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Abstract

Following the global economic downturn and a collapse in international equity markets, many financial institutions and corporations have sought the higher returns associated with higher risk from trading in foreign exchange derivatives. These derivatives have become increasingly complex to the point where few specialists are able to accurately determine the level of exposure. Top traders seek high rewards for their successful investments. Rogue traders seek high rewards by concealing their unsuccessful gambling, sometimes to the extent of endangering the viability of their employers. Current technology copes poorly with dynamically changing business requirements and conditions so there is little technological support available for organizations sensitized by reports of rogue trading and increasingly obliged by financial regulators to improve their risk management practices.

This paper proposes a risk management framework that can support FX derivative monitoring and trading based on the Williams-Elliot Agent Architecture. The framework uses agent technologies for improved management of treasury risk by continuous monitoring of all transactions across an organisation; continuous evaluation of exposures compared with prescribed parameters across an organisation; instantaneous reporting to senior management where trading begins to approach or violates the parameters. Rigorous examples of typical transactions illustrate how intelligent agents can be used to monitor risk and to make trades within a powerful risk modelling and management framework.

Keywords

Foreign Exchange Risk Management, Intelligent Agents, Knowledge Representation.

1 INTRODUCTION

A downturn in the global economy, a drive for increased Business Continuity Management arising from 2001's 9/11 terrorist activity, the collapse of iconic corporations and subsequent interventions by governments to expand business regulation have all contributed to a refocus of corporate attention on internal operations and controls. Central to this refocusing on business processes has been an emphasis on stringent cost containment and improved risk management. Within advanced economies, automated processing of business transactions has become ubiquitous for all standard or standardizable transactions. A consequence of automation is reduced data error rates and subsequent reduced business risk. Transactions that currently are not able to be processed automatically are often those requiring some degree of manual intervention. Examples include: negotiation, where prices are set dynamically by market interaction rather than being fixed by the seller, or where special terms and conditions are applied to or sought for the transaction by the seller or buyer, and transactions involving the exploitation of asymmetrical information. One particular category of manual transactions that presents a major challenge for corporations to manage and control is foreign exchange (FX) dealing. Most corporations that import or export their products and services must buy, sell or exchange foreign currency. Transactions may be simple: what price (or exchange rate) for a current purchase of a specified currency, or more complex: what price for a purchase in six months time. Actual or optional currency transactions or exchanges at some time in the future are referred to as FX derivatives. Renowned corporate investor, Warren Buffett, defines derivatives as, "instruments [that] call for money to change hands at some future date, with the amount to be determined by one or more reference items, such as currency values - with your gain or loss derived from movements in the index." He views these derivatives as 'time-bombs' and financial weapons of mass destruction' (Buffett 2002). See also glossary of financial terms (Harvey 2004).

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The most infamous FX rogue trader, Nick Leeson, caused the collapse of Britain's Barings Bank after losing $US 1.3 billion trading FX derivatives (Gray 2004). Further examples include Enron's accumulated losses from derivative trading and National Australia Bank's $US 270 million loss from three months trading in 2003 (Rao 1996). This paper describes recent findings of a seven year, on-going, multi-disciplinary research project into the current and potential impact of technology-enabled eBusiness innovation in the Australian Wholesale Financial Services sector. Funded by both industry and the national government, the project aims to assist firms in the sector achieve international competitiveness during a period of fundamental disruption and structural transformation. The project has identified Treasury risk management as being a current major concern to both banks and their corporate customers.

In this paper we show how Intelligent Agents can be used to monitor risk and to make trades within a rigorous risk management framework. Our research model seeks to evaluate the potential of emerging Intelligent Agent technologies to monitor, analyse and undertake complex FX trading autonomously based on pre-determined management approved business rules. The major purpose is to assist firms dramatically improve their risk management in FX transactions.

We argue that a multi-disciplinary integration of eBusiness strategy, finance, intelligent agent architectures and knowledge technologies offer a previously unexplored solution to this challenge confronting Australia's Wholesale Financial Services industry. Agent architectures transcend traditional information system designs for applications that require complex decision making in an open exception-rich environment where responsiveness is imperative.

A key difference between agent architectures and more traditional architectures is that instead of building relationships between software components at design time, agent architectures allow relationships to be formed on the fly at run-time. This results in highly responsive systems that can be sensitive to the dynamic financial services context and that are able to be opportunistic within prescribed boundaries in any competitive complex business environment. A representative trading application for Intelligent Agents could be arbitrage programmed trading. In FX, arbitrage traders aim to exploit small price differences between markets by simultaneously buying in one market and selling in another or by taking advantage of small differences between an index and its underlying components. Although price differences may be very small, by trading regularly in large volumes, the traders can accumulate considerable revenue with minimal risk. The essence of this strategy is continuous monitoring of markets and split second timing when an opportunity is identified. Intelligent agents' ability to conduct autonomous action in heterogenous environments based on prescribed rules means that they can undertake transactions in a distributed computing environment and as a result they can support arbitrage strategies and address treasury risk management issues. Further, the business rules may be established to ensure self-monitoring of transactions with the ability to advise management of transactions that approach a preset level of exposure. In this form, Intelligent Agents can monitor risk continuously for all transactions. With current levels of technology, organizations monitoring their trades are reduced to spot checks of selected transactions for review. A key issue is the definition of the business rules, the monitoring of those rules and the system to make sure that the monitoring is being conducted properly and the results analysed. We illustrate the kind of business rules required in our examples in Section 4.

2 INDUSTRY:ITS' PROBLEMS AND CHALLENGES

The Wholesale Financial Services industry provides bonds, cash management, deposit, equity, foreign currency exchange, investment, loan, settlement, custody and other facilities for enterprises and government organisations in support of their commercial operations.

In response to the increasingly complex nature of the risks taken by commercial banks the Basel Accord concerning capital adequacy was updated, following extensive deliberations and representations by central banks and commercial banks (among others) into the Basel II Accord (BIS 2004). Capital adequacy is an important issue for commercial banks if, for no other reason, commercial banks and their regulators have somewhat conflicting incentives. The banks attempt to maximise return on equity (ROE) within acceptable risk parameters as they define them. Given a specific spread between the rate on earning assets and the rate on interest-bearing liabilities, a bank's ROE increases as its capital ratio (capital divided by total assets) decreases. Therefore banks have an incentive to keep capital ratios as low as possible. Bank regulators, however, have an incentive to minimise the probability of a bank failing and therefore reflecting poorly on the bank supervision process. With all other aspects being equal, the probability of failure is lessened as the capital ratio increases. Hence the motivations of the bank regulators and commercial bankers are somewhat in conflict.

The Basel Accord attempted to reduce this conflict, and to provide a world-wide framework so that, in an increasingly global financial marketplace, commercial banks from different countries would be regulated in as similar a manner as possible concerning capital adequacy. The solution was to relate the amount of capital required by the amount of risk that the bank assumed. It was found that the original Basel Accord, by concentrating entirely on credit risk and then only in a summary fashion, was too crude to properly relate risk to capital adequacy for individual banks. Hence the new Basel II Accord has categories, in addition to credit risk, for operational risk (which would include computer system misspecifications in models) and trading risk (which includes foreign exchange trading).

In the sequel when we use the term risk we refer to treasury risk exclusively. Treasury risk management has become a major issue for corporations, as a result of well publicized exposures highlighting the risks, legislation requiring increased attention to corporate accounting practices, including risk management (Financial Services Reform Act 2002 in Australia and the Sarbanes-Oxley Act 2002 in the USA), the computerization of standardized transactions as part of corporate drives to increase process efficiencies and reduce cost that has focused the attention of corporate treasury departments on non-standardised, high value and high risk manually conducted transactions and the emergence of software tools to assist firms to better manage their treasury risk (Elliot 2004) (Thomson 2004).

Corporations operating in the FX market include: any organization trading with or investing in countries that use a different currency, banks or other financial institutions that service the corporate customers and currency traders. There are four types of activities in FX in which a corporation or bank can engage:

- As a hedger of its own balance sheet,
- As an arbitrage trader,
- As an active trader maintaining long and short positions to service client needs, and
- As an active trader for profit - risking its own capital.

A commercial bank could operate all four of the above activities. A non-financial corporation with business in foreign currencies would be likely to desire hedging products, usually purchased from its bankers. All of these activities create FX risk with the activity of being an active trader as a principal for profit carrying the largest risk. That activity needs constant monitoring for unacceptable risk being taken, either inadvertently or purposely on both individual trades but more importantly across the whole organisation. Banks have a greater exposure to this business risk since their trades are larger and more frequent. Their failures are also more spectacular. Following the Barings Bank collapse where a rogue trader managed to lose $US 1.3 billion in FX derivatives, banks moved to tighten their controls (Gray 2004). Unfortunately, it was not tight enough at Australia's NAB. Between October 2003 and January 2004, four traders lost $US 270 million in FX derivatives. It appears that NAB's critical issue may not have been a lack of controls but failure to apply their controls. The trading culture deliberately fostered by banks that rewards traders for taking risks. At the same time as NAB was publicly acknowledging its losses, in London the head of derivatives for Goldman Sachs was reportedly being paid a bonus of £30 million ($US 54 million) for his trading (gambling) successes without any quantification of the risk taken being disclosed[3].

From a regulatory standpoint, FX derivatives can be used to decrease FX risk in a commercial bank and could therefore be viewed very positively. Conversely, if a commercial bank used these derivatives to speculate excessively, the regulators could view those activities as improper. The measurement of the FX position becomes vital, both for the commercial bank and its regulator. The general issue of risk management and control, together with the categories of market, credit and operating risk (which coincides with the Basel II Accord) were addressed by Federal Reserve Governor Susan Schmidt Bies. She specifically addressed FX risk for financial and non-financial corporations and acknowledged the use of derivatives and securitization to manage that risk (Bies 2002). Chairman of the Federal Reserve Board of Governors, Alan Greenspan, stated that the use of credit derivatives, a rather recent and rapidly growing type of derivative, contributed to the negative effects of the 2002 recession being much less than the negative effects of the banking problems in the early 1990s. He feels that credit derivatives can be an effective hedging tool for commercial banks (Streeter 2002).

With the decline of global equities (or stock) markets particularly in the United States and the United Kingdom since 2000, financial institutions including banks and fund managers have focused on FX as an alternate revenue stream. Confronted by a declining US dollar, corporations have enthusiastically embraced currency hedging, often without the capabilities to assess the risks involved. Companies like BHP Billiton and Rio Tinto report FX

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[3] Driss Ben-Brahim head of "exotic derivative" at Goldman Sachs' London office is set to earn one of the biggest bonuses in City history - worth at least £ 30 million. He is credited with a series of audacious and highly profitable gambles on financial markets last year. Goldman Sachs refused to comment on the award but top bankers typically insist on a bonus equivalent to about 10 per cent of the profits they earn. A friend of Mr Ben-Brahim's said: "He has taken on some really big risks but has enjoyed great success in 2003. He is the person everyone is talking about and he has been the most profitable trader around for the past few years. He deserves some recognition for his work." (Sunday Times: 18 January 2004).

losses greater than $US 700 million while Qantas gained more than $US 100 million (Harcourt and Howarth 2003). Mining giant Pasminco collapsed following massive losses arising from complex derivatives trading (Rao 1996).

A root cause of FX derivative losses appears to have been the lack of capability to ensure trading complies with pre-determined rules (goals and corporate objectives) and that where exposures have materially increased (perhaps due to accumulated losses) adequate warning is not provided to responsible management.

Regulating bodies are mandating increased attention to the management of operational risk (e.g., in the BASEL II Accord it is a separate and much debated category) with estimated investments in risk management systems to be $US 6 billion by 2006 (Banker 2003). Traditional technologies, however, may not address the root cause of these documented FX exposures.

Australia is one of the world leaders in legislation and regulation of its financial services markets (Axiss 2002) with Canada, the UK and the USA among others acknowledge Australia's significance in their own reforms. A series of new laws in Australia, including the Financial Services Reform Act (2001, commencing March 2002 with a two year transition) replaced a range of prescriptive regulatory requirements with a clearly stated, cross-sector regulatory regime designed to encourage the creation of innovative products and flexible service delivery within a regulatory framework based on credibility and market integrity (Axiss 2002). One concern addressed by the reforms was the potential for organizations to have un-intermediated access to unregulated financial markets as a result of globalisation of financial markets and the growth of the Internet. Among other issues, the law no longer distinguishes between securities and futures exchanges but permits easier access to futures transactions. There is also a new requirement for all organisations trading financial instruments to demonstrate their risk management capabilities (Axiss 2002).

Corporations wishing to address their risk exposures can refer to an Australian / New Zealand Standard on Risk Management Systems (AS/NZS 1999). The standard outlines an approach by which organizations should document identified risks, analysis and evaluate the risks and determine treatment strategies to minimize the risks. Generic risks include; natural events, political circumstances, technology and IT issues, human behaviour, commercial and legal relationships, economic circumstances (local and international) and management activities and controls.

Within the financial services sectors, risk management activities are defined as those that 'reduce the financial impact of a risk once it has occurred'. Actions that manage the financial consequences of risk include; 'taking out insurance or hedging a risk by acquiring a futures contract or entering into a currency swap (Axiss 2002). Risk management activities are focused at an organizational level rather than addressing the characteristics of a particular market, i.e. systemic risk.

Publicity about corporate exposure to business risk has reached a level that a professional accountancy association (CPA) and the national Institute of Company Directors have jointly released guidelines for the boards of directors to better understand the activities and their consequences (CPA 2002).

The most important industry challenges that lie ahead include:

1. Improving risk management for non-standard FX transactions. The majority of FX transactions are high volume, low margin, standardized transactions where costs (and therefore pricing) is transparent to clients. The balance comprises low volume, high value and high risk transactions currently requiring manual intervention. These are typically FX derivatives, including options, future contracts and forward swaps (Harvey 2004). These manual transactions are also known as Over the Counter (OTC) transactions. Manual intervention may be due to the necessity for verification of a physical security on a bond issue or complications arising from exotic swap arrangements across currencies. Additionally, there is the issue of counterparty risk evaluation.
2. Improving treasury risk management in corporations in general. This has changed slowly over the past 15-20 years with few direct applications of technology. Improvements in the accuracy of cash flow forecasting has huge potential for cost savings. The more accurate the forecast the less the buffer required. In a large international corporation the potential reduction could be of the order of US $100 – US $200 million, sustained (Elliot 2004).
3. Regulatory bodies mandating improved risk management practices. For example, Australia's Financial Services Regulation (implemented in stages between 2002 and 2004) requires organisations to demonstrate their risk management capabilities. Unless CFOs can account for all transactions (as required by FSA), the level of complexity of transaction will have to reduce to a level where all aspects of the transaction can be captured. This may result in reduced use of complex FX derivatives that currently represent a significant source of revenue as well as risk for both financial institutions and non-financial corporations. NAB suspended a substantial portion of its FX trading operation following its

large losses. It has, as of April 2004, taken "the first steps towards a resumption of full-scale currency option trading as it attempts to minimise the loss of corporate client" (Oldfield 2004). In addition, John Stewart (the CEO) appointed an executive to liaise with the Australian Prudential Regulatory Authority (APRA - the regulator for financial institutions) to speed the process (Oldfield 2004).

Our Agent-Oriented Risk Management Framework can be used to alleviate many of the exposures identified with trading in FX derivatives. For example, it offers the potential to support autonomous and opportunistic trading activities but within pre-set boundaries. Agents also have the potential for self monitoring and reporting where material changes occur in the levels of exposure.

3 AN AGENT-ORIENTED RISK MANAGEMENT FRAMEWORK FOR FOREIGN EXCHANGE TRADING

Intelligent agents are autonomous computational entities capable of making decisions independently and without the intervention of other entities, e.g. humans (Williams 1998) and (Mullaney et al. 2003). They can be proactive, purposeful and exhibit goal-directed behaviour, as well as reactive and responsive to changes in the environment. They can interact and modify their environments, and most importantly they can interact with other agents. Being autonomous distinguishes them from objects in the object-oriented paradigm (Horrocks et al. 2004).

Agents are particularly well suited to applications that involve communication between heterogeneous information systems, a common occurrence within the typically large, mature IT user companies in the wholesale financial sector. Intelligent agents can be designed to reason and draw inferences and as a consequence they can perform sequences of complex operations based on their internal beliefs, goals and the information/messages they receive (Patel et al. 2003). They can use explicit representation of their internal beliefs, the services they offer, and their overall goals, which can then be communicated and shared with other agents.

Agent architectures support ebusiness innovation by providing a framework for genuine dynamic information system development, which leads to the kind of system agility that is crucial in the current highly competitive global financial environment.

The ability to be opportunistic is particularly pertinent and important in the current highly competitive global wholesale financial services industry. The pertinent advantages intelligent agents offer business for the purposes of trade execution and risk management are autonomy and proactive behaviour.

Agents are capable of making decisions based on the information at hand and taking appropriate actions. Therefore they can be used both for trade decision-making and as intelligent monitors that sit in the background to analyse trading transactions and identify suspect trades. For both trading and monitoring roles, the challenge lies in designing the decision making apparatus.

Intelligent Agents adopt three major roles in our foreign exchange trading risk management framework: monitoring risk, modeling risk, analysing risk, and managing risk across individuals and groups within an organisation. The framework is based on the Williams-Elliot Agent Architecture (Williams and Elliot 2004).

Treasury risk manifests itself in various guises and in many areas throughout an organisation. Our risk monitoring and management framework is designed to model and assess treasury risk within an organisation and is able to accumulate risk over time and aggregate risk across multiple organisational groupings, e.g. specific individuals such as traders, groups of traders, departments, etc. We envisage a CEO using systems based on the framework to develop an understanding of the overall treasury risk his company has undertaken and the exposures at stake where risk can be aggregated across individuals and groups in a drill-down fashion. The agent-oriented design allows users to drill-down to individual activities that generate risk and to analyse exposures and aggregate them in a flexible transparent fashion, ideally using a range of risk fusion strategies and algorithms. The Williams-Elliot Agent Architecture provides the necessary infrastructure for agents to compute levels of risk *on the fly* using the most recent information on trades available to the agents.

As a result not only do we model specific trades in our framework but also mechanisms that can be used to accumulate and aggregate risk and exposures across groups at varying levels of granularity. One factor facilitating use of agents is that exchange traded markets use fixed protocols and there is strong encouragement within the industry to extend the use of standard protocols.

Monitoring agents in our risk management framework continuously scrutinize transactions undertaken to ensure they support business goals within approved levels of exposure across the organisation. Monitoring agents also enforce the separation of front and back office or to control transaction activity in specific trades or by specified traders.

In order to better understand our Agent-Oriented Risk Management Framework in trading several examples are presented. The examples illustrate how the framework can be applied and how agent technology can produce superior outcomes to existing approaches to risk management.

4 OPTIONS RISK MODELLING AND MANAGEMENT EXAMPLES

Example 1: Suppose a financial institution in Australia has a US dollar (USD) position that it wishes to hedge. That position could come from any number of ways, for instance, the issue of a USD denominated loan. Further suppose that the financial institution, through its information systems, sums all of its net USD positions by time slots in order to develop an effective macro hedge. Finally suppose that the financial institution wishes to speculate, within a well-defined limit, in USD. All of the above transactions could occur in the FX futures market, the FX options market or a combination of the two.

Our framework and supporting architecture allows financial institutions to define goals for the purposes of monitoring and transacting to be automatically executed. For example, the hedges would be almost exact offsets that would be changed daily based on the transactions conducted by the bank. Size ranges would be programmed so that very small transactions would not be instituted because they would inordinately increase transaction costs. For the speculative transactions, criteria for when to enter the market can be predetermined, but, more importantly, "stop-losses" could be defined for when to exit a position. These stop-losses would effectively limit the amount of loss taken on trading. These "orders" could be in a cascading nature so that the total loss is managed but the financial institution does not go completely in and completely out of a position in rapid intervals of time. Conversely, the intelligent agents could be designed to "book" gains periodically as they occur.

Example 2: A *call option* gives the holder the right, but not the obligation, to buy a certain asset by a certain date for a certain price. A *put option*, on the other hand, gives the holder the right, but not the obligation, to sell the underlying by a certain date for a certain price. European options can only be exercised at maturity while American options can be exercised anytime up to and at maturity.

For an entity wishing to hedge a foreign exchange exposure, *foreign currency options* are an alternative to forwards and futures contracts. An Australian Bank expecting to receive American Dollars at a future date can hedge the effects of exchange rate fluctuations by either taking a short forward contract or buying put options. Both the forward and the put options guarantee that the exchange rate on the day will be the exercise price as stipulated in the contracts. However, the forward contract is an obligation which has to be fulfilled on the expiration date while the put option is an "option" which allows the bank to take advantage of favourable exchange-rate movements. Hence, options in general provide a form of insurance. Another important point to note is that while it costs nothing to enter a forward contract, the options have to be purchased at a premium.

For the purpose of illustration we assume that the spot exchange rate follows a Geometric Brownian motion and in a risk neutral world satisfies the following stochastic differential equation: $dS = (r_d - r_f)Sdt + \sigma Sdz.$ In the above equation S is the spot exchange rate, r_d is the domestic risk-free interest rate, r_f is the foreign risk-free interest rate, σ is the exchange rate volatility and z is a Wiener process. We can then use the Black-Scholes-Merton Equation (Merton 1995) to find the value of the options:

$$\text{(call)}\, c = S_0 e^{-r_f t} N(d_1) - X e^{-r_d t} N(d_2)$$

$$\text{(put)}\, p = X e^{-r_d t} N(-d_2) - S_0 e^{-r_f t} N(-d_1)$$

where S_0 is the exchange rate at time zero, T is the time to maturity and X is the strike price and

$$d_1 = \frac{\ln\left(\frac{S_0}{X}\right) + \frac{(r_d - r_f + \sigma^2)T}{2}}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

A financial institution that sells an option or any other derivative to a client in the over the counter market is faced with the problem of managing its risk. *Delta Hedging* offers a means of hedging the risk of an option.

The delta, Δ of an option is defined as the rate of change of the option price with respect to the price of the underlying. It is the slope of the curve that relates the option price to the underlying price. For example, if the delta of a call option is 0.75 then if the asset changes by a small amount then the option price changes by about

75% of that amount. The delta of a call option is calculated by the following equation: $\Delta = \frac{\partial V}{\partial S}$, where V is the value of the option. So for an European Call option on a currency the delta is: $\Delta_c = e^{-r_f T} N(d_1)$ and for an European Put option on a currency the delta is: $\Delta_p = e^{-r_f T}[N(d_1) - 1]$.

Suppose for example a Bank has written a six month European option to sell 1,000,000 units of a currency at an exchange rate of 1.6000. Suppose that the spot exchange rate is 1.6200, the domestic risk-free interest rate is 10% per annum, the foreign risk free interest rate is 13% per annum and the volatility of the currency is 15%.

According to the above equations then the delta for the put option is $\Delta_p = -0.458$. This means that for small exchange rate changes the price of the put goes down by 45.8% of the increase in the value of the currency. The Delta of the Bank's total short position is $-1{,}000{,}000 \times -0.458 = +458{,}000.$ Delta hedging would therefore require that a short position of 458,000 be set up initially. This short position has a delta of -458,000 and neutralises the delta of the option position. Such a situation is known as *delta neutral* (Hull 2000).

In the example above, it is important to realise that the bank's position is delta hedged only for a very short amount of time since the volatility of the currency, the domestic and the foreign interest rates are not constant. This causes the delta to change continuously. As a consequence the hedge has to be readjusted periodically. This is known as *rebalancing*. Continuous rebalancing to maintain a delta neutral position is prohibitively expensive because of the trading costs involved. However for a large portfolio delta neutrality is more feasible.

Suppose a bank in the US has the following three positions in the Australian Dollar:

1. A long position in 100,000 call options with a strike price of 0.55 and an expiration date in 3 months. The delta of each option is 0.533.
2. A short position in 20,000 call options with a strike price of 0.56 and an expiration date in 5 months. The delta of each option is 0.468.
3. A short position in 50,000 put options with a strike price of 0.56 and an expiration date in two months. The delta of each option is -0.508.

The delta of the whole portfolio is: $0.533 \times 100{,}000 - 0.468 \times 200{,}000 - (-0.508) \times 50{,}000 = -14{,}900.$
This means that the portfolio can be made delta neutral with a long position of AUD 14,900 (Hull 2000).

This shows that for a large portfolio only one trade in the underlying is necessary to cancel out the delta for the whole portfolio. The hedging transaction costs are absorbed by the profits on many different trades.

Agents developed in our framework have a major advantage over human decision makers because

they can monitor the hedge neutrality of a portfolio or a single option continuously. In fact agents can be used to continually simulate the effect of changing volatilities and domestic and foreign risk-free interest rates on the portfolio or the individual option thus in effect rebalancing the hedge within a certain prescribed limit. As a result techniques for risk management that are known to be extremely powerful but that require unrealistic monitoring requirements for humans become possible in an agent-oriented system.

The forward/future prices and the option values which are normally used for hedging are calculated using constant volatilities and interest rates. This is not necessarily true in the medium to long run even though in the short term interest rates can be assumed to be constant. The exchange rate depends upon many factors besides the interest rates and as a result there is a strong volatility in the exchange rate. This volatility has to be monitored continuously since the slightest change can increase/decrease the risk associated. Again it is not feasible for humans to model volatility continuously however agents can be designed to perform the necessary level of surveillance.

5 DISCUSSION

More effective treasury risk modelling and management is an important challenge confronting organisations that engage in foreign exchange trading. Success in meeting this challenge will depend on the ability to develop and to effectively implement flexible agent-oriented processes and strategies.

We have developed a risk management framework based on the Williams-Elliot Agent Architecture that offers a powerful solution and we have described the roles that Intelligent Agents can play in risk monitoring and management in foreign exchange trading. Agent architectures transcend traditional information system designs for applications that require complex, highly customized transactions in an open exception rich environment where responsiveness is imperative. Furthermore, agents can be proactive, have goals and make decisions autonomously and as such they naturally support monitoring and management of risk across an organisation, and FX trade execution. They have the potential to support the kind of system agility with appropriate responsibility that is crucial in the current highly competitive global financial environment.

Agents can perform better than humans in risk assessment because they can continuously monitor, build hypothetical scenarios, analyse the behaviour of the market, and make predictions by integrating information including exchange rate volatilities from multiple sources to help provide a coherent and robust picture almost instantaneously. Delta hedging provides a good example of how our agent-oriented risk management framework can out perform human decision makers because the agents can analyse aggregate risk across an organisation using up-to-date trading transaction information.

In addition simulations of possible scenarios and their expected values of the various variables can be efficiently carried out in our agent-oriented framework in the background and as a result it offers the possibility to provide effective reporting and predictions of the movements of various indices, etc, on the fly.

Our next step is to evaluate our prototype by comparing its performance using historical costs of risk monitoring and management, the levels of potential exposure and the increased effectiveness of monitoring and management to reduce the level of exposure and to reduce transaction costs.

As agents are implementations of software, standard approval processes for development, modification and testing of financial services software applications would need to be applied. In addition, and in recognition of their autonomous capabilities, monitoring of the agents for possible malfunction is necessary and specific audit action would be required by both internal and external auditors.

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