Centre for Research in Applied Economics (CRAE)

Working Paper Series
2007-07
July

"The Interaction Between Exchange Rates and Stock Prices: An Australian Context"

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ISSN 1834-9536

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THE INTERACTION BETWEEN EXCHANGE RATES AND STOCK PRICES: AN AUSTRALIAN CONTEXT

ABSTRACT

The aim of this paper is to examine the interaction between stock prices and exchange rates in Australia. During the period of the study, the value of the stock market increased by two-thirds and the Australian dollar exchange rate appreciated by almost one-third. The empirical analysis employed provides evidence of a positive co-integrating relationship between these variables, with Granger causality found to run from stock prices to the exchange rate during the sample period. Although commodity prices have not been included, the significance of the results lends support to the notion that these two key financial variables interacted in a manner consistent with the portfolio balance model, that is, stock price movements cause changes in the exchange rate. This challenges the traditional view of the Australian economy as export-dependent, and also suggests that the Australian stock market has the depth and liquidity to adequately compete for both domestic and international capital against other larger markets.

1. Introduction

The objective of this study is to ascertain the significance of the strength and direction of the influence of Australian stock price movements on the Australian dollar exchange rate between 2 January 2003 and 30 June 2006. This period was characterised by a high degree of co-movement between the two variables[1]. Indeed, there has never been a period in which these two key macroeconomic variables have moved so strongly and in the same direction since the float of the Australian dollar in 1983.

The initial analysis investigates the broad relationship between stock prices and exchange rates in Australia and is then expanded to investigate the changes in these key economic variables and the relationship between those changes.

The interaction between equity and currency markets has been the subject of much academic debate and empirical analysis over the past 25 years; and understandably so, given the crucial role that equity and currency markets play in facilitating economic activity.

Classical economic theory hypothesises that stock prices and exchange rates can interact by way of the 'flow oriented' and 'portfolio balance' models. Flow oriented models, first discussed by Dornbusch and Fisher 1980, postulate that exchange rate movements cause movements in stock prices. This approach is built on the macroeconomic view that because stock prices represent the discounted present value of a firm's expected future cash flows, then any phenomenon that affects a firm's cash flow will be reflected in that firm's stock price if the market is efficient as the Efficient Market Hypothesis suggests. Movements in the exchange rate are one such phenomenon.

Portfolio balance approaches, or 'stock oriented' models developed by Branson et. al. 1977 postulate the opposite to flow models – that is, that movements in stock prices can cause changes in exchange rates via capital account transactions. The buying and selling of domestic securities in foreign currency (either by foreign investors or domestic residents moving funds from offshore into domestic equities) in response to domestic stock market movements has a flow through effect into the currency market.

Although the literature on this subject has examined the relationship between stock prices and exchange rates in various economies, the results have been mixed in terms of the evidence as to which of the above models is most applicable to, or prevalent within an economy.

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[1] The value of the Australian stock market increased by two-thirds during this period, while the Australian dollar exchange rate appreciated by as much as 32 per cent relative to the US, implying a strong positive relationship existed between the two variables.

Ramasamy and Yeung (2005) suggest that the reason for these divergent results is that the nature of the interaction between stock and currency markets is sensitive to the stage of the business cycle and wider economic factors, such as developments or changes in market structures within an economy. So the period of time in which the interaction between stock and currency markets is observed is critical to the end result.

This observation is a key platform on which the current study of the interaction between stock prices and exchange rates in Australia is developed given the high degree of co-movement between Australian stock prices and the Australian dollar exchange rate during the period of the study.

This positive relationship is intriguing given the traditional importance of export earnings to the growth profile of the Australian economy. Indeed, this view of the economy lends itself to the flow oriented model, whereby exchange rate appreciation would be expected to cause stock prices to fall. This is also consistent with the conclusions of Mao and Ka (1990), who found that an appreciation in the currency of export-dominant economies tends to negatively influence the domestic stock markets of those economies.

Reinforcing this view is the fact that the Australian stock market lacks the depth and liquidity of other larger markets in Asia, Europe and North America. Hence, rises in stock prices here would not normally be expected to result in an appreciation in the value of the Australian dollar as the portfolio balance model postulates, and as is observed by the trends in these variables during the said period.

The results of this study, however, has value for policy makers and market practitioners in that it sheds light on the nature of the strong co-movement between stock prices and the Australian dollar. Indeed, any evidence that stock price movements are found to 'Granger cause' movements in the Australian dollar exchange rate would certainly challenge the traditional view that Australian financial markets reflect the economy’s traditional commodity base.

Section 2 examines the economic theory surrounding stock and currency market interactions, and also reviews the literature on the interaction between stock prices and exchange rates. Section 3 reviews the data used in the analysis and describes the hypotheses which underpin the study. Section 4 details the methodology employed in the study, and section 5 describes the results of the analysis. Section 6 provides concluding comments.

2. Theory and Literature Review

Classical economic theory hypothesises that stock prices and exchange rates can interact. The first approach is encompassed in 'flow oriented' models (Dornbusch and Fisher 1980), which postulate that exchange rate movements cause stock price movements. In the language of Granger-Sim causality, this is termed as 'uni-directional' causality running from exchange rates to stock prices, or that exchange rates 'Granger-cause' stock prices.

This model is built on the macro view that as stock prices represent the discounted present value of a firm's expected future cash flows, then any phenomenon that effects a firm's cash flow will be reflected in that firm's stock price if the market is efficient, as the Efficient Market Hypothesis suggests.

One of the earliest distinctions of how exchange rates affect stock prices is whether the firm is multinational or domestic in nature (Franck and Young 1972). In the case of a multinational entity, changes in the value of the exchange rate alter the value of the multinational's foreign operations, showing up as a profit or loss on its books which then affect its share price.

Flow oriented models postulate a causal relationship between exchange rates and stock prices. Clearly, the manner in which currency movements influence a firm's earnings (and hence its stock price) depends on the characteristics of that firm. Indeed, today most firms tend to be touched in some way by exchange rate movements, although the growing use of derivatives, such as forward contracts and currency options, might work to reduce the manner in which currency movements effect a firm's earnings.

In contrast to flow oriented models, 'stock oriented' or 'portfolio balance approaches' (Branson et. al 1977) postulate that stock prices can have an effect on exchange rates. In contrast to the flow oriented model - which postulate that currency movements influence a firm's earnings and hence causes change in stock prices - stock oriented models suggest that movements in stock prices Granger-cause movements in the exchange rate via capital account transactions.

The degree to which stock oriented models actually explain real world stock and currency market reactions is critically dependent upon issues such as stock market liquidity and segmentation. For example, illiquid markets make it difficult and/or less timely for investors to buy and sell stock, while segmented markets entail imperfections, such as government constraints on investment, high transactions costs and large foreign currency risks, each of which may discourage or hinder foreign investment (Eiteman et. al. 2004).

It is clear from this theoretical review that there are various ways by which stock and currency markets can interact. This makes empirical analysis of the degree and direction of causality between stock prices and exchange rates particularly interesting and has provided the motivation for several studies in examining the interaction between stock prices and exchange rates.

Although theory such as the flow and portfolio models, and the money demand equation hypothesise that a relationship should exist between exchange rates and stock prices, the evidence provided by the literature on this subject matter has been mixed.

Perhaps one of the earliest empirical works that examined the relationship between stock prices and exchange rates was by Franck and Young (1972). This study looked for evidence that exchange rate movements affected stock prices by examining the degree of stock price reaction of multinational firms to re-alignments in the exchange rate. Six different exchange rates were used, although no evidence of a relationship between these variables was found.

A study by Aggarwal (1981) provided some evidence in support of the flow model. In contrast to Franck and Young (1972), which used the individual stocks of multinational firms, this study examined the relationship between exchange rates and stock prices by looking at the correlation between changes in the US trade-weighted exchange rate and changes in US stock market indices each month for the period 1974 to 1978.

The study found that the trade-weighted exchange rate and the US stock market indices were positively correlated during this period, leading Aggarwal (1981) to conclude that the two variables interacted in a manner consistent with the flow model. That is, movements in the exchange rate could directly affect the stock prices of multinational firms by influencing the value of its overseas operations, and indirectly affect domestic firms through influencing the prices of its exports and/or its imported inputs.

Solnik (1987) shed a different light on this relationship by examining the influence of key macroeconomic variables such as exchange rates, interest rates and changes in inflationary expectations on stock prices in each of nine developed economies, including the US.

Soenen and Hennigar (1988) found a significant negative correlation between the effective value of the US dollar and changes in US stock prices using monthly data between the period 1980 to 1986. While this finding is in contrast to Aggarwal (1981), who found a positive correlation, it still provides evidence in support of the flow model.

While the above studies focussed exclusively on the United States, a later study by Mao and Ka (1990) examined the relationship between exchange rates and stock prices in six industrialised economies, including the UK, Canada, France, West Germany, Italy and Japan.

Using monthly data between January 1973 and December 1983, the authors tested the degree of stock price reaction to exchange rate changes in each of the above jurisdictions. Their findings were consistent with the flow model, leading the authors to conclude that the relationship between exchange rates and stock prices hinged on the extent to which an economy depended on exports and imports.

These early studies were useful in establishing a foundation for further studies on the interaction between exchange rates and stock prices, but they were limited in that they only applied simple regression analysis to establish a correlation between the variables, or only tested the 'reaction' of one variable to changes in the other.

Bahmani-Oskooee and Sohrabian (1992) were one of the first to utilise tests of causality in examining the relationship between stock prices and exchange rates in the US context. They also used a much longer time period (15 years) and utilised tests of co-integration. Co-integration techniques allow one to establish if the variables share a long-run relationship, as the interactions uncovered by the Granger-Sim method are intrinsically short-run in nature.

Using monthly data of the US S&P 500 index and the effective exchange rate of the US dollar, the authors employed an autoregressive framework, finding that US stocks and the exchange rate shared a dual or bi-causal relationship (i.e. changes in the exchange rate effected stock prices and vice versa) in the sample period, 1973 to 1988. These results would seem to affirm both the portfolio and flow models. Meanwhile, the co-integration test found little evidence that the variables shared any relationship in the long-run.

A study by Ajayi et al. (1998) examined the relationship between exchange rates and stock prices among developing and developed nations. Like Bahmani-Oskooee and Sohrabian (1992) and Yu Qiao (1997), Ajayi et al. (1998) used Granger-Sim causality to examine the relationship between movements in the stock price indexes and movements in the exchange rates.

However, unlike previous studies, the authors studied this interaction in six advanced economies - including Canada, Germany, France, Italy, Japan and the UK – and eight Asian emerging economies – including Hong Kong, Taiwan, South Korea, Singapore, Thailand, Indonesia, Malaysia and the Philippines.

The study found uni-directional causality running from stock price changes to changes in the exchange rates for each of the advanced or developed economies during the sample period.

This is in contrast with the results of Yu Qiao (1997), where evidence of bi-causality between exchange rates and stock prices in Japan were established during the period 1983 and 1994.

Importantly, the findings of Ajayi et al. (1998) appeared to have uncovered a consistency in the relationships between stock prices and exchange rates among developed economies, which were in accordance with the portfolio model. On the contrary, the patterns of causality among the emerging Asian economies examined were mixed.

No significant causal relationships were detected in Hong Kong, Singapore, Thailand or Malaysia. Notably, this result is again in contrast with those of Yu Qiao (1997), which found uni-directional causality from exchange rates to stock returns in Hong Kong, although the findings of Ajayi et al. (1998) are consistent with those of Yu Qiao (1997) in that neither study found a relation between stock prices and exchange rates for Singapore.

Ajayi et al. (1998) attributed the difference in their findings between developed and emerging economies to structural differences between the currency and stock markets of each.

Specifically, the authors suggest that markets are likely to be more integrated and deep in advanced economies, and that emerging markets tend to be much smaller, less accessible to foreign investors and more concentrated. The authors also made note of wider risks such as political stability and the legislative environments which might make investment in emerging markets less attractive. Hence, the study concluded that activity in emerging stock markets tends to portray wider macroeconomic factors less strongly than in developed markets and as a result, these markets tend to have weaker linkages to the currency market.

While most literature in this context had previously focussed on developed markets or on comparisons between developed and emerging markets, the Asian financial crisis of the late 1990s sparked interest in the interaction between currency and stock markets solely in developing markets. Indeed, the Asian crisis was characterised by plunging currency and stock markets within South East Asia.

Granger et al. (2000) was one such study which focussed on this region. It examined the interaction between stock and currency markets in Hong Kong, Indonesia, Japan, South Korea, Malaysia, the Philippines, Singapore, Thailand and Taiwan, all of which were effected by the crisis.

The empirical results showed that, with the exception of Singapore (where exchange rate changes led stock prices as per the flow model), all countries displayed little evidence of interaction between currency and stock markets during the first period. In the second period, the exchange rate in Singapore again led its stock market, while the reverse (as per the portfolio model) was evident in the cases of Taiwan and Hong Kong.

The contrasting results across the body of literature regarding this issue suggest that there is no underlying or intrinsic causal relationship between exchange rates and stock markets across jurisdictions. Rather, the differing causal relationships uncovered through empirical analysis implies that the interaction between currency and stock markets are influenced by the business cycle and different economic structures present within individual countries, meaning causality between the two financial variables is sensitive to the time period in which the analysis is undertaken.

This view is confirmed by Ramasamy and Yeung (2005), who suggest that causality is unique within jurisdictions, within specific time periods and is even sensitive to the frequency of data utilised. In their study, the authors examined the degree of exchange rate and stock price causality in the same nine Asian economies studied in Granger et al. (2000), but during the period 1 January, 1997 to 31 December, 2000 – the entire period of the Asian currency crisis.

The empirical results of Ramasamy and Yeung (2005) differ from those of Granger et al. (2000). While Granger et al. (2000) found a bi-causality for Malaysia, Singapore, Thailand and Taiwan, Ramasamy and Yeung (2005) found that stock prices lead exchange rates for these countries. On the other hand, Granger et al. (2000) found that stock prices lead exchange rates for Hong Kong, but a bi-causality was detected by Ramasamy and Yeung (2005).

The current study on the interaction between exchange rates and stock prices in the Australian context differs from previous work in a number of ways. Firstly, it employs a current data set.

Secondly, it does not seek to postulate the existence of some underlying causal relation between stock prices and exchange rates as early studies on this subject have sought to.

Rather, recognising the robust and changing dynamics between these variables, this study examines how these variables interacted during the sample period. This is done specifically with a view to challenging the traditional export-dependent view of the Australian economy which lends itself to the flow oriented model of stock price and exchange rate interaction.

Hence, the focus is on ascertaining the significance of the strength and direction of the influence of Australian stock price movements on the Australian dollar exchange rate in the said period.

Given the importance of both equity and currency markets to the functioning of an economy, the empirical results provide useful information to market practitioners and policy makers on the interaction between stock prices and exchange rates.

3. Data and Hypothesis

This study examines the interaction between Australian stock prices and the Australian-USD exchange rate from 2 January 2003 to 30 June 2006. Daily observations of Australian stock prices and the Australian-US dollar exchange rate was gathered and analysed using the *EViews 4* statistical package.

Stock prices are measured using the daily (five days a week) closing prices of the All Ordinaries stock price index. The All Ordinaries index is chosen as it is considered to be Australia's leading share market indicator, representing the 500 largest companies listed on the Australian Stock Exchange. Level stock price series is expressed by the symbol 'SP' and first difference data for SP (denoted SP1) is equal to Log (SP_t/SP_{t-1}).

Similarly for the Australian-US dollar exchange rate, five day-a-week daily, nominal observations at the close of market are gathered from the Reserve Bank of Australia. The exchange rate is expressed in terms of the number of Australian dollars per unit of US currency (i.e. direct quote). Using this form of quotation is consistent with previous empirical studies (Granger et. al. 2000 and Ajayi et. al. 1998). The level exchange rate series is expressed by the symbol 'EX' and first difference data for EX (denoted EX1) is equal to Log (EX_t/EX_{t-1}).

Although both sets of data are at close of trade in Australian markets, some date synchronisation was required to ensure that the trading days of both time-series matched. In total, there are 877 observations in the sample data series.

Three hypotheses are explored in this study in examining the interaction between stock prices and exchange rates in Australia during the period in question. Each of the ensuing hypotheses are stated in the null format.

Both the flow and portfolio models postulate that a relationship exists between stock prices and exchange rates. Hence, the first step in the empirical analysis of this study is to investigate the broad relationship between stock prices and exchange rates using OLS regression analysis. Because the exchange rate series in this study is expressed in terms of Australian dollars per unit of US currency (i.e. direct quotation), a negative correlation between stock prices and exchange rates would be indicative of a positive co-movement between the variables. Hence, the first hypothesis is as follows:

H_o 1a: There is a significant positive relationship between level series of Australian stock prices and the Australian dollar exchange rate.

H_o 1b: There is a significant positive relationship between first differences in Australian stock prices and first differences in the Australian dollar exchange rate.

According to Brooks (2002), if one financial variable significantly and consistently influences another, the two variables should be co-integrated. In the context of this study, a co-integrating relationship will provide evidence that Australian stock price movements significantly explain expected movements in the Australian dollar exchange rate over the long term. The second hypothesis follows:

H_o 2a: There are no co-integrating relationships between level series of Australian stock prices and the Australian dollar exchange rate.

H_o 2b: There are no co-integrating relationships between changes (first differences) in Australian stock prices and changes (first differences) in the Australian dollar exchange rate.

According to Granger (1969), if a pair of variable series are co-integrated, the bi-variate co-integrating system must possess a causal order in at least one direction. If the evidence is such that exchange rate variability is linked to stock price movements, it can also be shown that the change in the exchange rate either lags or leads movements in stock prices. Based on this theory, the third and most important hypothesis of the study is:

H_o 3a: There is no directional causality between the level series of Australian stock prices and the level series of the Australian dollar exchange rate.

H_o 3b: There is no directional causality between the changes in Australian stock prices and changes in the Australian exchange rate.

4. Methodology and Results

The level series are tested first and an unrestricted vector autoregression (VAR) model is applied. A VAR model is required to investigate causality as standard regression models are limited to examining the degree of correlation between two variables and can not establish a causal connection between the variables.

Standard regression analysis assumes that the relationship between the dependent variable and the explanatory variable is contemporaneous, that is, that the variables interact at the same point in time (Brooks 2002). Hence, the standard regression framework is inadequate to test the causal relationship between variables. The regression of the Australian dollar exchange rate against Australian stock prices is analysed in order to examine the relationship between the two variables. The variables have been previously defined. The regression undertaken is as follows:

$$\mathrm{Log}(Ex_t) = a + ß_1 \mathrm{Log}(SP_t) + e_t \qquad (1)$$

According to Brooks 2002, the key premise of causal analysis lies in the assumption that the variables are non-contemporaneous in that the value of a variable in the current time period is influenced by its value in some prior time period. This difference is known as the lag. This is essentially the foundation of autoregressive models.

The standard auto-regression process is based on the standard regression process, except that the value of the dependent variables in the system depends only on the lagged values of the dependent variable plus an error term. Extending this model one step further gives the vector autoregressive model which applies when the dependent variable in the system not only depends on its own lags, but also on the lags of another explanatory variable.

a. Level Series

(i) Normality

In the case of the level series of stock prices, the BJ test null hypothesis that the residuals are normally distributed is rejected at the 5 per cent level of significance. The SP series has skewness of 0.36 and kurtosis of 1.99 (a normal distribution is not skewed and is defined to have a coefficient of kurtosis of 3).

This indicates that the distribution of SP is flat (or platykurtic) relative to the normal distribution. In the case of the level series of exchange rates (EX), the test null hypothesis is also rejected, with the distribution of EX possessing skewness of 1.31 and kurtosis of 3.88. This would indicate that the distribution of EX is peaked (or leptokurtic) relative to the normal distribution.

Although the variables are not normally distributed, OLS is still used. As noted above, this violation is not expected to have a major effect on the outcomes of the study given that the sample size (877 observations in each data series) is sufficiently large.

(ii) Ordinary Least Squares Regression

When OLS regression analysis is run on the level series data as in equation 1, the adjusted R-square value is found to be 0.4818, with an F-value at 815.7186 (highly significant at p = 0.0000). With regard to the coefficients (the significance level is in parenthesis), the intercept t-statistic is 32.2487 (p = 0.0000) and the stock price t-statistic is -28.5607 (p = 0.0000). See Table A in Appendix 1 for more details on this regression.

The correlation matrix (the correlation measure is in parenthesis) shows stock prices and exchange rates to be highly negatively correlated (-0.6946) during the sample period. Note that the exchange rate series is expressed in terms of direct quotation (Australian dollars per unit of US currency), and therefore a decline in the exchange rate in direct quotation terms is indicative of an appreciation of the Australian dollar. Therefore, a negative correlation between the two variables is indicative of a positive co-movement between them.

The DW statistic is equal to 0.0152, which is far less than the adjusted R-square value (0.4818). This would indicate that if the level series of stock prices is integrated, the regression may be spurious. In addition, the DW statistic is very close to zero and substantially less than two. This indicates a high degree of positive serial correlation in the series which supports the rejection of the DW test null hypothesis of zero autocorrelation, indicating that there may be a high degree of time dependence in the series.

The relatively high adjusted R-square value (of close to 0.50) and the significance of the coefficients in the above regression provide some support for accepting the null hypotheses 1a, which states there is a significant positive relationship between the level series of Australian stock prices and the Australian dollar exchange rate. But this evidence needs to be treated with caution in light of the spurious nature of the regression.

(iii) Testing for Unit Roots

Each of the level series was tested for a unit root using the ADF test. The results indicate that the level series of stock prices and exchange rates are non-stationary processes at the 1 per cent ADF critical level. See Tables A, B and C in Appendix 2 for more details on these ADF test results.

In the case of stock prices, the ADF statistic was 0.0712 which compares against the 1 per cent, 5 per cent and 10 per cent critical values of -3.5000, -2.8918 and -2.5827 respectively. As this ADF test statistic is greater than the 1 per cent, 5 per cent and 10 per cent critical values, the ADF test-null hypotheses of a unit root is accepted.

In the case of the exchange rate series, the ADF statistic was -2.9038, which is greater than the 1 per cent critical value, but less than the 5 per cent and 10 per cent critical values. Hence, the ADF test of a unit root is accepted at the 1 per cent critical level.

When the residual of the stock price regression was tested for a unit root, it was found that the ADF test statistic was less than the 1 per cent, 5 per cent and 10 per cent critical values at -12.7339, meaning that the residuals are stationary. Therefore, some evidence is provided to suggest that there are stationary processes in the level series regression even if the variables themselves are non-stationary.

(iv) Heteroskedasticity

Before estimating any ARCH type models, the Engle (1982) test for ARCH effects is first carried out to ensure this class of models is appropriate for the data. The ARCH LM test is undertaken on the level series regression of exchange rates against stock prices to test the null hypothesis that there is no ARCH up to order five in the residuals.

The test results show that both the F-statistic (4539.163) and the LM statistic (839.9502) are very significant (both with p-values of 0.0000), suggesting the presence of ARCH in the level series data.

An ARCH model was then applied to the regression of stock prices against exchange rates. The ML-ARCH model was applied to the data of 877 observations with convergence achieved after 230 iterations. The variance equation coefficients for ARCH 1 and GARCH 1 respectively were 1.0033 and -0.0293. The sum of the coefficients is close to unity (approximately 0.99), meaning that shocks to the conditional variance are persistent in the data. This confirms autoregressive conditional heteroskedasticity is present in the level series data.

With the OLS regression re-specified as an ARCH-ML model, the adjusted R-square value falls to 0.4765 with an F-statistic of 200.4115, which is highly significant ($p = 0.0000$). The z-statistic for the stock price is -76.9117, which is highly significant ($p = 0.0000$). However, at 0.0153 the DW test statistic remains near zero and less than two, indicating that the regression results remain spurious.

The use of the ARCH model again provides evidence to support the acceptance of the null hypotheses 1a, which states that there is a significant positive relationship between the level series of Australian stock prices and the Australian dollar exchange rate. However, this evidence again needs to be treated with caution in light of the spurious nature of the regression. See Tables A and B in Appendix 3 for more information on the results of the ARCH-LM test and ARCH ML model.

(v) Co-Integration

With the level series established as being integrated, non-stationary processes, the study then proceeded to check if the level series are co-integrated. An unrestricted VAR model was applied to the level series data, with lag intervals of between 1 and 6. The VAR is expressed as follows:

$$\mathbf{LogSP_t = \alpha_0 + \sum_{i=1}^{P}\alpha_i\, LogSP_{t-i} + \sum_{i=1}^{P}\beta_i\, LogEX_{t-i} + \mu_t} \qquad (2)$$

$$\mathbf{LogEX_t = \varphi_0 + \sum_{i=1}^{P}\varphi_i\, LogEX_{t-i} + \sum_{i=1}^{P}\gamma_i\, LogSP_{t-i} + v_t} \qquad (3)$$

A critical issue in using VAR models is the choice of lag length. Prior research (notably Granger et al. 2000, Ajayi et al. 1998, and Ramasamy and Yeung 2005) intuitively employed a one-day lag length in their models sighting the fact that the highly integrated nature of financial markets is likely to mean that the flow of information to investors is very efficient, allowing them to react quickly to developments in either of the markets.

This study employs maximum likelihood tests to establish the optimum lag length. Under this approach, the optimum length is the one in which the value of most information criteria are minimised. Lag length criteria tests were undertaken for lengths of between 1 and 8 for the sample period, with most criteria minimised at 1 lag length for the level series. Table A in Appendix 4 shows the results of this maximum likelihood test.

The lag structure/AR Roots Test was also applied as a test of the VAR's stability condition. *EViews 4* undertakes the test and reports the roots of the characteristic autoregressive polynomial. The VAR is considered stable or stationary if all roots have a modulus less than one and lie inside the unit circle. The results of this test show that the unrestricted VAR satisfies the stability condition, as all polynomial roots have a value of less than one and lie within the unit circle. See Table A in Appendix 5 for detailed results of this test.

When the Johansen co-integration test was applied (assuming an intercept and a linear deterministic trend in the data), it was found that the test null hypothesis of zero co-integration could be rejected. For the test of zero co-integrating relations, the trace statistic (32.2484) and maximum eigenvalue statistic (25.9395) were each greater than the 5 per cent and 1 per cent critical values. In contrast, the trace and maximum eigenvalue statistics for the test of at least one co-integrating relation were both less than the 5 per cent and 1 per cent critical values. See Table A in Appendix 6 for the co-integration results.

Therefore, there is evidence to support the rejection of the null hypotheses 2a of no co-integrating relationship between the level series data. It is therefore evident that even though the level series are integrated (i.e. contain one unit root or I(1)), a linear combination of these I(1) variables becomes I(0) when the variables are co-integrated. This indicates that the level series of Australian stock prices and exchange rates share a long-run relationship.

(vi) Causality

Pair-wise Granger causality tests were run on the level series at the optimal one lag length. It is found that the level series of the variables are independent during the sample period at the adopted 5 per cent level. The F-statistic for the test of causality running from stock prices to the exchange rate at one lag length is 1.0951, with a significance level of 0.2956. Meanwhile, the F-statistic for the test of causality running from exchange rates to stock prices is 0.0478, with a significance level of 0.8268.

However, uni-directional causality is found at the 5 per cent level at a lag length of two, with causality running from stock prices to exchange rates. The F-statistic of this test is equal to 3.3122, with a significance of 0.0368. At three, four, five and six lag lengths (the other lengths in the VAR), the variables again appear independent, with no significant causal relationship. Notably, at five lengths there is some evidence of causality running from exchange rates to stock prices, but only at the 10 per cent level of significance.

Detailed results of Granger-Sim causality on the level series at various lag lengths are provided in Tables A to K in Appendix 7.

It is apparent that causality is one-way, running from stock prices to exchange rates at a two-day lag, although one-day is the optimal lag. This would suggest a relationship in line with the portfolio model whereby stock price movements influence exchange rates via capital account transactions.

Support is therefore provided for the rejection of the Null Hypothesis 3a, that there is no directional causality between the level series of Australian stock prices and the level series of the Australian dollar exchange rate.

b. First Differences

(i) Ordinary Least Squares Regression

As reported in the section on *Data and Hypothesis* on page 9, first difference data for SP is denoted 'SP1' and is equal to Log (SP_t/SP_{t-1}). Similarly, first difference data for EX is denoted EX1 and is equal to Log (EX_t/EX_{t-1}).

When OLS regression analysis is run on the first difference data (in the same form as in equation 1 except with SP1 and EX1), it is found that the adjusted R-square value falls to just 0.00428, with an F-statistic of 4.7687 which is significant at the 5 per cent level (with p = 0.02924). See Table B in Appendix 1 for detailed results on this regression.

It also evident from the first differences regression that exchange rate changes are negatively related to changes in stock prices, with a t-statistic of -2.1837 (where p = 0.0292) which is significant at the 5 per cent level. As reported earlier, the exchange rate series is expressed in terms of direct quotation (Australian dollars per unit of US currency) and therefore, a decline in the exchange rate in direct quotation terms is indicative of an appreciation of the Australian dollar. Therefore, a negative relationship between the two variables is indicative of a positive co-movement between them.

Notably, the DW statistic at 1.9987, which is greater than the adjusted R-square value, sufficiently higher than zero, and close to two, leads to the conclusion that the regression may be relied upon. That is, unlike the level series regression, the relationship uncovered by the regression of the first differences series is unlikely to be spurious. Nevertheless, it is apparent that substantial information has been lost in the first differencing process, given the very low adjusted R-square value.

Therefore, Null Hypothesis 1b which states that there is a significant positive relationship between first differences in Australian stock prices and the Australian dollar exchange rate, cannot be rejected. Again, as in the case of the level series, this result needs to be treated with caution due to the low explanatory power of the model.

(ii) Testing for Unit Roots and Co-Integration

Each of the first differenced series was tested for a unit root using the ADF test. The results indicate that the first differenced series of stock prices and exchange rates are stationary processes at the 1 per cent, 5 per cent and 10 per cent ADF critical levels. See Tables D and E in Appendix 2 for detailed results on the ADF tests.

In the case of stock prices, the ADF statistic was -12.9268 which compares against the 1 per cent, 5 per cent and 10 per cent critical values of -3.5000, -2.8918 and -2.5827 respectively. As this ADF test statistic is lower than the 1 per cent, 5 per cent and 10 per cent critical values, the ADF test null hypotheses of a unit root is rejected.

In the case of the exchange rate series, the ADF statistic was -12.8839, which is also less than the 1 per cent, 5 per cent and 10 per cent critical values indicating rejection of a unit root.

When the ADF test was applied to the error terms of the first difference regression of stock prices, the test statistic was found to be -13.1280 which is also less than the 1 per cent, 5 per cent and 10 per cent ADF critical values, meaning that the residuals are also stationary.

As evidence is provided that the first difference data are non-integrated, non-stationary processes, checks of co-integration are not required. Null Hypothesis 2b, which states that there are no co-integrating relationships between the first difference series, therefore cannot be rejected.

(iii) Heteroskedasticity

The ARCH LM test is undertaken on the first differences regression of exchange rates against stock prices to test the null hypothesis that there is no ARCH up to order five in the residuals. The test shows that both the F-statistic (0.9760) and the LM statistic (4.8866) are not significant, with p-values of 0.4313 and 0.4298 respectively. This suggests there is no presence of ARCH in the first differenced data series. See Table C in Appendix 3 for more details on this result.

(iv) Causality

An unrestricted VAR model for the first differenced data is specified in order to undertake Granger-Sim causality. The VAR model, which is specified with lag intervals of between 1 and 6, is expressed as follows:

$$SP1_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \, SP1_{t-i} + \sum_{i=1}^{p} \beta_i \, EX1_{t-i} + \mu_t \qquad (4)$$

$$EX1_t = \varphi_0 + \sum_{i=1}^{p} \varphi_i \, EX1_{t-i} + \sum_{i=1}^{p} \gamma_i \, SP1_{t-i} + v_t \qquad (5)$$

Note again that SP1 and EX1 denote the first difference data, with SP1 equal to Log (SP_t/SP_{t-1}), while EX1 is equal to Log (EX_t/EX_{t-1}).

The lag structure/AR Roots Test was again applied as a test of the VAR's stability condition. The results of this test show that the unrestricted VAR satisfies the stability condition, as all polynomial roots have a value of less than one and lie within the unit circle. See Table B in Appendix 5 for detailed results on this test.

When lag order selection criteria are applied to the first difference data, it is found that Akaike's information criteria is at its minimum at 0 lags, with a value of -14.4907. Other information criteria, such as the Schwarz information criterion and the Hannan-Quinn information criterion, are also at their minimum values at zero lags.

However, the sequential modified LR test statistic is minimised at four lag lengths, and using the lag exclusion Wald test, all lags except lag four are also rejected, where the joint Chi-Square value of lag four is 8.6088. This value is significant at the 10 per cent level, with p = 0.0716. See Tables B and C in Appendix 4 for detailed results of maximum likelihood and lag exclusions tests. Pair-wise Granger causality tests were then run on the first differenced series for lags one to six.

At one lag length, uni-directional causality is found at the 5 per cent level, with causality running from stock prices to the exchange rate with an F-statistic equal to 5.3983 and a significance level of 0.0203. Meanwhile, the F-statistic for the test of causality running from exchange rates to stock prices at one lag is 0.4527, with a significance level of 0.5012.

At two lags, uni-directional causality from stock prices to exchange rates is evident again, although at a lower significance level. Here, causality is again seen to run from stock prices to the exchange rate, but only at a significance level of 10 per cent, as p = 0.08157. Meanwhile, the significance of the test of causality running from exchange rates to stock prices at two lags is 0.1410.

Beyond two lags, the direction of causality appears to switch from stock prices to exchange rates, to exchange rates influencing stock prices. Indeed, for three lags the significance of the test for stock prices Granger-causing exchange rates rises to 0.2167, while the test of significance for exchange rates Granger-causing stock prices falls to 0.0663 – significant at the 10 per cent level only.

However, at the optimal 4 lags uni-directional causality from exchange rates to stock prices is evident at the 5 per cent significance level. In this case, the F-statistic is equal to 2.4506 and the p-value is equal to 0.0446. Meanwhile, the F-statistic for the test of causality running from stock prices to exchange rates at four lags is 1.416, with a significance level of 0.2265.

At five lags, exchange rates are again seen to Granger cause stock prices, but only at the 10 per cent level of significance (p = 0.09588), while little evidence of causality is demonstrated from stock prices to exchange rates (p = 0.26012). At six lags, there does not appear to be any significant causal relationship in the first difference data for the model of stock prices and exchange rates.

Detailed results of Granger-Sim causality on the first differenced series at various lag lengths are provided in Tables G to L in Appendix 7.

In summary, it is apparent from the first difference analysis, that exchange rate changes Granger cause stock price changes with an optimal four-day lag. However, for lags less than three days, the opposite is true. At one and two lag lengths, causality runs from stock prices to exchange rates with the significance of causality at the one lag interval the strongest of any other causality test in this study, at p = 0.0203.

Evidence is therefore provided for the rejection of Null Hypothesis 3b, that there is no directional causality between changes in Australian stock prices and changes in the Australian exchange rate.

5. Conclusion

The motivation for this paper was to test the degree of interaction between stock prices and exchange rate movements in Australia in the period 2 January 2003 to 30 June 2006. This period is somewhat intriguing considering that the value of the Australian stock market increased by two-thirds during the sample period, while the Australian dollar exchange rate appreciated by as much as 32 per cent relative to the US dollar.

This would imply a strong positive relationship existed between the two variables during the period in question, although it is not known if the two markets interacted or caused movements in the other during this period as postulated by economic theory.

In terms of the broad relationship between the two variables, the level series regression results support the above observation of a short-term positive relationship between the Australian dollar exchange rate and stock prices during the sample period. However, these results should be treated with caution in light of the spurious nature of the OLS and ARCH regressions estimated.

When first differences are examined, evidence of a positive relationship between these variables remains, although these results again need to be treated with caution in light of the low explanatory power of the first differences OLS regression.

Evidence is also provided for co-integration of the subject level variables, implying that the variables not only appear to be related in the short-run of the sample period, but that longer-term expectations also play some part in activity in stock and currency markets in Australia.

With the broader short and longer term relationship between stock prices and exchange rates established, the pair-wise Granger-Sim causality tests provide a deeper insight into the degree of interaction between the two variables during the sample period.

From this analysis, it is evident that a significant uni-directional causal relationship exists between the variables, with stock price changes found to Granger cause changes in the

Australian dollar exchange rate during the sample period. This demonstrates a relationship consistent with the portfolio balance approach.

Although causality was evident in the opposite direction (i.e. from exchange rates to stock prices), the degree of causality from stock prices to exchange rates was the most statistically significant in the analysis of both the level series and first differences series.

It may be that commodity prices are the 'missing link' between these two variables, with high commodity prices often bolstering both the Australian stock market and the domestic currency given the economy's strong commodity base. Although this study has shown that the broad relation between stock prices and the exchange rate during the sample period to not be spurious (on first differences), the regression model utilised lacks explanatory power as noted above.

However, there are wider issues which suggest that commodity prices might not have had a significant effect on these variables during the sample period. Importantly, the relationship between commodity prices and the Australian dollar broke down at the turn of the decade[2] and this 'marriage' has not yet resumed. Furthermore, commodity prices only began rising sharply in early 2005 while the exchange rate and stock prices trended higher together before this period. Even as commodity prices have accelerated sharply since 2005, the dollar has continued to trade between a fairly narrow band, while stock prices have continued to increase.

In addition, the findings of this study are also consistent with broader macroeconomic trends given that the sample period studied was characterised by relatively low levels of economic growth in the United States, Japan and Europe, compared to the Australian economy which experienced broad-based growth on the back of strong consumer spending and high investment into dwellings and fixed capital - as illustrated by the positive gains on the domestic stock market during this period.

Hence, this would have made the Australian equity market a more attractive proposition for domestic and foreign investors, which lends itself to stock and currency markets interacting in a manner postulated by the portfolio model, as uncovered in this study.

The result of this study has implications for both policy-makers and market practitioners alike, as it suggests that Australian stock prices and the exchange rate can interact in a manner in

[2] Reserve Bank of Australia, *Statement on Monetary Policy*, February 2004. Page 17.

accordance with the portfolio model, whereby stock price movements influence exchange rates via capital account transactions.

This is a shift from the traditional view of the Australian economy as an export-dependent economy - a notion which lends itself more to the flow oriented model, which implies that exchange rate movements should cause movements in stock prices, or that a sharp appreciation in the Australian dollar (as is the case in this sample period) should negatively influence the domestic stock market.

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Appendix 1 – OLS Regression Results

A. Level Series Regression

Dependent Variable: LNEX
Method: Least Squares
Date: 10/07/06 Time: 15:11
Sample: 1 877
Included observations: 877

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.886034	0.089493	32.24877	0.0000
LNSP	-0.310427	0.010869	-28.56079	0.0000

R-squared	0.482469	Mean dependent var	0.330641
Adjusted R-squared	0.481877	S.D. dependent var	0.079328
S.E. of regression	0.057101	Akaike info criterion	-2.885704
Sum squared resid	2.852982	Schwarz criterion	-2.874811
Log likelihood	1267.381	F-statistic	815.7186
Durbin-Watson stat	0.015280	Prob(F-statistic)	0.000000

B. First Difference Regression

Dependent Variable: EX1
Method: Least Squares
Date: 10/15/06 Time: 08:53
Sample(adjusted): 2 877
Included observations: 876 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.000266	0.000235	-1.130305	0.2587
SP1	-0.085092	0.038966	-2.183748	0.0292

R-squared	0.005427	Mean dependent var	-0.000316
Adjusted R-squared	0.004289	S.D. dependent var	0.006945
S.E. of regression	0.006930	Akaike info criterion	-7.103645
Sum squared resid	0.041973	Schwarz criterion	-7.092743
Log likelihood	3113.397	F-statistic	4.768755
Durbin-Watson stat	1.998759	Prob(F-statistic)	0.029246

Appendix 2 – Testing for Unit Roots

A. Level Series Regression – Log of SP

ADF Test Statistic	0.071217	1% Critical Value*	-3.4405
		5% Critical Value	-2.8653
		10% Critical Value	-2.5688

*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNSP)
Method: Least Squares
Date: 10/08/06 Time: 09:25
Sample(adjusted): 6 877
Included observations: 872 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNSP(-1)	8.20E-05	0.001151	0.071217	0.9432
D(LNSP(-1))	-0.042473	0.034023	-1.248369	0.2122
D(LNSP(-2))	0.007044	0.034087	0.206660	0.8363
D(LNSP(-3))	0.029949	0.034121	0.877738	0.3803
D(LNSP(-4))	0.077086	0.034067	2.262808	0.0239
C	-0.000139	0.009479	-0.014624	0.9883

R-squared	0.008285	Mean dependent var	0.000577
Adjusted R-squared	0.002559	S.D. dependent var	0.006015
S.E. of regression	0.006007	Akaike info criterion	-7.384920
Sum squared resid	0.031249	Schwarz criterion	-7.352093
Log likelihood	3225.825	F-statistic	1.446994
Durbin-Watson stat	1.983016	Prob(F-statistic)	0.204969

B. Level Series Regression – Log of EX

ADF Test Statistic	-2.903822	1% Critical Value*	-3.4405
		5% Critical Value	-2.8653
		10% Critical Value	-2.5688

*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNEX)
Method: Least Squares
Date: 10/08/06 Time: 09:28
Sample(adjusted): 6 877
Included observations: 872 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNEX(-1)	-0.008737	0.003009	-2.903822	0.0038
D(LNEX(-1))	0.003401	0.033966	0.100128	0.9203
D(LNEX(-2))	0.002522	0.033890	0.074412	0.9407
D(LNEX(-3))	-0.059829	0.033842	-1.767861	0.0774
D(LNEX(-4))	0.029432	0.033907	0.868037	0.3856
C	0.002575	0.001019	2.528076	0.0116

R-squared	0.013949	Mean dependent var	-0.000297
Adjusted R-squared	0.008256	S.D. dependent var	0.006944
S.E. of regression	0.006915	Akaike info criterion	-7.103357
Sum squared resid	0.041411	Schwarz criterion	-7.070531
Log likelihood	3103.064	F-statistic	2.450141
Durbin-Watson stat	1.990278	Prob(F-statistic)	0.032327

C. Level Series Regression –Residuals

ADF Test Statistic	-12.73394	1% Critical Value*	-3.4405
		5% Critical Value	-2.8653
		10% Critical Value	-2.5688

*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RESID1)
Method: Least Squares
Date: 10/08/06 Time: 09:40
Sample(adjusted): 7 877
Included observations: 871 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID1(-1)	-0.982424	0.077150	-12.73394	0.0000
D(RESID1(-1))	-0.023253	0.069024	-0.336875	0.7363
D(RESID1(-2))	-0.016439	0.058961	-0.278813	0.7805
D(RESID1(-3))	-0.071511	0.048191	-1.483886	0.1382
D(RESID1(-4))	-0.033381	0.034047	-0.980426	0.3272
C	2.51E-05	0.000329	0.076201	0.9393

R-squared	0.504195	Mean dependent var	-2.28E-05
Adjusted R-squared	0.501329	S.D. dependent var	0.013743
S.E. of regression	0.009705	Akaike info criterion	-6.425471
Sum squared resid	0.081473	Schwarz criterion	-6.392615
Log likelihood	2804.293	F-statistic	175.9275
Durbin-Watson stat	1.986549	Prob(F-statistic)	0.000000
ADF Test Statistic	-12.92684	1% Critical Value*	-3.4405
		5% Critical Value	-2.8653
		10% Critical Value	-2.5688

*MacKinnon critical values for rejection of hypothesis of a unit root.

D. First Difference Series Regression – SP1

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(SP1)
Method: Least Squares
Date: 10/15/06 Time: 09:29
Sample(adjusted): 7 877
Included observations: 871 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SP1(-1)	-0.984940	0.076193	-12.92684	0.0000
D(SP1(-1))	-0.052718	0.069343	-0.760257	0.4473
D(SP1(-2))	-0.043965	0.060396	-0.727952	0.4668
D(SP1(-3))	-0.012591	0.049166	-0.256089	0.7979
D(SP1(-4))	0.063164	0.034099	1.852405	0.0643
C	0.000573	0.000208	2.760225	0.0059

R-squared	0.523836	Mean dependent var	2.01E-05
Adjusted R-squared	0.521084	S.D. dependent var	0.008666
S.E. of regression	0.005997	Akaike info criterion	-7.388156
Sum squared resid	0.031112	Schwarz criterion	-7.355300
Log likelihood	3223.542	F-statistic	190.3203
Durbin-Watson stat	1.990013	Prob(F-statistic)	0.000000

E. First Difference Series Regression – EX1

ADF Test Statistic	-12.88392	1% Critical Value*	-3.4405
		5% Critical Value	-2.8653
		10% Critical Value	-2.5688

*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(EX1)
Method: Least Squares
Date: 10/15/06 Time: 09:32
Sample(adjusted): 7 877
Included observations: 871 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
EX1(-1)	-0.990629	0.076889	-12.88392	0.0000
D(EX1(-1))	-0.005654	0.068665	-0.082338	0.9344
D(EX1(-2))	-0.001441	0.058598	-0.024596	0.9804
D(EX1(-3))	-0.061527	0.047963	-1.282782	0.1999
D(EX1(-4))	-0.029880	0.034074	-0.876914	0.3808
C	-0.000287	0.000236	-1.213314	0.2253

R-squared	0.499292	Mean dependent var	-1.61E-05
Adjusted R-squared	0.496398	S.D. dependent var	0.009788
S.E. of regression	0.006946	Akaike info criterion	-7.094455
Sum squared resid	0.041733	Schwarz criterion	-7.061599
Log likelihood	3095.635	F-statistic	172.5110
Durbin-Watson stat	1.987376	Prob(F-statistic)	0.000000

F. First Difference Series Regression – Residuals

ADF Test Statistic	-13.12809	1% Critical Value*	-3.4406
		5% Critical Value	-2.8653
		10% Critical Value	-2.5688

*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RESID2)
Method: Least Squares
Date: 10/15/06 Time: 09:39
Sample(adjusted): 12 877
Included observations: 866 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID2(-1)	-1.002452	0.076359	-13.12809	0.0000
D(RESID2(-1))	0.004988	0.068346	0.072980	0.9418
D(RESID2(-2))	0.002608	0.059123	0.044116	0.9648
D(RESID2(-3))	0.000411	0.048269	0.008519	0.9932
D(RESID2(-4))	0.003944	0.034199	0.115327	0.9082
C	1.06E-05	0.000330	0.032062	0.9744

R-squared	0.496457	Mean dependent var	-3.43E-05
Adjusted R-squared	0.493529	S.D. dependent var	0.013643
S.E. of regression	0.009709	Akaike info criterion	-6.424545
Sum squared resid	0.081074	Schwarz criterion	-6.391539
Log likelihood	2787.828	F-statistic	169.5793
Durbin-Watson stat	1.990574	Prob(F-statistic)	0.000000

Appendix 3 – Heteroskedasticity

A. ARCH LM Test – OLS regression, Log of EX on Log of SP

ARCH Test:

F-statistic	4539.163	Probability	0.000000
Obs*R-squared	839.9502	Probability	0.000000

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 10/14/06 Time: 10:58
Sample(adjusted): 6 877
Included observations: 872 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.52E-05	3.33E-05	2.559063	0.0107
RESID^2(-1)	0.966773	0.033977	28.45370	0.0000
RESID^2(-2)	-0.007510	0.047188	-0.159142	0.8736
RESID^2(-3)	-0.005353	0.047211	-0.113385	0.9098
RESID^2(-4)	0.076496	0.046728	1.637055	0.1020
RESID^2(-5)	-0.065224	0.032869	-1.984398	0.0475

R-squared	0.963246	Mean dependent var	0.003112
Adjusted R-squared	0.963033	S.D. dependent var	0.004074
S.E. of regression	0.000783	Akaike info criterion	-11.45917
Sum squared resid	0.000531	Schwarz criterion	-11.42634
Log likelihood	5002.197	F-statistic	4539.163
Durbin-Watson stat	1.989313	Prob(F-statistic)	0.000000

B. ML-ARCH Model, Level Series Regression – Log of EX on Log of SP

Dependent Variable: LNEX
Method: ML - ARCH (Marquardt)
Date: 10/14/06 Time: 11:01
Sample: 1 877
Included observations: 877
Convergence achieved after 230 iterations
Variance backcast: ON

	Coefficient	Std. Error	z-Statistic	Prob.
C	3.102778	0.035976	86.24471	0.0000
LNSP	-0.336704	0.004378	-76.91175	0.0000
	Variance Equation			
C	5.24E-05	1.12E-05	4.676868	0.0000
ARCH(1)	1.003319	0.229230	4.376914	0.0000
GARCH(1)	-0.029396	0.086830	-0.338548	0.7350

R-squared	0.478982	Mean dependent var	0.330641
Adjusted R-squared	0.476592	S.D. dependent var	0.079328
S.E. of regression	0.057392	Akaike info criterion	-3.858982
Sum squared resid	2.872203	Schwarz criterion	-3.831750
Log likelihood	1697.163	F-statistic	200.4115
Durbin-Watson stat	0.015315	Prob(F-statistic)	0.000000

C. ARCH LM Test – OLS regression, EX1 on SP1

ARCH Test:

F-statistic	0.976083	Probability	0.431309
Obs*R-squared	4.886698	Probability	0.429864

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 10/15/06 Time: 18:31
Sample(adjusted): 7 877
Included observations: 871 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.11E-05	4.46E-06	9.221683	0.0000
RESID^2(-1)	0.046003	0.034252	1.343077	0.1796
RESID^2(-2)	0.011021	0.034255	0.321724	0.7477
RESID^2(-3)	0.034953	0.034237	1.020913	0.3076
RESID^2(-4)	0.039425	0.034247	1.151210	0.2500
RESID^2(-5)	0.010909	0.034237	0.318626	0.7501

R-squared	0.005610	Mean dependent var	4.79E-05
Adjusted R-squared	-0.000137	S.D. dependent var	8.56E-05
S.E. of regression	8.56E-05	Akaike info criterion	-15.88653
Sum squared resid	6.34E-06	Schwarz criterion	-15.85367
Log likelihood	6924.583	F-statistic	0.976083
Durbin-Watson stat	1.986700	Prob(F-statistic)	0.431309

Appendix 4 – Maximum Likelihood Tests and Lag Exclusions Tests

A. Level Series Maximum Likelihood Test

VAR Lag Order Selection Criteria
Endogenous variables: LNEX LNSP
Exogenous variables: C
Date: 10/14/06 Time: 11:48
Sample: 1 877
Included observations: 869

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1556.947	NA	9.57E-05	-3.578704	-3.567732	-3.574505
1	6303.336	9460.006	1.74E-09*	-14.49329*	-14.46038*	-14.48070*
2	6307.043	7.372459	1.74E-09	-14.49262	-14.43776	-14.47163
3	6308.806	3.497519	1.75E-09	-14.48747	-14.41067	-14.45808
4	6311.832	5.989174	1.75E-09	-14.48523	-14.38648	-14.44744
5	6316.818	9.845987*	1.75E-09	-14.48750	-14.36681	-14.44132
6	6319.086	4.466871	1.76E-09	-14.48351	-14.34087	-14.42893
7	6320.214	2.217680	1.77E-09	-14.47690	-14.31232	-14.41393
8	6324.472	8.349784	1.77E-09	-14.47750	-14.29097	-14.40612

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

B. First Difference Maximum Likelihood Test

VAR Lag Order Selection Criteria
Endogenous variables: EX1 SP1
Exogenous variables: C
Date: 10/15/06 Time: 16:11
Sample: 1 877
Included observations: 868

Lag	LogL	LR	FPE	AIC	SC	HQ
0	6291.003	NA	1.74E-09*	-14.49079*	-14.47981*	-14.48659*
1	6294.609	7.185471	1.75E-09	-14.48988	-14.45694	-14.47727
2	6296.342	3.446375	1.76E-09	-14.48466	-14.42975	-14.46365
3	6299.424	6.114548	1.76E-09	-14.48254	-14.40567	-14.45313
4	6304.316	9.682076*	1.76E-09	-14.48460	-14.38576	-14.44678
5	6306.589	4.488278	1.76E-09	-14.48062	-14.35982	-14.43439
6	6307.727	2.241863	1.77E-09	-14.47402	-14.33126	-14.41939
7	6311.939	8.279165	1.77E-09	-14.47451	-14.30978	-14.41148
8	6313.716	3.484910	1.78E-09	-14.46939	-14.28270	-14.39795

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

C. First Difference Wald Lag Exclusion Test

VAR Lag Exclusion Wald Tests
Date: 10/15/06 Time: 16:22
Sample: 1 877
Included observations: 870

Chi-squared test statistics for lag exclusion:
Numbers in [ ] are p-values

	EX1	SP1	Joint
Lag 1	4.990367	1.962579	7.359374
	[0.082481]	[0.374827]	[0.118073]
Lag 2	0.060186	3.686060	3.782670
	[0.970355]	[0.158337]	[0.436216]
Lag 3	2.907081	4.656516	7.180172
	[0.233741]	[0.097465]	[0.126668]
Lag 4	2.011021	6.672676	8.608873
	[0.365858]	[0.035567]	[0.071655]
Lag 5	1.597753	2.953329	4.359496
	[0.449834]	[0.228398]	[0.359534]
Lag 6	0.515443	1.832439	2.247771
	[0.772810]	[0.400029]	[0.690294]
df	2	2	4

Appendix 5 – VAR Stability Condition Test – AR Roots Table

A. Level Series

Roots of Characteristic Polynomial
Endogenous variables: LNEX LNSP
Exogenous variables: C
Lag specification: 1 6
Date: 10/14/06 Time: 13:02

Root	Modulus
0.999582	0.999582
0.988322	0.988322
-0.621231	0.621231
-0.149082 + 0.598596i	0.616881
-0.149082 - 0.598596i	0.616881
0.136542 - 0.536471i	0.553574
0.136542 + 0.536471i	0.553574
0.533136	0.533136
0.445279 + 0.238351i	0.505059
0.445279 - 0.238351i	0.505059
-0.410513 - 0.153454i	0.438256
-0.410513 + 0.153454i	0.438256

No root lies outside the unit circle.
VAR satisfies the stability condition.

B. First Difference Series

Roots of Characteristic Polynomial
Endogenous variables: EX1 SP1
Exogenous variables: C
Lag specification: 1 6
Date: 10/15/06 Time: 18:37

Root	Modulus
-0.665431	0.665431
-0.218424 + 0.579948i	0.619716
-0.218424 - 0.579948i	0.619716
0.077891 + 0.582732i	0.587914
0.077891 - 0.582732i	0.587914
0.557964	0.557964
-0.493742 + 0.218709i	0.540014
-0.493742 - 0.218709i	0.540014
0.448817 - 0.226242i	0.502615
0.448817 + 0.226242i	0.502615
0.218600 + 0.369721i	0.429511
0.218600 - 0.369721i	0.429511

No root lies outside the unit circle.
VAR satisfies the stability condition.

Appendix 6 – Johansen Co-Integration Test

A. Level Series

Date: 10/14/06 Time: 13:19
Sample(adjusted): 10 877
Included observations: 868 after adjusting endpoints
Trend assumption: Linear deterministic trend (restricted)
Series: LNEX LNSP
Lags interval (in first differences): 1 to 8

Unrestricted Co-integration Rank Test

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5 Percent Critical Value	1 Percent Critical Value
None **	0.029442	32.24849	25.32	30.45
At most 1	0.007242	6.308928	12.25	16.26

*(**) denotes rejection of the hypothesis at the 5%(1%) level
Trace test indicates 1 co-integrating equation(s) at both 5% and 1% levels

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	5 Percent Critical Value	1 Percent Critical Value
None **	0.029442	25.93957	18.96	23.65
At most 1	0.007242	6.308928	12.25	16.26

*(**) denotes rejection of the hypothesis at the 5%(1%) level
Max-eigenvalue test indicates 1 co-integrating equation(s) at both 5% and 1% levels

Appendix 7 – Pair-wise Granger Causality Tests

A. Level Series – 1 Lag

Pairwise Granger Causality Tests
Date: 10/14/06 Time: 16:00
Sample: 1 877
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Probability
LNSP does not Granger Cause LNEX	876	1.09516	0.29562
LNEX does not Granger Cause LNSP		0.04788	0.82684

B. Level Series – 2 Lags

Pairwise Granger Causality Tests
Date: 10/14/06 Time: 16:02
Sample: 1 877
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Probability
LNSP does not Granger Cause LNEX	875	3.31227	0.03689
LNEX does not Granger Cause LNSP		0.29125	0.74740

C. Level Series – 3 Lags

Pairwise Granger Causality Tests
Date: 10/14/06 Time: 16:02
Sample: 1 877
Lags: 3

Null Hypothesis:	Obs	F-Statistic	Probability
LNSP does not Granger Cause LNEX	874	2.07498	0.10199
LNEX does not Granger Cause LNSP		1.38339	0.24647

D. Level Series – 4 Lags

Pairwise Granger Causality Tests
Date: 10/14/06 Time: 16:04
Sample: 1 877
Lags: 4

Null Hypothesis:	Obs	F-Statistic	Probability
LNSP does not Granger Cause LNEX	873	1.36064	0.24579
LNEX does not Granger Cause LNSP		1.86248	0.11499

E. Level Series – 5 Lags

Pairwise Granger Causality Tests
Date: 10/14/06 Time: 16:11
Sample: 1 877
Lags: 5

Null Hypothesis:	Obs	F-Statistic	Probability
LNSP does not Granger Cause LNEX	872	1.36982	0.23329
LNEX does not Granger Cause LNSP		2.02371	0.07308

F. Level Series – 6 Lags

Pairwise Granger Causality Tests
Date: 10/14/06 Time: 16:13
Sample: 1 877
Lags: 6

Null Hypothesis:	Obs	F-Statistic	Probability
LNSP does not Granger Cause LNEX	871	1.28196	0.26287
LNEX does not Granger Cause LNSP		1.60327	0.14309

G. First Difference Series – 1 Lag

Pairwise Granger Causality Tests
Date: 10/15/06 Time: 16:34
Sample: 1 877
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Probability
SP1 does not Granger Cause EX1	875	5.39831	0.02039
EX1 does not Granger Cause SP1		0.45271	0.50123

H. First Difference Series – 2 Lags

Pairwise Granger Causality Tests
Date: 10/15/06 Time: 17:36
Sample: 1 877
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Probability
SP1 does not Granger Cause EX1	874	2.51358	0.08157
EX1 does not Granger Cause SP1		1.96296	0.14106

I. First Difference Series – 3 Lags

Pairwise Granger Causality Tests
Date: 10/15/06 Time: 17:37
Sample: 1 877
Lags: 3

Null Hypothesis:	Obs	F-Statistic	Probability
SP1 does not Granger Cause EX1	873	1.48649	0.21674
EX1 does not Granger Cause SP1		2.40248	0.06633

J. First Difference Series – 4 Lags

Pairwise Granger Causality Tests
Date: 10/15/06 Time: 17:37
Sample: 1 877
Lags: 4

Null Hypothesis:	Obs	F-Statistic	Probability
SP1 does not Granger Cause EX1	872	1.41649	0.22652
EX1 does not Granger Cause SP1		2.45069	0.04469

K. First Difference Series – 5 Lags

Pairwise Granger Causality Tests
Date: 10/15/06 Time: 17:38
Sample: 1 877
Lags: 5

Null Hypothesis:	Obs	F-Statistic	Probability
SP1 does not Granger Cause EX1	871	1.30367	0.26012
EX1 does not Granger Cause SP1		1.87697	0.09588

L. First Difference Series – 6 Lags

Pairwise Granger Causality Tests
Date: 10/15/06 Time: 17:38
Sample: 1 877
Lags: 6

Null Hypothesis:	Obs	F-Statistic	Probability
SP1 does not Granger Cause EX1	870	1.06384	0.38260
EX1 does not Granger Cause SP1		1.75285	0.10593