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Central bank intervention and exchange rate volatility — Australian evidence

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Abstract

This paper examines the key characteristics of foreign exchange intervention by the Reserve Bank of Australia in the period 1983–1997, which can be broken into five distinct phases. We investigate the changing effectiveness of daily intervention on the $US/$A exchange rate by decomposing the exchange rate response to the intervention into various separate components. We find contemporaneous positive correlation between the direction of intervention and the conditional mean and variance of exchange rate returns. We show that sustained and large interventions have a stabilising influence in the foreign exchange market in terms of direction and volatility. Without these interventions, the market would have moved further and exhibited more volatility. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

The effectiveness of foreign exchange intervention by central banks has been studied at length in the last 30 years. Much of the early literature focused only on the longer term implications and objectives of intervention, being constrained by the availability of only low frequency data on the central bank activities. Generally the evidence on the effectiveness hypothesis from this data was weak, and that is a generous interpretation. Yet central banks have continued to intervene, believing from their experience that intervention does indeed work. In the last 20 years, many central banks have made available information on their daily interventions, which have allowed researchers to study the inter-daily features of exchange rate intervention on the foreign exchange market. Although tick-by-tick data is really needed to fully evaluate the effectiveness on an intra- and inter-daily basis, daily data availability has meant that it is possible to test effectiveness arising from microstructural features of the foreign exchange market.

There is a popular view that central banks (or their treasuries, where they are dependent) have no special knowledge or ability in the busy foreign exchange market place, nor do they have adequate reserve resources to determine the direction of the exchange rate. Any intervention is believed to add further confusion in periods of turbulence exacerbating uncertainty and thus volatility. If the case for a fixed exchange rate, or an EMS bandwidth system, cannot be supported, then the central bank is advised to keep out of the market altogether. Looking at intervention data, it is immediately apparent that there are often long stretches of time when intervention has been dormant, even in periods when there has been considerable turbulence in the markets. So this popular view has certainly had some influence.

In apparent support, almost all the empirical work with high frequency data has found that the intervention on any day is positively correlated to the conditional variance of exchange rate change for that day, or else uncorrelated. Dominguez (1998) finds some significant rises in conditional volatilities of US exchange rate returns on the days of secret intervention by the Federal Reserve Bank, the Bundesbank and the Bank of Japan (although there were some falls for reported interventions by the first two banks). Baillie and Osterberg's (Baillie and Osterberg, 1997) GARCH research shows that foreign exchange intervention by these central banks in 1985–1990 had no significant impact on the conditional mean and variance of changes in the spot US exchange rates. Others who report significant positive intervention effects on exchange rate volatilities include Almekinders and Eijffinger (1994) and Bonser-Neal and Tanner (1996).

A similar phenomenon sometimes shows up with the conditional mean, which may suggest the central bank adds to destabilising speculation in the market. Baillie and Osterberg (1997) conclude that intervention generally had no effect on the change in the exchange rate, though purchases of the $US by the Fed was correlated with contemporaneous depreciations of the dollar. Dominguez (1998) estimates but does not report conditional mean effects, though Dominguez and Frankel (1993) do find that in 10 out of 11 episodes of clustered interventions involving more than one central bank, intervention moved the exchange rate in the appropriate direction (see Edison, 1993, for a survey). However these may be occurring because of the standard simultaneity problem — intervention occurs in response to turbulent foreign exchange market conditions on a day, and the exchange rate process on that day may be affected by that intervention. This sort of evidence is not a good test of that popular view.

Despite the evidence for effectiveness being generally mixed, there is increasing support for the alternative belief that central banks can have some influence on the stochastic properties of exchange rate processes. And of course, this view has some support in central bank circles, because there are so many daily occurrences of strategic interventions, conducted secretly or accompanied by official statements. In an influential monograph, Frankel and Dominguez (1993) concluded that intervention has a maximum impact when it occurs unexpectedly, with as much publicity as possible on the day and when it is done in coordination with other central banks.

In Australia, the Reserve Bank is responsible for conducting interventions on the $US/$A exchange rate, and for the post-floating periods (since December 1983) five distinct periods of intervention can be identified. The aim of this paper is to investigate the changing effectiveness of the RBA's intervention on the exchange rate (in conjunction with monetary policy) with particular emphasis on the effects on the conditional volatility of the daily exchange rate returns.

The paper is organised in sections. In Section 2, we discuss some theoretical explanations of the possible effects of intervention, and link the standard explanations to recent developments in understanding the microstructure of financial markets. In Section 3, we develop the key characteristics of the Australian dollar foreign exchange market, and of the intervention patterns of the Reserve Bank of Australia (RBA). In Section 4, we develop the GARCH model that we use to estimate the effectiveness of the intervention. In Section 5, our results are discussed, and the paper ends with our key conclusions in Section 6.

2. Theoretical explanations for intervention effectiveness

There are a number of potential channels and modes of intervention through which a central bank may have an effect on the exchange rate process. The first is the monetary channel and involves unsterilised foreign exchange interventions. If purchases of foreign currency assets and accompanied sales of domestic currency assets by the central bank are allowed to be reflected in a higher reserve position of the domestic banking system, this would represent an easing of monetary policy and a consequent depreciation of the currency. This channel requires an unlikely domination of domestic monetary policy by foreign exchange intervention policy in a floating exchange rate regime, and so it is generally disregarded. In the USA, the Treasury has de facto responsibility for foreign exchange intervention, while the Federal Reserve Board conducts domestic monetary policy. In Australia, the RBA is responsible for both and the interventions are sterilised. Intervention in the $US/$A is carried out almost exclusively by the RBA, although there have been some occasions (during Australian 'overnight' hours), when the Fed of New York has intervened on behalf of the RBA. Such interventions however, involve the use of Australian, rather than US, foreign exchange reserves. Thus in the case of Australia, it is more unlikely that monetary policy will be suborned to intervention policy. For countries with fixed or targeted exchange rate regimes, domestic monetary policy is always dominated by the intervention stance.

The second is the portfolio-balance channel, and this is associated with sterilised interventions that have no net effect on bank reserves. In the case of Australia, interventions that effectively inject or withdraw funds from the Australian money market are followed by offsetting domestic market operations by the RBA. Accordingly, all the foreign exchange interventions by the RBA are effectively sterilised on a daily basis[3]. By changing the outstanding supplies of domestic and foreign currency outside assets, the central bank may cause portfolio re-balancing that would lead to exchange rate changes. For this to occur, domestic and foreign outside assets must be imperfect substitutes in diversified portfolios, leading to a relative risk premium.

The third channel operates through the 'signalling' effect of the intervention. This has a number of variants. The central bank can proclaim its view of the inappropriateness of the direction of trades by trading in its own name (rather than anonymously through brokers) or by announcing its intentions to the press. In some instances, it may make these announcements but never actually act on them. By providing information of its beliefs, possible intentions and perhaps actual trades, it can empower relatively uninformed non-colluding participants to bet against colluding ones (such as hedge funds), perhaps frightening off these bandwagon speculators. It may also give pause for thought to all the participants that the central bank is getting closer to its implicit threshold for varying its domestic monetary policy stance. Ghose (1992) finds empirical support for the hypothesis that reported intervention (changes in reserves) helped to explain future changes in monetary policy in the US. However, in general, there is little support in the literature for this particular signalling hypothesis.

It would seem that the 'signalling' channel demands that the central bank declare its intentions and actions with as much publicity as possible. Yet, there are many recorded instances in which intervention is undertaken under the cloak of secrecy. In fact, it is only recently that some of the major central banks have begun to make data available on their daily operations (albeit with a substantial lag). The Swiss National Bank is an exception — it has always provided its daily intervention data. In 1982, the G7 central banks co-operated in the provision of daily data on a confidential basis to a working party that published useful results (see Loopesko, 1984). Since then the policy on release has eased in a number of countries. The Reserve Bank of Australia recently began to release daily data going back to 1983, but updated after a 6-month lag.

[3] The RBA began to use, from the early 1990s, foreign exchange swaps as its main tool of sterilisation so as to reduce disruptions in the domestic securities market (see Rankin, 1998). This had the effect of enhancing the effectiveness of the sterilisation process.

There are some compelling reasons for the secrecy of intervention. Secrecy may be an element of a mixed strategy that prevents agents from distinguishing between the effects of intervention and those of other market factors on exchange rates, so that the intervention cannot be interpreted as the reneging on previously declared policy commitments. In this way, the central bank can protect a fragile credibility of its monetary policy stance (see Cukierman and Meltzer, 1986). Another reason for restricting information is so that the market participants cannot easily work out the stock position of foreign currency assets at the central bank. The resolve and ability of the central bank to defend a position will obviously depend on its available resources — thus it may be optimal to let the market know of its presence in the market without giving away detailed information on its current actions or the level or composition of reserves. In addition, a central bank may recognise the influence of destabilising psychological or technical phenomena operating in the foreign exchange market (such as bandwagon effects leading to one-way bets or threats to resistance levels), but does not wish to be seen to acknowledge their existence. By discreetly intervening, it may hope to restore some orderliness. However the danger is that by creating ambiguity in their signals, the central bank may disturb, rather than calm the market. Another reason for secrecy may be that a central bank has been asked to intervene on behalf of another central bank that prefers to remain confidential. Finally, a central bank may intervene to replenish its reserve inventory and would naturally prefer to make advantageous trades to compensate for any losses incurred in its more active, public interventions. In practice, the RBA, in its Annual Report, has often declared profits from its intervention activities. Also, Andrew and Broadbent (1994) report that the RBA intervention had been profitable generating realised profit of $A 382 million by June 1994.

The evidence on secrecy versus reported intervention suggests that secret intervention generally increases conditional volatility (see Dominguez, 1998), and has no significant effects on the conditional mean (see Dominguez and Frankel, 1993) of the change in the spot rate.

The central bank can influence the exchange rate process by reversing its recent direction (or by slowing its movement), or by calming a disturbed market. The first is associated with effects of intervention on the conditional mean of the changes of the exchange rate is commonly described as 'leaning against the wind'. The second may be seen in the way it changes the conditional variance.

The central bank might perceive that the market is unnecessarily weak on one side of the market, and so choose to support that side. In this regard, most interventions are concerned with very short horizons (about a week at most), and typically have nothing to do with the underlying medium-term and long-term fundamentals that greatly concern international economists. In the last 15 years, there have been a number of successful co-ordinated international interventions by the major central banks of the world. These were certainly motivated by concerns of long-term misalignments. On the day of intervention, it is quite likely that the change in the exchange rate has breached the threshold for action, and so it would not be surprising that sales of foreign currency assets might be correlated on that day with a large depreciation of the currency. Subsequently, the intervention may generate the required effect of reducing the depreciation, or maybe even lead to an appreciation if it is a sustained campaign. Within the day, the fall in the currency might have been far worse had the intervention not taken place. Also larger than average interventions might have a disproportionate effect on the exchange rate. We test below whether actual (secret or reported) interventions by the RBA have had any success in 'leaning against the wind'.

A central bank may also operate to try to 'smooth' or 'calm' market conditions. In practice, this is associated with reductions in clustered swings in the exchange rate, and in dampening trading volumes within and across days. It has been well established in the microstructure literature on capital markets that the conditional variance of asset prices and trading volumes are strongly correlated (see Tauchen and Pitts, 1983; Joiron, 1996). In fact both of these are highly persistent (or serially correlated). This means that if there have been large changes in any direction of the exchange rate in a day, there is a very high probability of another approximately equal large change of either sign on the next day. A persuasive explanation for this observed clustering over time of the absolute value of exchange rate changes over a fixed time period such as a day is that the associated trading volumes are serially correlated, even if tick-by-tick returns are *iid* (see Steigerwald, 1998). Therefore, to understand the time-varying conditional variance of the exchange rate, one needs to know why trading volumes tend to be correlated across days.

If all the participants in foreign exchange markets were homogeneous in their beliefs and knowledge, and aggregate behaviour could be modelled as that of a representative agent, any shocks would lead to immediate exchange rate re-alignments, and little trading volume would be required within the day to re-balance portfolios. These random events would provide no second moment information and so the conditional volatility of the exchange rate would be undisturbed. However, the assumption of equally informed and comprehending participants is far too strong, and in the presence of asymmetric information along with different beliefs there will be heterogeneity in responses in the market to the shocks. The greater the heterogeneity, the greater will be the observed volumes of trades. Trades will take place because of differences of opinion, but also because participants need to find out about the knowledge and beliefs of others that are crucial for determining the general direction of the market. Therefore, a shock will lead to immediate changes in the level of the exchange rate, as well as a persistent surge in trading volumes. The volume jumps as agents rebalance their portfolios in response to their own knowledge and beliefs and their perceptions of that of others, and then subsequently in response to the re-balancing by others. The process will continue until the marginal information gain about others becomes insignificant. This persistence of trading volumes will naturally lead to persistence in measured price volatility.

With regard to private information shocks, there is a well-established literature that characterises traders as being either well informed or uninformed (for example, see Glosten and Milgrom, 1985). If dealers are unable to determine who are the informed, adverse selection leads to a necessary general widening of bid-ask spreads, with shocks encouraging a flurry of trades that persist for some time to allow the information to percolate through the market.

For public information shocks, such as macroeconomic announcements, the learning from volume trading is about discovering the degree of understanding and conviction held by particular important participants. For example, if an influential hedge fund responds negatively to, say, a surprise inflation announcement, dealers will be keen to narrow their spread (even to zero) for that fund, simply to determine how they are responding. Other dealers who know that the first one frequently gets this sort of information early will be keen to narrow their spreads to exact information from a trade with that dealer. So the process continues, with information percolating slowly through the market through persistent but declining volume trades. These time-dependent trades will be reflected in the measured conditional variance of the exchange rate.

In the absence of data on volumes, the conditional variance of exchange rate changes, or volatility, gives a measure of the systematic disorderliness of the foreign exchange market. The central bank's intervention, reported or secret, may have the effect of calming or exciting the market. On the day of intervention, presumably the central bank has been prompted to act because the volatility (and therefore volume) has exceeded an implicit threshold. Thus on that day we may observe a positive correlation between the intervention action and the estimated conditional variance. On subsequent days, particularly if the intervention is a sustained campaign, we may observe that the central bank successfully smoothes or calms the market. The central bank would have to trade in sufficient volume in the market over a few days if it is to signal to the disorderly market that it is acting with conviction. Smaller interventions over much longer periods are less likely to have the same sidelining effect on nervous participants. We test to see whether any of our measures of intervention by the RBA have been effective in 'smoothing' the spot market for the Australian dollar.

3. Key features of the Reserve Bank of Australia's interventions and the Australian exchange rate

3.1. Reserve Bank of Australia intervention operations

This section briefly summarises key features of Australia's foreign exchange intervention operations since the floating of the currency in December 1983. Profiles of daily foreign exchange transactions[4] undertaken by the Reserve Bank of Australia over the period December 1983–1997 are shown in Fig. 1 and Fig. 2. Key summary statistics on the nature and extent of the RBA's daily foreign exchange intervention operations over this 'post-float' period are shown in Table 1. Intra-daily data on foreign exchange intervention by the RBA are not available to the public. However, net market purchases of foreign currency on a daily basis,

[4] Foreign exchange holdings by the RBA are invested mainly in government securities, bank deposits and IMF SDRs. It makes use of futures contracts to hedge against adverse movements in yields. It also utilises foreign currency swaps, for its own purposes, as well as for other central banks.

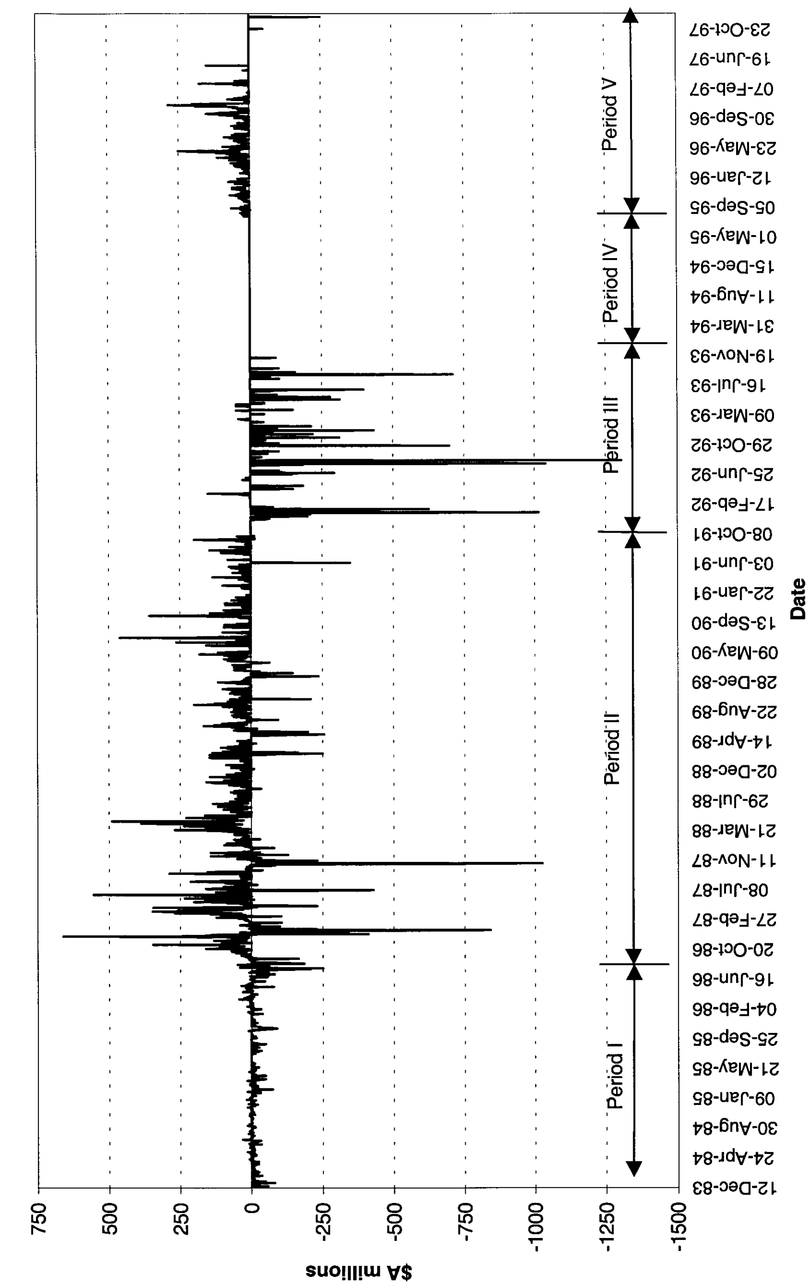

Fig. 1. Daily net market purchases of foreign currency (December 1983–1997).

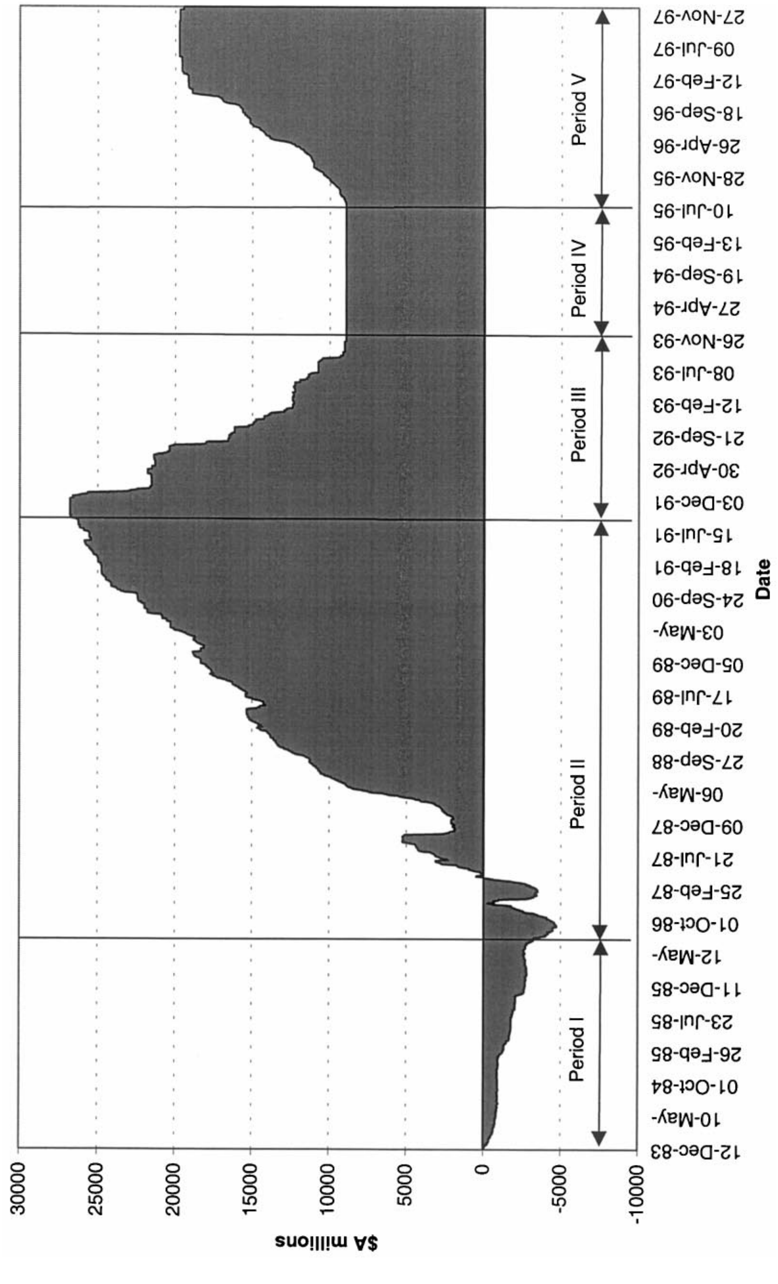

Fig. 2. Cumulative net market purchases of foreign currency (December 1983–1997).

Table 1
Summary statistics on RBA foreign exchange market transactions (December 1983–December 1997)

	Total post-float period	Period I, December 1983–June 1986	Period II July 1986–September 1991	Period III October 1991–November 1993	Period IV December 1993–June 1995	Period V July 1995–December 1997
Frequency of RBA official FX transactions (%)	46.5	84.6	68.9	23.5	–	43.7
Average absolute value of transactions ($A million)	56	8	63	145	–	40
Frequency of purchases of $A (%)	13.8	35.9	10.7	20.8	–	0.5
Average value of purchases of $A(−) ($A million)	−75	−16	−101	−160	–	−101
Frequency of sales of $A (%)	32.7	48.7	58.3	2.7	–	43.2
Average value of sales of $A(+) ($A million)	48	9	57	35	–	39
Maximum daily transaction ($A million)	−1305	−90	−1026	−1305	–	286
Frequency of official statements on intervention on intervention days (%)	3.18	1.56	6.31	1.99	–	0

measured in millions of $A, are available with a lag of six months. These include the amount of intervention aimed at influencing the exchange rate, as well as foreign exchange transactions carried out on behalf of the Commonwealth government — hence the degree of intervention can be inferred from these transaction data[5].

Over the entire period since the float, the Reserve Bank has intervened on slightly less than half of all the trading days, with an average volume of $A 56 million on those days in which it did enter the market. Fig. 1 and Table 1 reveal that at different times Reserve Bank intervention operations have been targeted at both supporting the Australian currency, as well as moderating its rise. The data, however, suggests an asymmetry in the nature of the Bank's intervention operations. While the frequency of purchases of Australian dollars (13.8%) has been significantly lower than the frequency of sales (32.7%), the average value of transactions involving purchases of the Australian currency ($A 75 million) has been significantly greater than transactions involving sales of the currency ($A 48 million).

The nature and aims of the Australia's intervention policy has not been uniform. Rankin (1998) highlights that the RBA's intervention operations have undergone several shifts in policy over the period. Typically, five distinct episodes have been identified. We provide some key summary statistics for each of these episodes in Table 1.

3.1.1. Period I: December 1983 to June 1986

Interventions during this immediate post-float period were characterised as operations where the Reserve Bank was engaged in 'smoothing and testing' of the market. The frequency of interventions was the highest (85%) and fairly evenly divided between purchases and sales of Australian dollars, however the average magnitude of transactions undertaken by the Bank was modest ($A 8 million). On less than 2% of the intervention days, there were official statements from either the RBA or the Commonwealth government regarding the undesirability of prevailing conditions in the foreign exchange market.

3.1.2. Period II: July 1986 to September 1991

While the intervention frequency remained quite high during this period, with the RBA being present in the market for approximately 7 out of every 10 days, the most noticeable shift in policy was the marked increase in the magnitude of interventions. On those days that the Bank was in the market, the average absolute value of transactions jumped to $A 63 million. The fact that the Reserve Bank was pursuing a 'leaning against the wind' intervention policy, attempting to moderate rises in the currency during 1988 and the latter part of 1990, is evident in that 84% of the transactions during this period involved sales of the Australian dollar. Interventions in support of the currency while less frequent, were considerably

[5] Neely (1998) reports that the inclusion of client transaction data does not significantly affect the statistical properties of the intervention data in the US.

larger in magnitude, with the average value of purchases of the Australian dollar nearly twice the size of the average value of sales. The largest defence of the currency (a purchase of $A 1026 million) occurred at the time of the October 1987 worldwide stock market crash. The Bank issued a statement of its interventions on 9% of the days of activity. We test below to see whether the Bank had any success in 'leaning against the wind', or in 'smoothing' in this period, and we find positive evidence.

3.1.3. Period III: October 1991 to November 1993

A very distinctive shift in the RBA's intervention strategy is noticeable over this period. Almost all of the interventions undertaken by the Bank involved purchases of the Australian currency. The Bank's presence in the market was considerably less frequent (approximately 1 out or every 4 days), although the intensity of its intervention as measured by the average value of transactions ($A 145 million), was substantially higher. On 8.5% of its intervention days, the Bank put out a statement declaring its presence. Episodic sharp falls in the value of the currency, during a period in which the Bank was easing monetary policy, appears to have underpinned this shift in intervention strategy. As one official states "As the Bank did not want to have to stall or reverse the easing of monetary policy in order to support the exchange rate, it sought to maximise the impact of its interventions through careful management of their size and timing (see Rankin, 1998)". The largest defenses occurred in August 1992. In the months leading up to that, the weakening world economy had reduced Australia's terms of trade, putting continuous downward pressure on the currency. The RBA preferred not to raise the cash rate in these circumstances (since real interest rates were perceived to be high, and the recovery of activity still nascent), and opted for intervention[6]. Unfortunately many other OECD countries faced the same dilemma, and most decided to raise their interest rates. This meant that the RBA needed to commit much larger volumes in defense of the currency. We test whether the RBA was successful in this substituting of monetary policy imperatives with the intervention instrument, and we find that it was not.

3.1.4. Period IV: December 1993 to June 1995

In this time period RBA did not undertake any foreign exchange transactions and it constituted the longest period of inactivity for the Bank over the post-float period.

3.1.5. Period V: July 1995 to December 1997

In July 1995, the Bank returned to the market undertaking foreign exchange transactions targeted specifically at retirement of the large swap positions built up during Period III. Thus, market transactions were motivated to take advantage of the strong $A to retire the bulk of its existing swap positions at favourable prices,

[6] See the Reserve Bank of Australia's Report and Financial Statements, 1993, pp. 3–5.

rather than motivated by the aim to achieving specific goals. Accordingly, the frequency of official foreign exchange transactions undertaken in this period is not low, with nearly all the transactions involving moderate average sales ($A 40 million) of Australian dollars.

3.2. Statistical properties of the Australian nominal exchange rate

The exchange rate we are examining for the analysis is the $US/$A exchange rate over the period December 1983 to December 1997 (see Fig. 3). The sample consists of 3558 daily observations. The exchange rate is defined as the $US price of one unit of $A, and the percentage changes are calculated as the difference in natural logarithms between successive daily 16:00 h (Sydney closing) quotations for the exchange rates from the inter-bank market multiplied by 100 ($\Delta s_t = \log(S_t/S_{t-1}) \times 100$), thus representing approximately the continuous compounding returns in holding $A measured in terms of the $US (see Fig. 4). The returns series possesses the usual features of positive skewness, excess kurtosis, significant linear and non-linear serial autocorrelation, and significant volatility asymmetry as measured by Engle–Ng sign bias tests[7].

4. Modelling intervention

The various motivations behind a central bank's foreign exchange market intervention and the channels of influence identified in Section 2 suggest that central banks can influence not only the level of exchange rate but also the volatility of exchange rate changes. There are broadly two types of exchange rate volatility one might consider in relation to interventions: option price implied volatility (see Bonser-Neal and Tanner, 1996) and GARCH volatility (see Dominguez, 1998, etc.). We chose the latter owing to the lack of readily available data for the $US/$A options contracts, but more importantly, because GARCH models of exchange rate volatility allow the empirical testing of the effectiveness of intervention to be carried out simultaneously on both the mean and conditional volatility of exchange rate returns.

The effects of the RBA's foreign exchange intervention are modelled by investigating the statistical properties of changes in the daily $US/$A exchange rate on the days of intervention. This requires an appropriate model structure that can cater for the key characteristics of daily exchange rate returns[8]. We have chosen Nelson (1991)'s Exponential GARCH modelling strategy as it ensures positivity of the variance coefficients and also addresses the volatility asymmetry issue. The model of choice is parsimonious EGARCH(1,1) with Student's t-distribution for the

[7] Interested readers can obtain detailed results from the corresponding author.

[8] See Hsieh (1989), and Baillie and Bollerslev (1989) for the modelling of the daily $US exchange rates, and Kim (1998, 1999) for the daily $A exchange rates.

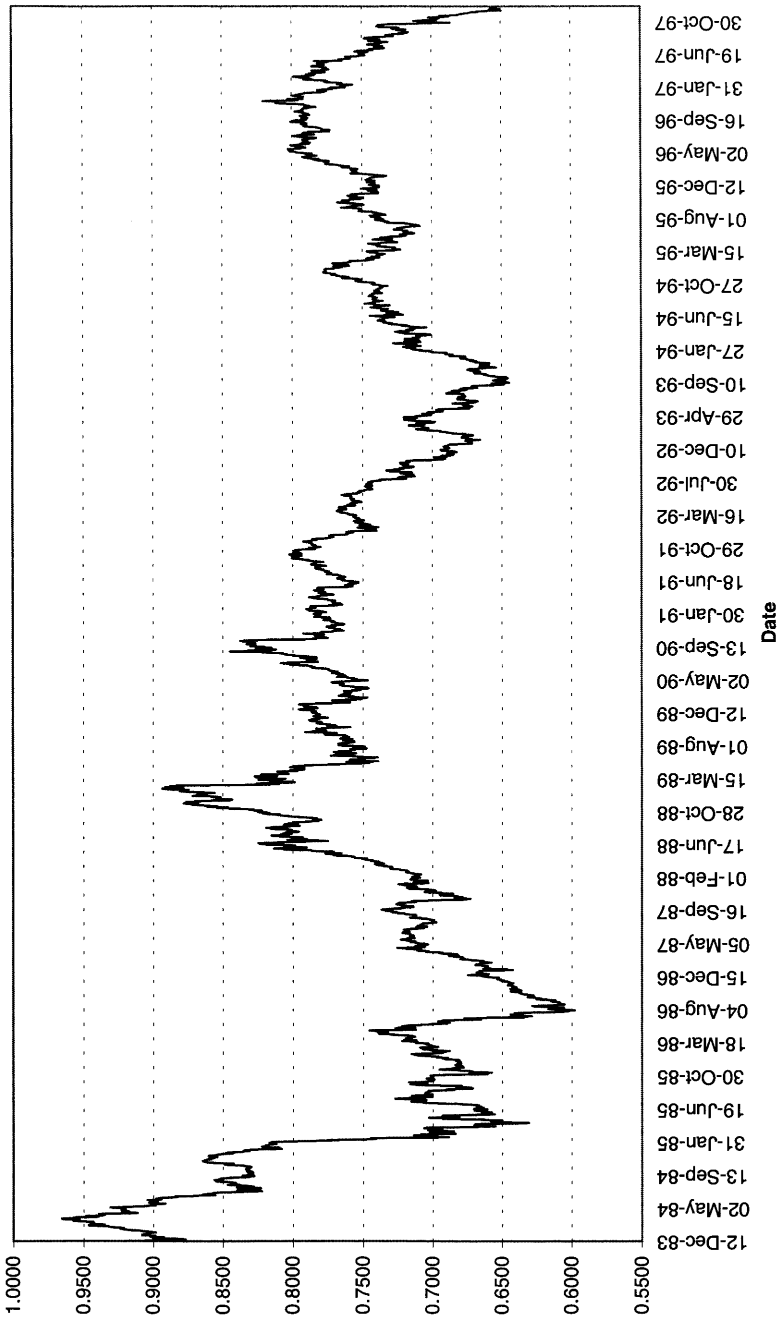

Fig. 3. $US/$A exchange rate: 12 December 1983–31 December 1997.

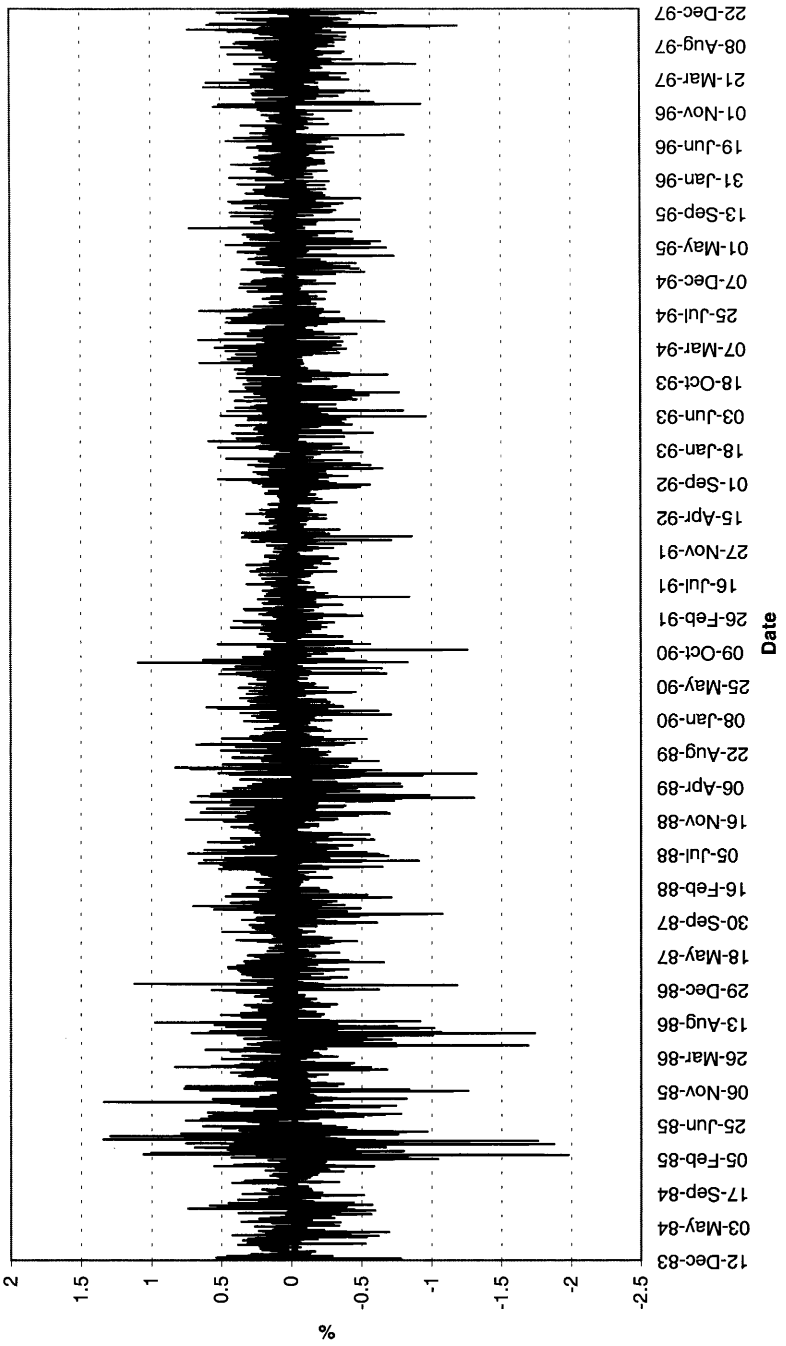

Fig. 4. Daily $US/$A returns: 13 December 1983–31 December 1997.

standardised residuals as shown below[9]:

$$\Delta s_t = \alpha_c + \sum_{i=\mathrm{MON}}^{\mathrm{THU}} \alpha_i D_{i,t} + \alpha_{\mathrm{HOL}} D_{\mathrm{HOL},t}$$
$$+ (\alpha_{\mathrm{INTV}} + \alpha_{\mathrm{CIDUM}}\mathrm{CIDUM}_t + \alpha_{\mathrm{SIDUM}}\mathrm{SIDUM}_t + \alpha_{\mathrm{RIDUM}}\mathrm{RIDUM}_t)\mathrm{Intv}_t$$
$$+ \alpha_{\mathrm{STDUM}}\mathrm{STDUM}_t + \varepsilon_t\!: \ \varepsilon_t = z_t\sqrt{h_t};\ \varepsilon_t \sim t(0,h_t,d),\ z_t \sim iid(0,1) \qquad (1)$$

$$\ln h_t = \beta_c + \beta_h \ln h_{t-1} + \beta_{\varepsilon 1}\frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} + \beta_{\varepsilon 2}\left(\frac{|\varepsilon_{t-1}|}{\sqrt{h_{t-1}}} - \sqrt{\frac{2}{\pi}}\right) + \sum_{i=\mathrm{MON}}^{\mathrm{THU}} \beta_{i,t} D_{i,t}$$
$$+ \beta_{\mathrm{HOL}} D_{\mathrm{HOL},t} + (\beta_{\mathrm{INTV}} + \beta_{\mathrm{CIDUM}}\mathrm{CIDUM}_t + \beta_{\mathrm{SIDUM}}\mathrm{SIDUM}_t$$
$$+ \beta_{\mathrm{RIDUM}}\mathrm{RIDUM}_t)|\mathrm{Intv}_t| + \beta_{\mathrm{STDUM}}|\mathrm{STDUM}_t| \qquad (2)$$

where $D_{i,t}$, daily dummy that takes the value of one for day i and zero otherwise; $D_{\mathrm{HOL},t}$, holiday dummy that takes the value of one for the day immediately after public holidays; Intv_t, the RBA intervention proxied by net market purchases of foreign currency, measured in \$A billions; CIDUM_t, cumulative intervention dummy variable that takes the value of one if intervention at day t is preceded by intervention in the same direction at day $t-1$ and $t-2$, and zero otherwise; SIDUM_t, intervention size dummy variable that takes the value of one if the absolute amount of intervention at day t is greater than the whole sample average daily net market purchase of \$A 56 million, and zero otherwise; RIDUM_t, reported intervention dummy variable that takes the value of one for the days of known intervention proxied by a report of such in the *Australian Financial Review* the following day, and zero otherwise; STDUM_t, official statement dummy that takes the value of positive (negative) one for days of official statement suggesting the value of the \$A should rise (fall), and zero otherwise; h_t, conditional variance of daily exchange rate changes.

Exogenous variables included in the mean and variance equations given above are different measures of foreign exchange intervention, plus day of the week and holiday dummies.

The effectiveness of the daily intervention on the exchange rate may be dependent on a number of features. First, the response of the foreign exchange market may depend on whether the intervention on the day is large enough to have a significant effect on the current trend. The size of the intervention matters — given the relatively large turnover in the Australian foreign exchange market (\$US 46.6 billion per day in April 1998[10]), the size of intervention has to be substantial enough to be able to move the 'equilibrium' exchange rate. Second, it is important to

[9] The generalised t-distribution of McDonald and Newey (1988) which nests both Nelson (1991)'s GED and the Student's t-distribution has also been tried and the two estimated shape parameters reveal that the conditional error distributions are much closer to the Student's t than the GED. It comes as no surprise, then, the results of the estimations are qualitatively the same as the ones presented in this paper for the standardised Student's t-distribution.

[10] Bank for International Settlement (1998) 'Central Bank Survey of Foreign Exchange and Derivatives Market Activity in April 1998' Australian data available from www.rba.gov.au/media/mr_98_12.html.

determine whether the intervention transaction for the day is a one-off episode, or a part of a series of interventions over many days. The RBA may spread out the intervention transaction over a number of days to maximise the effects of the intervention through the signalling channel. An intervention stance may be perceived to be more credible to market participants if they see a series of intervention transactions rather than a one-off entry into the market. Third, publicised interventions may have different effects to secret ones. Publicised interventions will have their greatest effects if the RBA action is seen as a credible source of information about future market conditions, in particular the future monetary policy stance. Secret interventions may also have some effect if the RBA can stimulate herding behaviour in a desired direction by entering the market and placing large disguised orders.

The market perception of different effects of intervention is modelled in this paper by allowing the intervention coefficient to differ depending on the features of the intervention on the day. This is accomplished by incorporating three slope dummy (or indicator) variables into the coefficient for the intervention variable in the conditional mean and variance equations. These are a size dummy (SIDUM_t) that takes the value of one for interventions of larger in amount than the average daily intervention for the whole sample (A$ 56 million) and zero otherwise, a cumulative intervention dummy (CIDUM_t) that takes the value of one for days of intervention that are preceded by at least 2 previous days' intervention in the same direction and zero otherwise, and a secrecy dummy (RIDUM_t) taking the value of one for interventions that are known by the market (as measured by a report of intervention in the *Australian Financial Review* the next day) and zero otherwise. Another intervention indicator variable (STDUM_t) tested is an indicator for official statements from either the RBA or the Commonwealth government regarding the undesirability of prevailing conditions in the foreign exchange market. This takes the value of minus (plus) one for days with announcements conveying the authority's preference to have a weaker (stronger) $A and zero in the absence of such announcements.

In addition to the intervention variables, the day of the week ($D_{i,t}$) and holiday dummy ($D_{\mathrm{HOL},t}$) variables are included to account for possible seasonal effects on the conditional mean and variance of the daily exchange rate returns.

5. Results

Table 2 reports the estimation results for the EGARCH(1,1) model with the exclusion restrictions for the intervention dummy variables. The restricted model is estimated first in order to examine the overall contemporaneous effects of intervention on the mean and variance of the exchange rate returns. Table 3 reports the disaggregated intervention effects estimated from the unrestricted model.

Table 2
EGARCH(1,1) estimation results: restricted model (see Eqs. (1) and (2)); restrictions imposed are $\alpha_{\mathrm{CIDUM}} = \alpha_{\mathrm{SIDUM}} = \alpha_{\mathrm{RIDUM}} = \beta_{\mathrm{CIDUM}} = \beta_{\mathrm{SIDUM}} = \beta_{\mathrm{RIDUM}} = 0$[a]

	Whole post float period (December 1983–1997)		Period I (December 1983–June 1986)		Period II (July 1986–September 1993)		Period III (October 1991–November 1993)		Period V (July 1995–December 1997)	
	Coefficient	*P*-value	Coefficient	*P*-value	Coefficient	*P*-value	Coefficient	*P*-value	Coefficient	*P*-value
α_{C}	−0.0122	(0.4237)	−0.0146	(0.6606)	−0.0171	(0.4815)	0.0241	(0.4720)	−0.1346**	(0.0002)
α_{MON}	0.0185	(0.4148)	−0.0064	(0.9071)	0.0215	(0.5621)	−0.0327	(0.5347)	0.1162*	(0.0210)
α_{TUE}	0.0194	(0.3819)	0.0471	(0.3127)	0.0579	(0.1126)	0.0020	(0.9679)	0.0213	(0.6737)
α_{WED}	0.0418$^{\dagger\mathrm{sb}}$	(0.0537)	0.1313*	(0.0126)	0.0633†	(0.0685)	−0.0002	(0.9968)	0.0592	(0.2469)
α_{THU}	0.0062	(0.7774)	0.0639	(0.2509)	0.0078	(0.8327)	−0.0317	(0.4988)	0.0682	(0.1792)
α_{HOL}	0.0126*	(0.0248)	0.1177	(0.1477)	0.0348	(0.6413)	0.1765	(0.2211)	0.2144*	(0.0328)
α_{INT}	1.6397**	(0.0000)	31.4570**	(0.0000)	1.7106**	(0.0000)	1.2639**	(0.0000)	3.5415**	(0.0000)
α_{ST}	0.957	(0.2792)	0.4861*	(0.0401)	0.1529	(0.2036)	−0.1844	(0.2483)		
β_{C}	−0.1977*	(0.0156)	−0.7051**	(0.0004)	−0.3544**	(0.0059)	−0.2077	(0.3258)	0.0079	(0.9672)
$\beta_{\varepsilon 1}$	−0.0219	(0.1395)	0.0437	(0.3838)	0.0330	(0.1937)	0.0213	(0.6125)	−0.0343	(0.2492)
$\beta_{\varepsilon 2}$	0.2348**	(0.0000)	0.3616**	(0.0000)	0.2338**	(0.0000)	0.1862**	(0.0020)	0.0969*	(0.0177)
β_{h}	0.9578**	(0.0000)	0.8930**	(0.0000)	0.9596**	(0.0000)	0.9664**	(0.0000)	0.9743**	(0.0000)
β_{MON}	0.3834**	(0.0060)	1.1332**	(0.0010)	0.5380*	(0.0136)	0.6007†	(0.0898)	−0.1300	(0.6922)
β_{TUE}	0.0594	(0.6127)	−0.2187	(0.4221)	0.3982*	(0.0385)	−0.0190	(0.9515)	−0.0075	(0.9788)
β_{WED}	0.1925	(0.1022)	1.0544**	(0.0002)	0.1625	(0.3870)	0.2112	(0.4745)	0.1030	(0.7094)
β_{THU}	0.1055	(0.4508)	0.5311	(0.1060)	0.3597	(0.1045)	−0.0703	(0.8557)	−0.1386	(0.6830)
β_{HOL}	0.1689†	(0.0961)	0.5313†	(0.0946)	0.0345	(0.8395)	0.0850	(0.7702)	−0.3875†	(0.0722)
β_{INTV}	0.4486**	(0.0000)	14.5117**	(0.0000)	0.5472**	(0.0016)	0.7192**	(0.0002)	−0.0311	(0.9265)
β_{ST}	0.1849	(0.1147)	−0.1698	(0.6349)	0.4203*	(0.0106)	−0.1886	(0.4223)		
D	4.4797**	(0.0000)	5.7969**	(0.0000)	4.9164**	(0.0000)	5.9291**	(0.0017)	5.3559**	(0.0000)
Diagnostics for standardised residuals, Z_t										
Skewness	−0.4291		−0.3164		−0.3308		−0.3482		−0.3972	
Kurtosis	2.8780		3.9738		2.2421		1.2506		2.4566	
$Q(20)$	27.1812	(0.1302)	30.4024†	(0.0636)	13.5030	(0.8548)	18.5818	(0.5491)	35.2221*	(0.0190)
$Q^2(20)$	14.7186	(0.7923)	6.5265	(0.9980)	36.2518*	(0.014)	14.9450	(0.7795)	13.8238	(0.8393)
E–N	4.9881	(0.1727)	2.7063	(0.4392)	5.2638	(0.1535)	1.6030	(0.6587)	0.9244	(0.8195)
Rest.	48.8219**	(0.0000)	11.3035†	(0.0794)	20.2462**	(0.0025)	16.0312*	(0.0136)	31.7854**	(0.0000)
Ln L	−599.60		−173.21		−229.69		8.28		−13.14	

[a] $Q(20)$ and $Q^2(20)$ are the Q statistics for the Ljung–Box test of white noise for the linear and squared standardised residuals. E–N is the test statistic for the Engle–Ng's Joint test of asymmetric response of conditional variance to lagged innovations in the underlying series ($\chi^2(3)$). The null is a presence of significant positive and negative asymmetric effects. Rest. is the test statistic for the exclusion restrictions. $\chi^2(6)$ for all the periods except for period V where $\chi^2(4)$ is relevant. Numbers inside the brackets are asymptotic P-values.

[b] †, Significance at 10%; *, significance at 5%; **, significance at 1%.

Table 3
EGARCH(1,1) estimation results: unrestricted model[a]

	Whole post float period (December 1983–1997)		Period I (December 1983–June 1986)		Period II (July 1986–September 1991)		Period III (October 1991–November 1993)		Period V (July 1995–December 1997)	
	Coefficient	*P*-value	Coefficient	*P*-value	Coefficient	*P*-value	Coefficient	*P*-value	Coefficient	*P*-value
α_c	−0.0294†a	(0.0603)	−0.0150	(0.6350)	−0.0306	(0.2361)	0.0375	(0.2448)	−0.1758	(0.0000)
α_{MON}	0.0218	(0.3389)	−0.0124	(0.8159)	0.0205	(0.5831)	−0.0267	(0.6257)	0.1204*	(0.0179)
α_{TUE}	0.0208	(0.3451)	0.0467	(0.3133)	0.0436	(0.2330)	−0.0127	(0.8028)	0.0426	(0.3921)
α_{WED}	0.0415†	(0.0567)	0.1295**	(0.0098)	0.0586†	(0.0930)	−0.0019	(0.9685)	0.0528	(0.3209)
α_{THU}	0.0082	(0.7129)	0.0560	(0.2939)	0.0060	(0.8738)	−0.0374	(0.3978)	0.0542	(0.2898)
α_{HOL}	0.1056*	(0.0212)	0.1345+	(0.0726)	0.0578	(0.4329)	0.1680	(0.4144)	0.0205*	(0.0159)
α_{INT}	4.4184**	(0.0000)	33.3426**	(0.0000)	3.4816**	(0.0000)	3.8530*	(0.0165)	8.5854**	(0.0000)
α_{CUM}	−0.2792	(0.1584)	−4.3331	(0.4417)	−0.5491†	(0.0697)	0.0737	(0.9222)	−3.5565**	(0.0009)
α_{SIZE}	−2.2115**	(0.0000)	−15.6778†	(0.0576)	−0.8359	(0.2376)	−3.6575*	(0.0258)	−2.0132†	(0.0597)
α_{RPT}	−0.7314**	(0.0023)	−0.1227	(0.9803)	−0.7856*	(0.0147)	1.1517*	(0.0476)		
α_{ST}	0.1011	(0.2450)	0.5727†	(0.0689)	0.1253	(0.2719)	−0.1757	(0.2976)		
β_c	−0.1917*	(0.0189)	−0.7715**	(0.0001)	−0.4061**	(0.0016)	−0.1263	(0.5715)	0.0070	(0.9741)
$\beta_{\varepsilon 1}$	−0.0222	(0.1381)	0.0412	(0.4124)	0.0259	(0.3445)	0.0246	(0.5588)	−0.0547	(0.1782)
$\beta_{\varepsilon 2}$	0.2389**	(0.0000)	0.3621**	(0.0000)	0.2516**	(0.0000)	0.1889**	(0.0037)	0.1374*	(0.0333)
β_h	0.9537**	(0.0000)	0.8915**	(0.0000)	0.9431**	(0.0000)	0.9354**	(0.0000)	0.8875**	(0.0000)
β_{MON}	0.3624**	(0.0095)	1.1981**	(0.0005)	0.5405*	(0.0143)	0.5287	(0.1351)	−0.3368	(0.3438)
β_{TUE}	0.0372	(0.7509)	−0.1764	(0.5211)	0.4391*	(0.0231)	−0.1966	(0.5336)	−0.1423	(0.6300)
β_{WED}	0.1928	(0.1009)	1.0147**	(0.0004)	0.1638	(0.3814)	−0.0866	(0.7701)	0.0736	(0.7996)
β_{THU}	0.0930	(0.5050)	0.5617+	(0.0867)	0.4190†	(0.0575)	−0.2831	(0.4502)	−0.2794	(0.4080)
β_{HOL}	0.1349	(0.1887)	0.4651	(0.1361)	−0.0346	(0.8517)	0.5799	(0.1404)	−0.5054	(0.1167)
β_{INTV}	0.7841	(0.2726)	26.2766**	(0.0000)	1.8617	(0.1888)	−0.2369	(0.9407)	−4.1049†	(0.0862)
β_{CUM}	−0.5610*	(0.0394)	−13.5642†	(0.0649)	−0.8663*	(0.0343)	−5.2948**	(0.0012)	−3.4081*	(0.0499)
β_{SIZE}	−0.3187	(0.6851)	4.7326	(0.6460)	−1.0633	(0.4444)	3.4942	(0.3068)	8.0486**	(0.0013)
β_{RPT}	0.3818	(0.3356)	−12.4546	(0.1589)	0.5166	(0.3614)	−1.9785	(0.2617)		
β_{ST}	0.1697	(0.1633)	0.3218	(0.4352)	0.3918*	(0.0340)	−0.0690	(0.8117)		
D	4.5090**	(0.0000)	6.1524**	(0.0000)	5.0120**	(0.0000)	7.0919**	(0.0062)	5.4281**	(0.0002)
Diagnostis for standadised residuals, Z										
Skewness	−0.4341		0.0539		−0.2499		−0.3060		−0.1760	
Kurtosis	2.9082		2.7958		2.0184		1.1104		1.5908	
Q (20)	27.4545	(0.1230)	32.8394**	(0.0351)	12.8450	(0.8839)	18.0259	(0.5857)	28.5019†	(0.0980)
Q^2 (20)	14.2929	(0.8153)	6.8043	(0.9973)	38.0616	(0.0087)	24.1896	(0.2342)	20.3280	(0.4376)
χ^2 (3)	3.3827	(0.3363)	3.7904	(0.2850)	0.9106	(0.4352)	2.7021	(0.4399)	0.9250	(0.8194)
Ln L	−578.13		−167.69		−221.24		17.74		3.90	

[a] See notes for Table 2.

5.1. Conditional mean

In the restricted model the intervention has a strong positive impact on the value of the $A on the day of intervention (see Table 2)[11]. The positive sign of α_{INT} suggests an appreciation of the $A in response to a sale of the $A (almost always against the $US). A purchase of $US 1 billion led to a 1.64% appreciation of the $A on the day of the purchase for the whole sample in the restricted model This contemporaneous positive effect is due to the simultaneity between the exchange rate returns and intervention.

Negative slope dummy variable coefficients in the unrestricted model (reported in Table 3) for the intervention will provide evidence of the stabilising effects of intervention. The coefficient for the cumulative dummy variable is negative for all samples except for period III, and is significant in periods II and V. The size slope dummy is significant in all the sample periods except for period II suggesting that the larger is the size of intervention the greater is the influence on the movements of exchange rate. A negative coefficient indicates that the exchange rate moves in the desired direction for intervention, that is, a sale of $A depresses its value. The reported intervention dummy is negative for the whole sample and periods I and II, suggesting that known interventions move the $A in the right direction. In period III, reported interventions had an opposite impact that may suggest the market in general was speculating against the RBA, and so the positions taken against the known intervention exceeded the amount of intervention for the day. In sum, all the significant coefficients for the intervention slope dummy variables are negative suggesting that the RBA's interventions did have trend dampening effects on the exchange rate movements. Fig. 5 depicts each of the four intervention coefficients, and the sum of the four that represents the net effects of intervention for each sample periods. In all cases, the net effect of intervention is smaller than the contemporaneous effect suggesting that there are indeed trend-reducing effects of intervention.

The official statement dummy is positive in general but significant only for Period I. This indicates that market participants do not appear to pay attention to official statements regarding the desirability or otherwise of the current exchange rate level. Some seasonal dummy variables contribute to the modelling of the daily exchange rate return behaviour. The Wednesday and the holiday dummies are significant in more than one periods. All the significant coefficients are positive in sign suggesting an appreciation of the $A on these days.

[11] Large coefficients for the intervention variable in the mean and variance equations in period I estimations are due to the small size of market transactions in this period. The average absolute value of transaction in this period is $US 8 million compared with $US 56 million for the whole period, and so a one $US billion purchase or sale would have a big impact on both the mean and variance in this period.

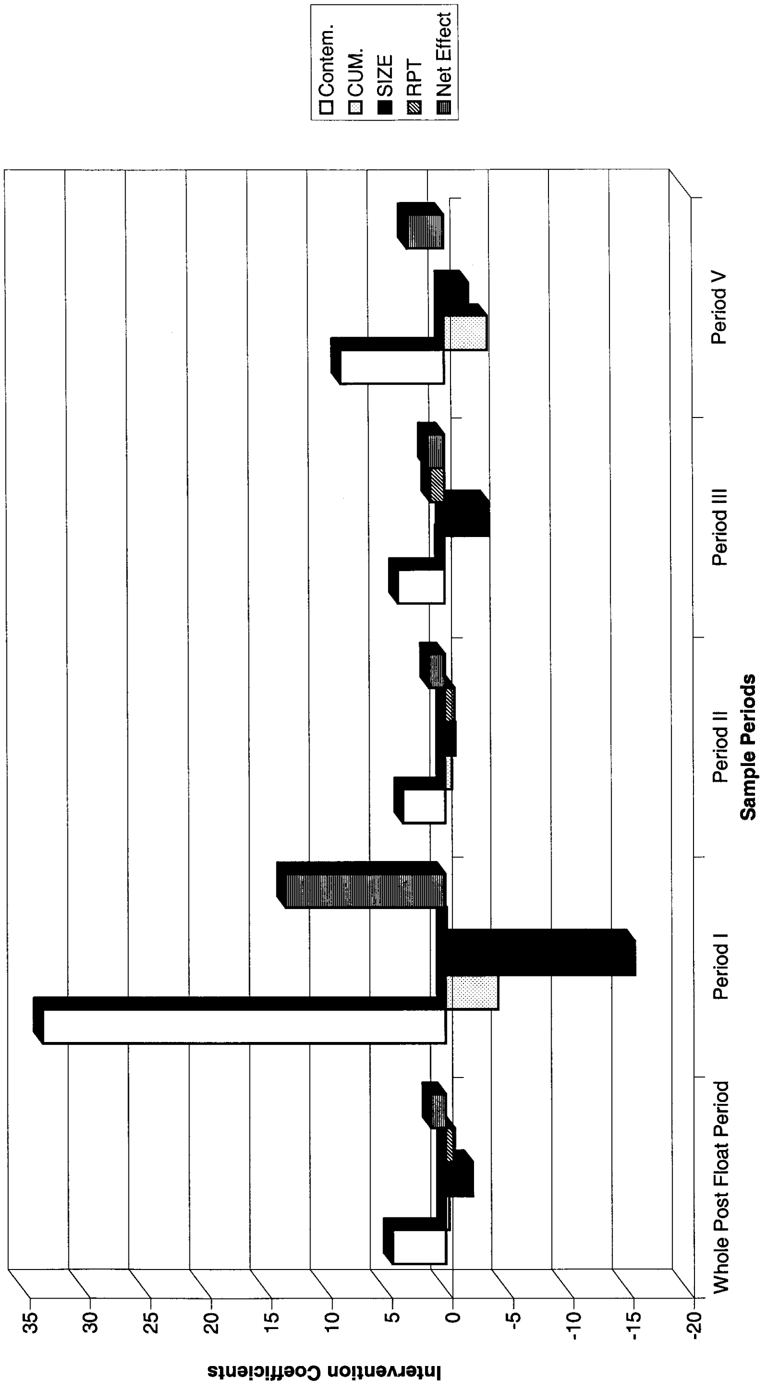

Fig. 5. The effects of intervention: conditional mean.

5.2. Conditional variance

The pattern of effects of intervention on the conditional volatility is similar to that on the conditional mean — the contemporaneous effects of intervention suffer from the simultaneity issue but there are moderating forces at work. On the days of intervention, the conditional volatility of the exchange rate return is significantly raised, as reported in Table 2 for the restricted model, for all the estimation periods except for period V, which might (erroneously) suggest that the RBA's involvement in the market adds to volatility[12]. This implies that the presence of the RBA in the market appeared to have increased the degree of heterogeneity (of beliefs and information sets) among market participants whether it was intended or not. However, the market-exciting effect of intervention is offset partially by the cumulation component of the intervention as reported in Table 3 for the unrestricted model. The coefficient for the cumulation dummy is significantly negative in all the periods suggesting that the presence of the RBA in the market over a number of consecutive days convinces the market of its intention of market smoothing. The size dummy is found to be relevant only in period V. The positive and significant coefficient indicates a rise in market volatility in response to an intervention. This should not be viewed as a failure of the RBA in its objective to reduce volatility since all the forex transactions carried out in this period were primarily to reverse the swap positions that had built up during period III. Fig. 6 shows the net effect of intervention on the conditional variance is lower than the contemporaneous effect in all the cases suggesting that market calming effects of intervention is present.

The release of official information regarding the RBA's position on foreign exchange market conditions did not have any effect. It is significant and positive only in period II in which one of the stated aims of the interventions was to signal to the market the RBA's position on the desirability or otherwise of the current direction of the exchange rate. Unfortunately, however, this apparently added more uncertainty to the market undermining the purpose of information release. This seems to suggest that the official statements were either irrelevant at best or unwarranted at worst resulting in added uncertainties in the market leading to higher daily volatility.

Overall, despite the consistent market calming effect of the cumulative intervention, the RBA's intervention significantly raised volatility of the daily \$US/\$A exchange rate returns. However, due to the simultaneity issue raised above, one should be careful about interpreting the contemporaneous effects of intervention. In fact, these effects may indicate that the intervention, overall, moderated the exchange rate process change compared with what would have occurred in its absence.

[12] The non-responsiveness of the conditional variance to the intervention is not surprising since the market transactions by the RBA during this period were not purported to be anything other than the RBA's portfolio adjustments with no direct intervention aim.

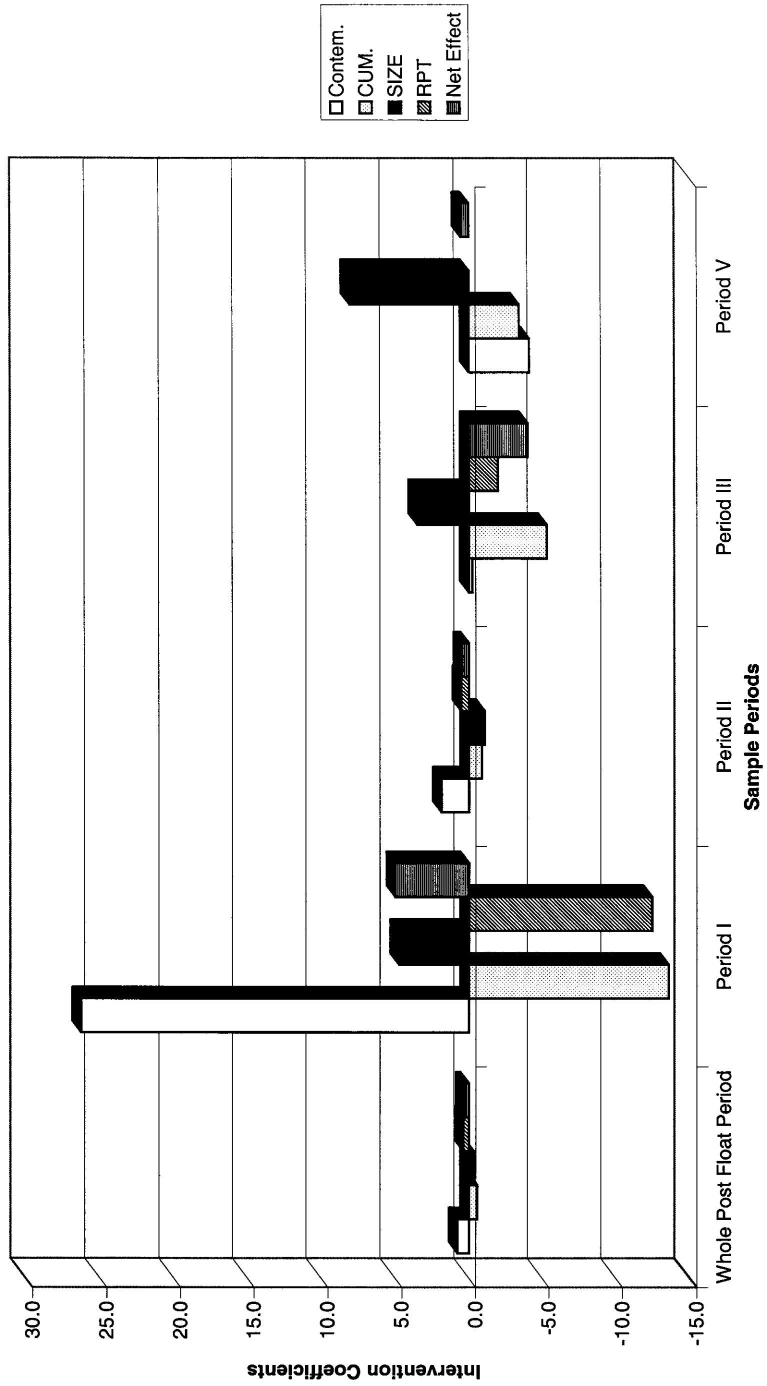

Fig. 6. Effects of intervention: conditional volatility.

The positive and significant Monday dummy for the whole and first two sub-periods confirms the a priori expectation regarding higher volatility on Mondays due to information accumulation over weekends. In addition, the Tuesday dummy is significant in the third sub-period, while the Thursday dummy is significant in the first two sub-periods. They all have a positive sign suggesting a higher conditional volatility of returns, on average, on these days.

The test of the exclusion restriction on both the mean and variance is rejected at least at 5% in all the periods except for the first indicating support for the hypothesis of stabilising effects of intervention.

6. Concluding comments

We have found evidence that the Reserve Bank of Australia has had some success in its foreign exchange intervention policy. Its stated objectives and the resulting performances varied over five distinct phases in the period 1983–1997. By checking the various components of the exchange rate response to the intervention, we find evidence of a stabilising influence on the $US/$A exchange rate process. That is, purchases of $A on a day tended to strengthen the currency and reduce its conditional volatility. The Reserve Bank will have been prompted to intervene when the exchange rate moved sufficiently far (down) on a particular day, breaching its threshold of inactivity. On that day, we would expect to see (a defensive) intervention action positively correlated with volatility and the (depreciating) change in the currency. This obviously accounts for the observed contemporaneous effects of intervention documented in the paper. Having laid the groundwork, one direction of future research would be to explicitly model this policy endogeneity effect.

In general, we find that official statements concerning intervention had little effect on the exchange rate process. In the second period (1986–1991), when there were some large swings in the exchange rate (e.g. a current account deficit blow out and a subsequent 'Banana Republic' statement by the Federal Treasurer in 1986, 1987 stock market crash, monetary policy tightening from 1988, the 1990 Gulf War) and the RBA aimed to ensure orderly conditions, its official statements had a very significant destabilising effect, which apparently undermined its intervention activity.

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