Assessing the maturity of the AUD/NZD market

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Abstract

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1. Introduction

Recent years have witnessed strong growth in trading in the AUD/NZD cross rate, most notably as a result of the activity of investors in the Australasian region who wish to take a position on the Australian or New Zealand dollar but do not want to be exposed to US dollar trends (Smyth, 2005). Since an investor can take a position on this currency pair by trading either directly in the AUD/NZD market or indirectly in the NZD/USD and AUD/USD markets, the economic significance of the direct AUD/NZD market remains an open question, particularly in the absence of any comprehensive trading data from the foreign exchange markets.

This paper attempts to asses the relative maturity of the direct AUD/NZD market by examining its role in the price discovery process. Our principal focus is on whether new information is reflected first in the direct rate for the AUD/NZD or in the indirect rate implied by the rates in the AUD/USD and NZD/USD markets. The sheer size of the US dollar markets relative to the AUD/NZD market suggests that the direct market will be a satellite market of the more liquid US dollar markets. In the extreme case, where the direct AUD/NZD rate is determined mechanically by the two US dollar rates, and where order flow through the direct market has no influence on the cross-rate implied by the US dollar rates, the direct market will be a pure satellite market and make no contribution to price discovery. Under such a scenario, the AUD/NZD market is said to be "informationally redundant", a clear signal that the market is immature.

We collect a high frequency data set of indicative quote data on the AUD/USD, NZD/USD and AUD/NZD foreign exchange markets for a recent six-month period. Using the Geweke (1982) feedback methodology, we find that information flows between the direct and indirect markets for the AUD/NZD are dominated by the contemporaneous information flow between the two markets during the most active part of the trading day and by the lagged flow of information from the indirect market when trading activity is lower. The lagged flow of information from the direct market to the indirect market is never the dominant channel. These results suggest that the locus of price discovery in the AUD/NZD rate is in the US dollar markets for the Australasian currency pair. We conclude that the AUD/NZD market is still relatively immature despite the recent sharp growth in trading activity.

The remainder of this paper is structured as follows. Section 2 discusses the likely roles of the direct and indirect markets for the AUD/NZD currency pair in the price discovery process. Section 3 describes the high frequency data set and the methodology employed in this paper. Section 4 presents and discusses the empirical results. Section 5 concludes.

2. Speculative capital flows, currency exchange and price discovery

The surge in trading in the AUD/USD, NZD/USD and AUD/NZD in recent years has been attributed in large part to an increase in short-term capital flows, driven by the high yields on offer in the Australasian currencies and by greater speculation on the AUD/NZD cross rate (Galati and Melvin, 2004; Smyth, 2005).

In the foreign exchange market both the Australian and New Zealand dollars are both regarded as "commodity currencies" since their real exchange rates are heavily influenced by the real price of their commodity exports (Chen and Rogoff, 2003). However the label 'commodity currency" obscures the fact that the Australian dollar is exposed to resource prices whilst the New Zealand dollar is exposed to agricultural prices. Thus although the two currencies tend to "move in tandem" against the US dollar – i.e. are cointegrated – over the long-run (Zhou, 1998), the AUD/NZD cross will be influenced by movements in relative commodity prices. In addition, a number of factors other than relative commodity prices are also believed to influence the AUD/NZD cross rate, including the nominal interest rate differential, the output differential and the inflation rate differential between Australia and New Zealand (see for example, Huang, 2004). These "empirical regularities" seem to make a wager on the AUD/NZD cross rate a relatively straightforward proposition. An example is a recent report in the financial press of a large international investment bank advising its clients to sell the Australian dollar and buy the New Zealand dollar based on the perception that the AUD/NZD cross rate fully now priced the likelihood of the Reserve Bank of Australia raising interest rates later in the year (New Zealand Herald, 2006).

One interesting question is in what markets the underlying transactions will be conducted. Clearly any investor wanting to take an outright position on the Australian dollar (or New Zealand dollar) versus the US dollar will tend to trade in the AUD/USD (or NZD/USD) market. Thus speculative capital flows will emerge in the US dollar markets.

For an investor wanting to take a position on the AUD/NZD cross rate, the choice is not so clear. Obviously, one option would be to trade in the AUD/NZD market, for example by liquidating an Australian dollar deposit, selling the Australian dollars spot for New Zealand dollars and investing in a New Zealand dollar deposit.[1]

[1] For an investor with no existing position in either Australasian currency, a broadly similar position could be replicated by borrowing Australian dollar, selling the Australian dollars for New Zealand dollars and investing the proceeds in a New Zealand dollar deposit.

Alternatively, the investor could liquidate the Australian dollar deposit, selling the Australian dollars spot for US dollars, sell the US dollar spot for New Zealand dollars and invest in a New Zealand dollar deposit. The first option involves trading the AUD/NZD directly while the second involves trading the AUD/NZD indirectly through the US dollar vehicle currency in two separate transactions. Additionally, under the first option, speculative capital flows will emerge in the AUD/NZD market while, under the second option, they will merge in the US dollar markets.

The law of one price, in this case enforced by triangular arbitrage, will ensure that the indirect rate for the AUD/NZD that emerges in the US dollar markets for the Australasian currency pair will be broadly the same as the direct rate that emerges in the AUD/NZD market. This suggests that it will not matter where the order flow occurs. However the location of speculative capital flows will influence the source of price discovery. If speculative capital flows concentrate overwhelmingly in the direct market then one would expect the direct market to dominate the price discovery process. The opposite applies when speculative capital flows concentrate in the indirect market.

Where can we expect speculative capital flows to emerge? A sound starting point would be to suggest that speculative capital flows will gravitate to the route that minimises transaction costs. The currency exchange literature suggests that the vast majority of the order flow in a currency pair will pass indirectly through the US dollar vehicle markets due to economies of size (Krugman, 1980) and positive network externalities (Rey, 2001). However this literature says little about the composition of these transaction costs and the factors that determine them.

Hence we prefer to start with the microstructure literature. We begin by broadly defining transaction costs to include bid/ask spreads, search costs and price impact costs.

The theoretical literature suggests that dealer bid/ask spreads in the foreign exchange market will be lower where the volume of customer orders is large, there is a large pool of potential speculators (i.e. other dealers) and volatility is relatively low, although high enough to attract speculators (Black, 1991).[2] The first two requirements are likely to be met by the large US dollar vehicle markets which attract a large number of dealers and account for the largest share of trading in both Australasian currencies (Smyth, 2005). A number of empirical studies that have confirmed the hypothesized inverse relationship between bid/ask spreads and trading volumes (Black, 1991; Bessembinder, 1994; Hartmann, 1998; and Huang and Masulis, 1999) and between bid/ask spreads and the number of dealers (Huang and Masulis, 1999).

The large size of the US dollar markets for the Australasian currencies relative to the size of the direct AUD/NZD market suggests that spreads will be lower in the former. The magnitude of the difference miggght be enough to compensate for the fact that indirect trading of the AUD/NZD will incur two spreads rather than the one spread

[2] In the Black (1991) model the dealer's bid/ask spread is determined by the interaction between three types of agents: liquidity traders, a risk-neutral competitive dealer and price-sensitive speculators. Liquidity traders place buy and sell orders with dealers, trading at the dealer's bid and ask prices. The dealer then looks to rebalance his inventory by trading with price-sensitive speculators. The trading between the dealer and the speculators determines the market-clearing price. The model's solution for the bid/ask spread shows that the spread is inversely related to the speculators' elasticity of currency demand and supply schedules and expected customer trading volume and positively related to price volatility.

incurred in direct trading. If this is the case then one would expect new speculative capital flows to be attracted to the US dollar markets rather than the direct market. Howeevr even if spread costs are higher under direct trading as a result of having to conduct two transactions, it does not necessarily follow that direct trading will be the preferred option.

The higher level of liquidity of the US dollar markets will also have a favourable impact on the other two dimensions of transaction costs, search costs and price impact costs. The presence of a large number of dealers will reduce the time it takes to find a dealer, reducing execution risk (Levich, 1998). The enhanced liquidity of the US dollar markets will also make it easier for an investor to conduct a large transaction since the dealer has greater ability to unload any unwanted inventory position onto other dealers. This will flatten the dealer's supply and demand schedules and reduce price impact costs. Lyons and Moore (2002) suggest an investor or dealer with private information will prefer to trade in the US dollar markets rather in the direct market since the price impact of an informed trade will be higher in the latter. They show that the price impact of a Yen/Euro trade is twice as high when conducted through the direct market rather than through the US dollar markets for the currency pair.

To summarise, the prior theoretical and empirical literature suggests that new speculative order flow in the AUD/NZD currency pair will tend to concentrate in the US dollar markets for both currencies rather than in the direct AUD/NZD market. This suggests that the locus of price discovery will be in the indirect market rather than the direct market. This prediction is borne out by prior research into the relative roles of the direct and indirect markets for the Deutschmark/Yen currency pair day (De Jong, 1998). The authors found that price discovery was primarily located in the

US dollar markets although the relative contributions changed over the course of the trading day.

3. Data and methodology

3.1 Data

We collect high frequency indicative quote data from the markets for the AUD/USD, NZD/USD and AUD/NZD for the six-month period from 1 January 2006 to 30 June 2006 from Securities Industry Research Centre Asia-Pacific (SIRCA). This data set comprises 3.9 million quotes on the AUD/USD rate, 3.6 million quotes on the NZD/USD rate and 0.5 million quotes on the AUD/NZD cross-rate.[3]

Preliminary analysis of the raw data reveals that quote activity, particularly in the AUD/NZD cross-rate, is highest during daytime trading hours in London and New York. Since we intend to partition the sample period into five-second intervals and wish to maximise the likelihood of observing fresh quotes on each currency pair in each interval, we restrict our analysis to the busiest time of the trading day, 1300

[3] The indicative quote data set includes indicative bid and ask quotes supplied by contributing dealers on the three currency pairs over the two-year sample period. Indicative quotes are not binding in that the dealer is not obligated to deal at his advertised bid or ask quote. There is debate over the appropriateness of using indicative quotes as proxies for transaction prices. On the one hand, reputation considerations should prevent dealers from abusing the indicative quote convention by displaying misleading "off market" quotes (Goodhart and Figliuoli, 1991), suggesting that indicative quotes are a reasonable proxy for transaction prices. However, other researchers have questioned the usefulness of indicative quotes as proxies for transaction prices, noting that such quotes serve more as advertisements of the willingness to trade (Flood, 1994) and that they will quickly become stale when trading activity is hectic and dealers become more focused on trading than on maintaining up to date quotes (Martens and Kofman, 1998).

GMT to 1600 GMT. We also delete 15 days from the sample where the number of quotes in the direct market is relatively low. Our final sample comprises data for the three-hour interval 1300 GMT to 1600 GMT over114 trading days.

The indicative quote data is filtered since prior research indicates the presence of human and technical errors in data sets of high frequency indicative quotes (Muller et al., 1990). The quotes are screened to remove one-sided quotes (i.e. either the bid or ask quote is missing) and quotes with negative spreads (i.e. the bid quote exceeds the ask quote). Likely input errors are also eliminated by deleting quotes where the midquote differed from the previous midquote by more than plus or minus 2.5%. The aim of this filter is to maximise the likelihood of eliminating erroneous quotes while at the same time minimising the likelihood of eliminating genuine quotes. The only data deleted related to one-sided quotes.[4]

After removing low activity days and filtering, our high frequency data set comprised 721,455 AUD/USD quotes, 646,487 NZD/USD quotes and 153,761 AUD/NZD quotes. These sub-samples comprised 18.4%, 18.0% and 30.2% respectively of the total quotes submitted in the three markets over the six-month sample period.

(insert Table 1 about here)

Table 1 reports summary data on the indicative quote data in the three currency pairs. The figures on total quotes over the sample period show that quote activity is highest in the AUD/USD currency pair, followed by the NZD/USD and the AUD/NZD. The relatively low level of quote activity in the NZD/AUD cross-rate is not surprising given that only a handful of dealers act as market makers in the cross-rate. The Herfindahl index of 0.558 for this market shows a high level of dealer concentration.

[4] We also deleted quotes in the AUD/NZD market where spreads where in excess of 20 pips.

In contrast, the AUD/USD and NZD/USD markets have more dealers, higher levels of quote activity and these markets are much less concentrated.

The much high liquidity of the Us dollar markets is immediately obvious. Based on the number of dealers posting quotes in a market, the US dollar markets are approximately 5 – 6 times as liquid as the direct market. This suggests that transaction costs – i.e. bid/ask spreads, search costs and price impact costs – will all be lower in these markets than in the direct AUD/NZD market.

The data on bid/ask spreads shows that these costs are indeed lowest in the US dollar markets, particularly the AUD/USD market. The median spreads are 3 pips (0.04% of the mid-quote) in the AUD/USD market, 5 pips (0.08%) in the NZD/USD market and 11 pips (0.10%) in the AUD/NZD market. This spread data also shows that indirect trading of the AUD/NZD incurs a cost of 0.12% (0.04% plus 0.08%) compared to a direct cost of 0.10%.[5] However this 0.02% premium might well be offset by reductions in search costs. Interestingly, the spread data shows that the dealers in the AUD/NZD are not simply pricing their bid/ask quotes on the AUD/NZD cross from quotes in the US dollar markets for the AUD and NZD, since if this were the case, the spread in the AUD/NZD market would equal 0.12%, the sum of the two spreads in the US dollar markets for the AUD and NZD.

3.2 Methodology

We construct our data set of direct and indirect quotes on the AUD/NZD rate in clock or calendar time by recording the most recent quote in each market at sampling

[5] In any case, many transactions in dealer markets are conducted inside the dealer's spread so effective spreads will be less than quoted spreads. Unfortunately we have no information on effective spreads.

intervals of five seconds. We use this data to calculate the midrate for each series and then calculate the indirect AUD/NZD midrate from the midrates of the NZD/USD and AUD/USD. We calculate returns over this five-second interval by taking the natural logarithm of successive quotes. The problem with the clock time approach is that if there is no fresh quote in the current interval the observation from the previous interval is carried forward and the return is set automatically to zero. The danger with this approach is that the market with the "slowest" pace will be assigned a subsidiary role in the price discovery process simply because of the large number of zero-return intervals.[6]

Panel A of Table 2 reports descriptive statistics on the returns on the three midrates and the indirect midrate for the AUD/NZD for the clock time data set. These show that the median quote change is zero for all four time series. The data on standard deviations show that the return on the indirect rate is more variable than the return on the direct rate. We test the null hypothesis of equal variances in the returns on the direct and indirect rates. The Brown-Forsythe test statistic of 123.75 shows that the difference in the variance of the midrates is statistically significant. This is consistent with prior research of De Jong et al. (1998) which found that that the returns on the indirect rate of the Deutschmark/Yen implied by the US dollar rates for the two currencies was more variable than the returns on the direct rate.

(insert Table 2 about here)

[6] An alternative is the transaction or quote time approach which involves recording quotes when prices or quotes in all markets have been updated. See Harris et al. (1995) for a variant of this approach. The problem with this approach is that the observation frequency is determined by the pace of the "slowest" market and the clock-time structure of the data is destroyed (De Jong et al., 1998).

The data in Panel B of Table 2 shows that the correlation between the returns on the direct and indirect midrates is 0.1349, consistent with our prior expectation that this coefficient would be positive. We had expected that increases (decreases) in the direct rate would be associated with increases (decreases) in the indirect rate and vice versa.

The results in Panel C of Table 2 show strong evidence of significant negative first-order autocorrelation in the returns on the AUD/USD, NZD/USD and indirect AUD/NZD. The significant negative first-order autocorrelation we report is a well-recognised phenomenon in a times series of returns computed from indicative foreign exchange quote data (e.g., Goodhart and Figliuoli, 1991; Dacorogna et al., 1993). This phenomenon has been attributed to a number of factors, including divergent opinions across dealers, differences in inventory imbalances across dealers (Bollerslev and Domowitz, 1993; Dacorogna et al., 1993) and differences in spread sizes across dealers (Bollerslev and Melvin, 1994). We attribute the weaker but longer negative autocorrelations in returns in the direct AUD/NZD rate to the much lower quote frequency in this time series and the resulting larger number of intervals where the return is zero (De Jong et al., 1998).

4. Empirical results

We use the Geweke feedback measure to capture the size of the information flows between the direct and indirect markets. But first we estimate the cross-correlations between the return on the direct rate and leads and lags of the return on the indirect rate. The results reported in Table 3 show significant contemporaneous correlation between the two return series and significant correlation at the first lag. The significant correlation at lag zero suggests that tools such as a VAR or VEC model will be inappropriate to model the information transmission process since these methods ignore the contemporaneous channel. As a result, we use the Geweke (1982) feedback measures to measure the information flows between the direct and indirect markets. The significant correlation at the first lag suggests that the information flow from the indirect market to the direct market will dominate the information transmission process.

(insert Table 3 about here)

The Geweke (1982) methodology identifies three specific types of feedback: the spontaneous or contemporaneous feedback between the indirect market and the direct market, feedback from the indirect market to the direct market, and feedback from the direct market to the indirect market. These three measures can also be summed to provide a measure of the total feedback between the two markets.[7]

The Geweke feedback measures are obtained as follows. First, consider the following VAR representation of the relationship between returns in the two markets:

$$r_{D,t} = \alpha_D + \sum_{i=1}^{n} \delta_{t-i} r_{I,t-i} + \sum_{i=1}^{n} \lambda_{t-i} r_{D,t-i} + e_{Dt} \tag{1}$$

$$r_{I,t} = \alpha_I + \sum_{i=1}^{n} \delta_{t-i} r_{D,t-i} + \sum_{i=1}^{n} \lambda_{t-i} r_{I,t-i} + e_{It} \tag{2}$$

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[7] We also estimate a vector error correction model but the results are unsatisfactory. The estimates of the error correction coefficients are very low and often have the 'wrong' sign. The latter problem results in nonsensical estimates of Gonzalo-Granger (1995) and Hasbrouck (1995) measures of contributions to price discovery. We attribute the poor results with the VECM to the small 'errors' (i.e. the small difference between the direct and indirect rate) relative to transaction costs. This implies that the 'error' can behave like a random walk so long as it remains with transaction-cost bounds. Accordingly we estimate a threshold VECM model but the estimation results are equally poor.

where $r_{D,t}$ and $r_{I,t}$ are the returns in the direct and indirect markets during the interval ending at time t and e_{Dt} and e_{It} are random error terms. The errors are assumed to be independent and identically normally distributed with a mean of zero and constant variance. However, while autocorrelation in disturbances is not permitted, contemporaneous correlation is allowed.

Next, consider the following hypotheses in respect of the VAR model outlined above:

H_A: There is no contemporaneous relationship between returns in the two markets.

H_B: Returns in the indirect rate do not "Granger cause" returns in the direct rate i.e. δ_{t-i}'s = 0 in equation (1).

H_C: Returns in the direct rate do not "Granger cause" returns in the indirect rate i.e. λ_{-i}'s = 0 in equation (2).

H_D: H_A, H_B and H_C.

Under the joint hypothesis H_D, the VAR model collapses to

$$r_{D,t} = \alpha_D + \sum_{i=1}^{n} \lambda_{t-i} r_{D,t-i} + u_{Dt} \tag{3}$$

$$r_{I,t} = \alpha_I + \sum_{i=1}^{n} \delta_{t-i} r_{I,t-i} + u_{It} \tag{4}$$

The VAR model represented by equations (1) and (2) can be estimated as a system of seemingly unrelated regressions. Equations (3) and (4) can be estimated using OLS.

Under H_A the Geweke measure of contemporaneous feedback between the direct and indirect markets is defined as

$$G_1 = \ln\left(\frac{\sigma^2_{e_D}\sigma^2_{e_I}}{|Y|}\right) \sim \frac{1}{N}\chi^2_1 \tag{5}$$

where $|Y|$ be the determinant of the residual covariance matrix of the model defined by equations (1) and (2) and N is the sample size.

Under H_B the measure of feedback from the indirect to the direct market is

$$G_2 = \ln\left(\frac{\sigma^2_{u_D}}{\sigma^2_{e_D}}\right) \sim \frac{1}{N}\chi^2_n \tag{6}$$

Similarly, under H_C the measure of feedback from the direct to the indirect market is

$$G_3 = \ln\left(\frac{\sigma^2_{u_I}}{\sigma^2_{e_I}}\right) \sim \frac{1}{N}\chi^2_n \tag{7}$$

Thus under H_D the measure of total feedback between the direct and indirect markets is

$$G_4 = G_1 + G_2 + G_3 = \ln\left(\frac{\sigma^2_{u_D}\sigma^2_{u_I}}{|Y|}\right) \sim \frac{1}{N}\chi^2_{2n+1} \tag{8}$$

An intuitive explanation of equations (6) and (7) is as follows (Kawaller et al., 1993). Since both feedback measures associate a higher degree of feedback with a larger reduction in error variances from estimating the VAR model compared with estimating equations (3) and (4), the reduction in error variance must be attributable to the lagged coefficients - the δ_{t-i}'s and λ_{t-i}'s - included in the VAR model but omitted from equations (3) and (4). For example, a greater degree of feedback from the direct market to the indirect market implies that the λ_{t-i}'s in equation (1) are larger in magnitude and/or more highly significant (ie. with smaller standard errors).

The asymptotic distributions of each feedback measure under its alternative hypothesis (to H_A through H_D) is approximately non-central chi-square as follows:

$$NG_1 \sim \chi_1'^2 \quad (9)$$

$$NG_2 \sim \chi_n'^2 \quad (10)$$

$$NG_3 \sim \chi_n'^2 \quad (11)$$

$$NG_4 \sim \chi_{2n+1}'^2 \quad (12)$$

The statistical significance of feedback measures is ascertained by comparing the computed measure with critical levels of the Chi-square distribution under the null hypotheses.

The Geweke feedback measures are reported in Table 4. All feedback measures are significant at the 0.001 level. The feedback measures yield two important results. First, of the three information transmission channels, the contemporaneous channel is the most important, with the contemporaneous transmission measure G1 almost equal to the sum of the lagged transmission measures, G2 and G3. Second, G2 is nearly twice the size of G3, showing that the lagged information flow from the indirect market to the direct market dominates the lagged information flow from the direct to the indirect market.

[insert Table 4 here]

These results are consistent with prior indications provided by the quote frequency data and cross-correlation analysis and suggest that the primary reason for the subordinate role of the direct market in the price discovery process is the relatively low level of quote activity, which in turn reflects the relatively lower level of order flow through this market.

To check how sensitive the results are to the time of the day, we estimate the Geweke feedback measures using five-second sampling intervals for each one-hour period between 0700 GMT when trading begins in London and 2200 GMT when markets close in New York. The results depicted in Figure 1 show that lagged information flows from the indirect to the direct market are the dominant information channel in morning trading in London and it is not until markets open in New York that the contemporaneous information flow becomes the dominant channel. This latter channel remains dominant for the remainder of trading hours in the New York. We suggest the prominence of the lagged indirect rate early in the trading day reflects the relatively low level of quote activity in the direct market during this time and the heightened tendency for dealers to base their AUD/NZD quotes on prevailing quotes in the more active US dollar markets for the Australasian currency pair.

[insert Figure 1 here]

It is also clear that the lagged information flow from the indirect market to the direct market dominates the lagged information flow in the reverse direction. We suggest that this persistent dominance is linked to the much higher order flow in the US dollar markets for the AUD and NZD than in the direct AUD/NZD market. We take the hourly ratio of the average level of quote activity in the two US dollar markets to the average level of quote activity in the AUD/NZD market. The correlation between this ratio and the ratio of G2 to G3 is a relatively high 0.526.

In summary, our empirical analysis shows that the information flow between the direct and indirect markets for the AUD/NZD is dominated by the contemporaneous flow of information between the two markets at times during the day when the level of quote activity is relatively high and by the lagged information flow from the direct market at times during the day when the level of quote activity is more subdued. The lagged information flow from the direct market to the indirect market plays only a minor role in the price discovery process. These findings suggest that the AUD/NZD market is relatively immature.

5. Summary

We assess the relative maturity of the direct AUD/NZD market by examining the role this market plays in price discovery for the AUD/NZD rate. Using a high frequency data set, our analysis shows that information flows between the direct and indirect markets for the AUD/NZD rate are dominated by the contemporaneous information flow when trading activity is high. At other times the lagged flow of information from the indirect market is the dominant channel. The lagged flow of information from the direct market to the indirect market plays a subsidiary role in the information transmission process.

We are not surprised to find that the direct market is a satellite market of the much large US dollar markets for the AUD and NZD since these markets are more liquid and more well-established. In contrast the direct market is immature. However, whilst the direct market accounts for a minority of the price discovery, the contribution is not negligible and the market is far from informationally redundant. Nonetheless we expect that further substantial growth in direct AUD/NZD trading volumes will be required before this market can be regarded as a mature market.

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Table 1
Comparison of the three currency pairs (based on indicative quote data)

	AUD/USD	NZD/USD	AUD/NZD
No. of quotes	721,455	646,487	453,761
No. of dealers	43	38	7
No. of dealers > 5,000 quotes	23	22	4
Herfindahl Index	0.055	0.064	0.558
Median spread (pips)	3	5	11
Median spread (%)	0.04%	0.08%	0.10%

Table 2
Summary statistics on returns

Panel A: Descriptive statistics

	AUD/USD	NZD/USD	Direct AUD/NZD	Indirect AUD/NZD
Mean	0.0	0.0	0.0	0.0
Median	0.0	0.0	0.0	0.0
Maximum	0.0022	0.0084	0.0077	0.0084
Minimum	-0.0024	-0.0083	-0.0075	-0.0084
Std deviation	0.000144	0.000231	0.000165	0.000270

Panel B: Correlations

	AUD/USD	NZD/USD	Direct AUD/NZD	Indirect AUD/NZD
AUD/USD	1			
NZD/USD	0.0169	1		
Direct AUD/NZD	0.0723	-0.1127	1	
Indirect AUD/NZD	0.5189	-0.8459	0.1349	1

Panel B: Autocorrelations

	AUD/USD	NZD/USD	Direct AUD/NZD	Indirect AUD/NZD
Lag 1	-0.346	-0.361	-0.222	-0.370
Lag 2	-0.026	-0.051	-0.072	-0.051
Lag 3	-0.021	-0.019	-0.031	-0.025
Q statistic	29,466***	32,084***	12,171***	33,646***

*** Significant at the 0.001 level.

Table 3
Cross-correlations between direct rate returns and leads and lags of indirect rate returns

Lead		Lag	
12	-0.0021	1	0.1336
11	0.0009	2	-0.0319
10	-0.0011	3	-0.0157
9	-0.0019	4	-0.0026
8	-0.0062	5	-0.0018
7	0.0028	6	-0.0024
6	-0.0029	7	-0.0079
5	-0.0075	8	-0.0074
4	-0.0065	9	-0.0015
3	-0.0096	10	0.0021
2	-0.0166	11	-0.0069
1	-0.0279	12	0.0003
0	0.1349		

* Significant at the 0.05 level ** Significant at the 0.01 level *** Significant at the 0.001 level

Table 4
Geweke feedback measures

	Feedback measure
Contemporaneous	0.0956***
Indirect lead Direct	0.0665***
Direct lead Indirect	0.0353***
Total	0.1974***

* Significant at the 0.05 level ** Significant at the 0.01 level *** Significant at the 0.001 level

Figure 1
Geweke feedback measures (7:00am to 10:00pm GMT)