reserves and other liabilities denominated in the same currency, effectively reducing our foreign currency exchange rate exposure "

[a] According to its 10-K, CNA also performed sensitivity analyses with respect to interest rate risk, equity price risk, and foreign currency exchange rate risk The impact of 10% and 20% changes in foreign currency exchange rates were estimated

Exhibit 1 (cont.)
Excerpts from SEC 10-K Filings

Source EDGAR Database, SEC website

(iv) Progressive Corporation

"Derivative instruments, as defined by Statement of Financial Accounting Standards (SFAS) 119, "Disclosures about Derivative Financial Instruments and Fair Value of Financial Instruments," include futures, options, short positions, forward positions, foreign currency forwards and interest rate swap agreements . . Hedges are evaluated on established criteria to determine the effectiveness of their correlation and ability to reduce risk of specific securities or transactions "

(v) Chubb Corp

"The Group's overseas business is developed by its foreign agents and brokers through local branch offices of the Group and by its United States and Canadian agents and brokers In conducting its overseas business, the Group reduces the risks relating to currency fluctuations by maintaining investments in those foreign currencies in which the Group transacts business, with characteristics similar to the liabilities in those currencies The net asset or liability exposure to the various foreign currencies is regularly reviewed

"Foreign currency risk is the sensitivity to foreign exchange rate fluctuations of the market value and investment income related to foreign currency denominated financial instruments The functional currency of our foreign operations is generally the currency of the local operating environment since their business is primarily transacted in such local currency We reduce the risks relating to currency fluctuations by maintaining investments in those foreign currencies in which we have loss reserves and other liabilities. Such investments have characteristics similar to our liabilities in those currencies...."

Chart 1
Time Series of Monthly Exchange Rates
British Pound / U S Dollar
(Data per FRED, St Louis FRB)

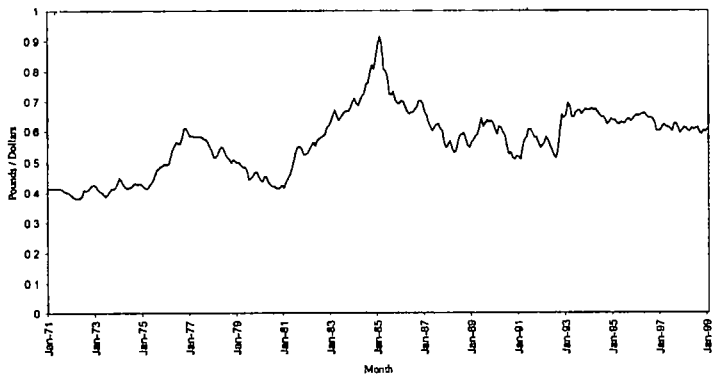


Chart 1A
Time Series of Monthly First Differences of Exchange Rates
British Pounds / U S. Dollars
(Data per FRED, St Louis FRB)

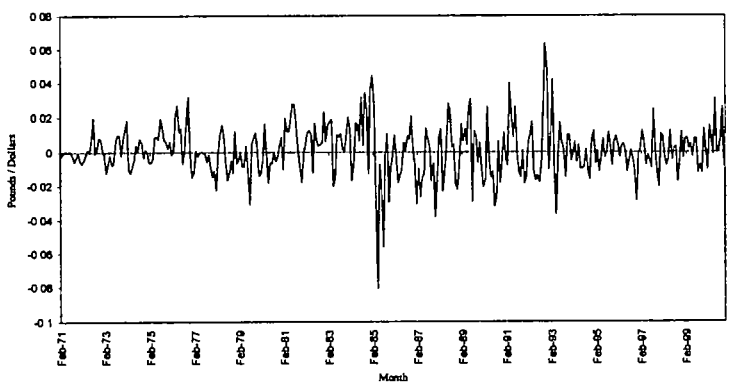


Chart 1B
Time Series of Monthly Percentage Changes in Exchange Rates
British Pounds / U S. Dollars
(Data per FRED, St Louis FRB)

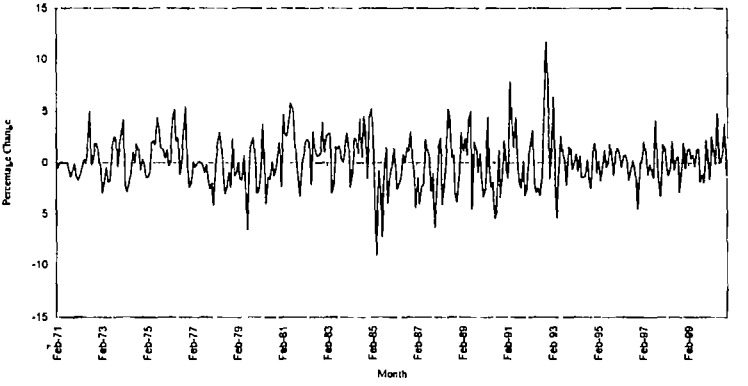


Chart 2
Time Series of Monthly Exchange Rates
French Franc / U S Dollar
(Data per FRED, St Louis FRB)

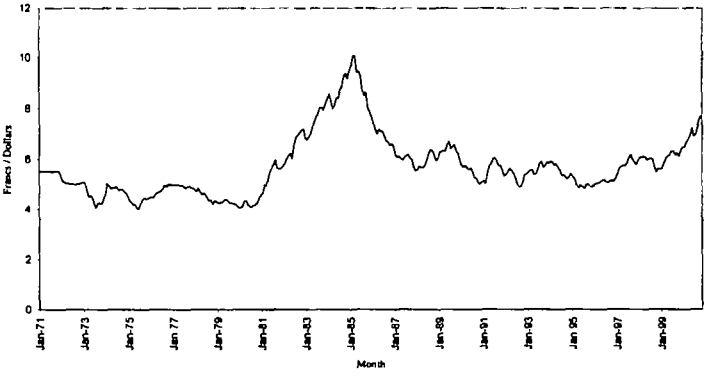


Chart 3
Time Series of Monthly Exchange Rates
German Marks / U.S. Dollar
(Data per FRED, St Louis FRB)

Chart 4
Time Series of Monthly Exchange Rates
Japanese Yen / U.S. Dollar
(Data per FRED, St Louis FRB)