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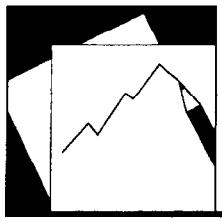

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Foreign Exchange Intervention and the Australian Dollar: Has It Mattered?

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Foreign Exchange Intervention and the Australian Dollar: Has It Mattered?

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Abstract

Since the Australian dollar was floated in December 1983, the Australian central bank (Reserve Bank of Australia) has actively intervened in the foreign exchange market. Using daily exchange rate and official intervention data from January 1984 to December 2001, this paper examines what effects, if any, foreign exchange operations by the Reserve Bank of Australia (RBA) have had on the level and volatility of the Australian dollar exchange rate. First, using an event study we evaluate the effectiveness of intervention by examining its direct effect on the *level* of the exchange rate. We find that over the period 1997-2001, the RBA has had some success in its intervention operations, by moderating the depreciating tendency of the Australian dollar. Second, we investigate the effects of RBA intervention policies on exchange rate *volatility* over the floating rate period. Our results indicate that intervention operations tend to be associated with an increase in exchange rate volatility, which suggests that official intervention may have added to market uncertainty. Overall, the effects of RBA intervention are quite modest on both the level and the volatility of the Australian dollar exchange rate.

JEL Classification Numbers: F31, G14, G15

Keywords: Foreign exchange intervention, exchange rate volatility, GARCH modeling

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I. INTRODUCTION

Central bank intervention is typically rationalized by claims that such intervention is effective in either altering the level of exchange rates or in dampening the volatility of exchange rate movements. However, while central bankers implicitly believe that their intervention activities are effective, there is a great deal of ambivalence among economists, policymakers and exchange market participants as to the efficacy of official intervention in foreign exchange markets. There are three main views on the effectiveness of foreign exchange rate intervention by central banks. In one view, intervention policy is believed to be not only ineffective in altering the level of the exchange rate ("leaning against the wind" to return the spot exchange rate to some target level), but also counterproductive, as it can increase the volatility of the exchange rate. Another view is that intervention operations can influence the level of the exchange rate, and can also "calm disorderly markets," thereby reducing exchange rate volatility. Finally, a skeptical group argues that intervention operations are of little import, as they do not affect either the level or the volatility of exchange rates (Dominguez, 1998).

There is a broad consensus in the literature that unsterilized intervention can affect nominal exchange rates by changing monetary supply and domestic interest rates. However, there is little in the way of consensus regarding the effects of sterilized intervention. Sterilized intervention (where the authorities take action to offset the effects of a change in official foreign assets on the domestic monetary base, leaving interest rates unchanged) alters the currency composition of domestic and foreign assets, and has been seen to affect the exchange rate through two principal channels (Mussa, 1981). First, the portfolio balance channel (where a change in the reserve holdings of the central bank induces private agents to revalue their portfolios of domestic and foreign assets); and second, the signaling channel (where the central bank uses foreign exchange operations to signal forthcoming changes in monetary policy). Dominguez and Frankel (1993) conclude that central bank intervention can be effective by changing expectations of future exchange rates. However, Edison (1993) argues that the horizon of intervention effects is rather short-lived. In a recent survey of the experience of the 1990s, Sarno and Taylor (2001) suggest that intervention is effective, and occurs through both the portfolio balance and signaling channels.

In this paper we examine the efficacy of official intervention in foreign exchange markets, using data on the Australian experience over the last two decades. We examine two related empirical questions. First, has intervention influenced the direction of exchange rates? Second, has intervention dampened the volatility of exchange rate movements? The Australian central bank, the Reserve Bank of Australia (RBA), has released data on its daily net purchases of foreign exchange over the period 1983-2001, which were undertaken for intervention purposes in order to affect the exchange rate. Analysis of the Australian dollar market is of interest as while the Australian economy is relatively small, the Australian dollar is the seventh largest currency traded in world markets—a reflection of its importance as the

world's leading commodity-based currency.[2] [3] In addition, the long-standing tradition of intervention by the RBA in the Australian dollar market provides many observations for testing hypotheses regarding the efficacy of official intervention (Kim and Sheen, 2002). In this connection, the intervention data cover the period of the late 1990s, which was marked by heightened exchange rate volatility as a consequence of the Asian economic crisis and the Russian financial crisis, and which prompted large-scale intervention in the Australian dollar market by the Reserve Bank of Australia.

In early work on the effectiveness of official intervention in the Australian dollar market, Andrew and Broadbent (1994) used Friedman's (1953) "profits test" to determine if intervention by the RBA had been successful in stabilizing the foreign exchange market. They conclude that in the first ten years of the float of the Australian dollar (1983-94), the RBA's foreign exchange operations yielded large profits, suggesting that its actions were stabilizing as it tended to buy (sell) foreign exchange when its price was low (high). In recent years there has been a surge in empirical studies of official intervention in the Australian dollar exchange market. Makin and Shaw (1997) conclude that official intervention during 1983-93 had neither influenced the direction of the exchange rate nor smoothed exchange rate volatility. However, Kearns and Rigobon (2002) support the view that over the period 1986-93, RBA intervention did have an economically significant contemporaneous effect in moving the level of the exchange rate. Using daily data covering the 1983-97 period, Kim and Sheen (2002) and Kim, Kortian, and Sheen (2002) conclude that the RBA was prudent in choosing when to intervene, and that its intervention typically exerted a stabilizing influence on exchange rate volatility. In addition, Rogers and Siklos (2003) find little evidence that the RBA was successful in moderating extreme outcomes in foreign exchange rate fluctuations during the 1990s.

In recent years the RBA has made substantial changes in the way it conducts its foreign currency operations. The rapid growth of foreign exchange markets and the dwindling supply of Australian government securities has induced the central bank to change its practices, by sterilizing intervention with foreign currency swaps rather than using open market operations. Since the RBA actively intervenes in the foreign exchange market, this paper investigates the main principles that govern RBA intervention policy and assesses its effectiveness. Our work has several innovations. First, we apply event analysis to examine whether official RBA intervention has affected the level of the U.S. dollar-Australian dollar

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[2] See Chen and Rogoff (2002) and Cashin, Céspedes, and Sahay (2002) for recent work on the Australian dollar as a commodity currency.

[3] The average daily turnover in the U.S. dollar/Australian dollar market was estimated to be about US$47 billion in April 2001 (Bank for International Settlements, 2002). In comparison, the average daily turnover in April 2001 for the U.S. dollar/euro, U.S. dollar/sterling, and U.S. dollar/Canadian dollar currency pairs were US$354 billion, US$125 billion, and US$57 billion, respectively.

exchange rate. Second, we utilize a GARCH framework to analyze whether intervention has influenced the volatility of the exchange rate, using intervention and exchange rate data, over a longer period (1984-2001) than previous studies.

The paper is set out as follows. In Sections II and III we review the foreign currency operations of the Reserve Bank of Australia, describing its objectives, methods, and intervention activities in the 18-year period from December 1983 (when the Australian dollar was floated) to December 2001. In Sections IV and V we explore the effects these official intervention transactions have had on the behavior of the Australian dollar exchange rate. First, we use an event study to evaluate the effectiveness of intervention, by examining the direct effect on the level of the exchange rate. We find that over the period December 1997 to December 2001, the RBA has had some success in its intervention. On days when the RBA intervenes to purchase Australian dollars, the currency often strengthens either immediately or over time by reversing a previously depreciating trend. Second, we investigate the effects of RBA intervention policies on exchange rate volatility over the floating rate period, using a GARCH specification. Unlike our results for the level effects on the exchange rate, our findings for volatility indicate that RBA intervention operations generally tend to be associated with an increase in exchange rate volatility, which suggests that official intervention may have added to market uncertainty. Some concluding comments are offered in Section VI.

II. Official Intervention: Policy and Practice

There are four broad reasons why the Reserve Bank of Australia intervenes in the foreign exchange market:[4]

- *Misalignment.* The RBA intervenes in the foreign exchange market to influence the level of the exchange rate. Usually this happens when the RBA believes that the market is driving the exchange rate away from its "equilibrium" value and intervenes to break the momentum.

- *Calming a disorderly market.* The RBA intervenes to calm the market and so prevent it from becoming disorderly. Rapid movement in the exchange rate may at times threaten the orderly functioning of the market, leading to a widening of spreads and at times loss of liquidity. This action also serves to discourage the market from becoming one-sided.

- *Signaling/accommodating monetary policy.* Intervention may be used to signal future changes to monetary policy or possibly calm expectations if monetary policy is changed unexpectedly, which might otherwise lead to a loss in confidence and thereby induce an unwarranted move in the exchange rate.

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[4] See Rankin (1998), various RBA Annual Reports, and Kim and Sheen (2002).

- *Reserve building*. The RBA intervenes to maintain an inventory of net foreign currency assets.

III. Data and Summary Statistics

The exchange rate data used in this study are daily interbank close mid-rate quotes, expressed as U.S. dollars per Australian dollar (US$/A$), so that a rise in the exchange rate is an appreciation of the Australian dollar. Official intervention is defined as any sale (negative) or purchase (positive) of foreign assets (U.S. dollars) against domestic assets in the foreign exchange market, measured in current Australian dollars, and is taken from Sharratt (1994) and its biannual updates.[5] Both the intervention and exchange rate data have been provided by the Reserve Bank of Australia. The exchange rate and intervention data are daily in frequency, and cover the period January 2, 1984 to December 31, 2001 (4,696 trading day observations).

Summary statistics indicate that negative skewness and positive kurtosis are typically present in the series for log change in the U.S. dollar-Australian dollar exchange rate. Box-Pierce Q-statistics for higher-order serial correlation reveal that the squared log change data contain much more autocorrelation than the unsquared data—this is indicative of the presence of conditional heteroskedasticity in the exchange rate series.[6]

The RBA conducts all of its interventions in the spot market versus the U.S. dollar, and sterilizes these operations. When the RBA intervenes, it simply sells (buys) Australian dollars, typically in exchange for U.S. dollars. If the RBA is of the view that the exchange rate has deviated excessively from (overshot) its equilibrium level, it would "lean against the wind" by selling (buying) Australian dollars at a time of an appreciating (depreciating) exchange rate. Historically, the RBA used open market transactions in Australian government securities (typically in the form of repurchase ("repo") obligations) to sterilize

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[5] The intervention series (which has been used to represent RBA intervention in all previous studies) comprises net purchases of foreign assets purely for official intervention purposes, and net purchases of foreign exchange by the RBA on behalf of the Australian Government. However, the RBA has discretion as to when it enters the foreign exchange market to restore the reserves of foreign exchange it may have sold to the government, and so it is appropriate to use this aggregate intervention series to measure of the overall effect of the RBA's intervention in the Australian dollar market (see Andrew and Broadbent, 1994).

[6] For the full sample period (January 1984-December 2001), the log change in the US$/A$ exchange rate exhibits: significant skewness and leptokurtosis (-0.51 and 7.48, respectively; a value of zero corresponds to the normal distribution); and substantial serial correlation (Q-statistic values of 38.92 (0.007) and 701.99 (0.000) for log change and squared log change, respectively (with p-values in parentheses)).

its intervention. However, with the stock of Australian government debt diminishing sharply in recent years, the Bank has shifted toward using foreign currency swaps for sterilizing its intervention, just as it does in conducting domestic monetary policy. On rare occasions, the RBA has used other intervention methods. For example, during the Russian financial crisis and the collapse of Long Term Capital Management in 1998, the RBA purchased call options on the Australian dollar (the right to buy Australian dollars at a predetermined price), instead of simply buying Australian dollars outright. This operation enabled the Bank, for a limited outlay, to stimulate significant market demand for the currency, as dealers who sold the options sought to hedge their positions against the possibility that the options would be exercised.[7]

Figure 1 and Tables 1-3 provide a profile of the Australian dollar vis-à-vis the U.S. dollar and the daily intervention operations (net foreign exchange purchases) undertaken by the Reserve Bank over the 18-year period from January 1984 to December 2001. Since the floating of the Australian dollar, the RBA has intervened on approximately 40 percent of all trading days, with daily interventions averaging A$57 million on those days when it did intervene.[8] The single largest daily intervention, A$1.3 billion, occurred in 1992, and the largest yearly average intervention occurred in 1998, which involved large net purchases of Australian dollars. The data suggest an asymmetry in the nature of the RBA's intervention operations. Specifically, net sales of foreign exchange are less frequent (occurring only 30 percent of the time), but on average these transactions tend to be larger (A$83 million) relative to net purchases of foreign exchange (A$47 million). Moreover, there appears to be a gradual change in the RBA's approach to intervention over time. Intervention has tended to become more targeted toward supporting the Australian dollar, reflecting the decline in the currency's value in recent years. In addition, in common with many other OECD central banks, official intervention by the RBA has also become less frequent. Over the past decade, for instance, the RBA has intervened on only 5 percent of all trading days.

The Reserve Bank has classified its intervention strategies in the post-float period into five distinct subperiods (Rankin, 1998). They are as follows: (i) December 1983 to June 1986, when the RBA is characterized as engaging in smoothing and testing of the market; (ii) July 1986 to September 1991, when the RBA was actively engaged in intervention (largely sales of the Australian dollar to ameliorate the rise in the US$-A$ exchange rate); (iii) October 1991 to November 1993, when the RBA intervened less frequently, but with greater intensity (largely involving purchases of the Australian dollar to support the exchange rate); (iv) December 1993 to June 1995, when the RBA did not intervene; and (v) July 1995

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[7] For details, see Rankin (1998) and Reserve Bank of Australia *Annual Report and Financial Statement, 1999.*

[8] In contrast, Neely (2001) finds that over the same period, 14 (mostly industrial country) central banks intervened (using either sterilized or unsterilized transactions) on average on only about 4-5 percent of all trading days.

Table 1. Reserve Bank of Australia's Yearly Average of Intervention (Absolute Volume), 1984-2001

(In millions of Australian dollars)

Year	Mean	Median	Max	Min.	Std. Dev.	Number of Intervention Days
1984	9.8	7.6	81.2	1.1	9.7	141
1985	19.1	13.6	90.0	2.0	17.9	105
1986	43.3	20.0	661.0	0.5	72.5	190
1987	95.1	39.8	1,025.8	0.5	148.0	198
1988	53.2	37.2	489.4	0.5	59.1	225
1989	52.8	40.0	255.5	0.5	49.0	176
1990	55.3	40.8	461.3	0.5	63.6	141
1991	51.5	32.5	349.0	0.5	55.3	80
1992	163.0	77.0	1,305.0	4.1	261.5	78
1993	124.9	73.5	712.2	8.0	137.5	42
1994	...	...	...	...	...	...
1995	7.8	22.9	74.1	2.8	16.9	69
1996	43.7	30.0	285.7	0.1	47.8	189
1997	50.2	23.2	250.0	0.1	70.6	18
1998	163.9	49.7	1188.5	13.4	281.4	27
1999	30.5	25.3	119.9	1.9	21.3	84
2000	80.8	50.0	319.0	1.9	86.8	29
2001	91.6	50.0	335.0	3.0	98.0	25
Total	57.4	30.0	1,305.0	0.1	101.9	1,817

Sources: Reserve Bank of Australia and authors' calculations.

Table 2. Reserve Bank of Australia's Yearly Averages of Daily Net Purchases of Foreign Currency, 1984-2001

(In millions of Australian dollars)

Year	Mean	Median	Max	Min.	Std. Dev.	Number of Intervention Days
1984	6.9	5.9	32.2	1.1	5.4	42
1985	7.4	7.0	17.0	2.0	4.8	17
1986	44.3	21.0	661.0	0.5	77.2	116
1987	75.4	40.0	553.7	0.5	83.9	143
1988	54.1	38.0	489.4	0.5	59.8	217
1989	45.3	37.8	201.0	0.5	37.5	158
1990	53.4	40.0	461.3	0.5	62.7	130
1991	46.9	33.8	199.0	0.5	38.8	56
1992	30.6	15.3	150.0	4.1	43.6	10
1993	44.4	50.0	50.0	29.9	8.8	5
1994	...	...	...	...	...	...
1995	28.2	22.9	74.1	5.0	16.8	68
1996	43.7	30.0	285.7	0.1	47.8	189
1997	37.8	18.8	176.4	0.1	53.1	16
1998	30.3	29.1	63.5	13.4	13.7	15
1999	30.5	25.3	119.9	1.9	21.3	84
2000	44.4	21.2	250.0	1.9	63.9	13
2001	25.8	25.0	50.0	3.0	19.6	4
Total	46.6	30.0	661.0	0.1	56.9	1,283

Sources: Reserve Bank of Australia and authors' calculations.

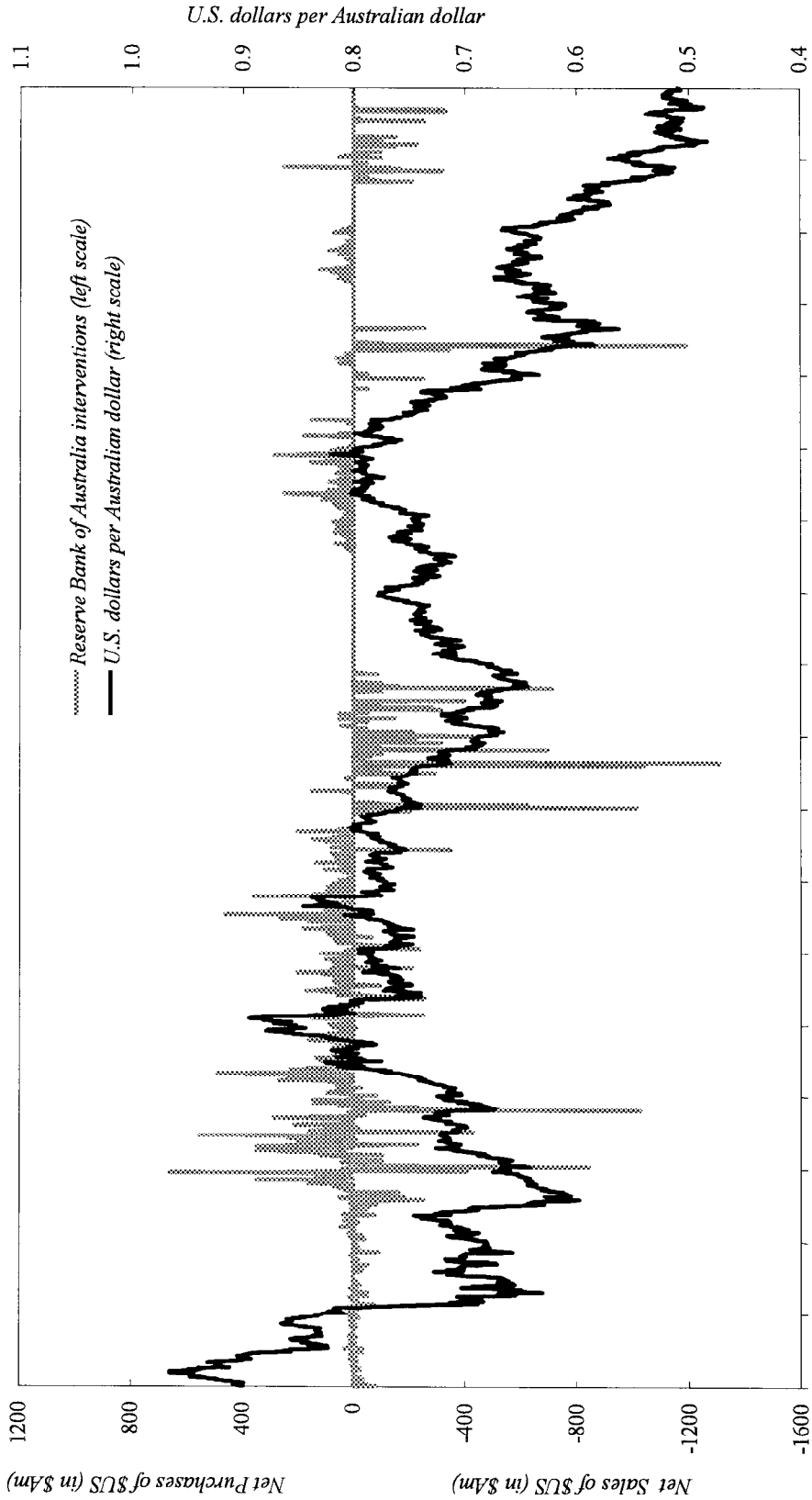
Table 3. Reserve Bank of Australia's Yearly Averages of Daily Net Sales of Foreign Currency, 1984-2001

(In millions of Australian dollars)

Year	Mean	Median	Max	Min.	Std. Dev.	Number of Intervention Days
1984	-11.1	-8.9	-1.1	-81.2	10.9	99
1985	-21.3	-15.0	-2.0	-90.0	18.7	88
1986	-41.7	-19.0	-1.0	-411.0	64.8	74
1987	-146.3	-30.0	-0.6	-1,025.8	240.1	55
1988	-27.1	-22.4	-0.7	-81.0	26.8	8
1989	-118.0	-112.8	-17.9	-255.5	81.9	18
1990	-78.3	-52.5	-6.0	-237.0	72.1	11
1991	-62.3	-29.3	-0.7	-349.0	82.1	24
1992	-182.5	-88.7	-5.0	-1,305.0	274.4	68
1993	-135.8	-93.0	-8.0	-712.2	143.2	37
1994	...	...	...	...	...	...
1995	-2.8	-2.8	-2.8	-2.8	...	1
1997	-150.0	-150.0	-50.0	-250.0	141.4	2
1998	-330.8	-222.0	-50.0	-1,188.5	363.6	12
1999	...	...	...	...	...	...
2000	-110.4	-74.0	-20.0	-319.0	93.3	16
2001	-104.2	-75.0	-3.0	-335.0	102.2	21
Total	-83.3	-28.0	-0.6	-1,305.0	163.1	534

Sources: Reserve Bank of Australia and authors' calculations.

Figure 1. Australia: Foreign Currency Operations and Level of Exchange Rate, 1984-2001



Source: Reserve Bank of Australia

to December 2001, when the RBA initially intervened to build reserves (involving sales of Australian dollars) and subsequently (especially during 1998 and 2001) engaged in Australian dollar purchases to support the exchange rate.

Intervention data for the full period and each of the five subperiods is given in Table 4. The probability of official intervention is clearly much lower in the last subperiod than during the first two subperiods. Net purchase of foreign currency is the dominant form of intervention during the second and fifth subperiods. The intensity of intervention in the third subperiod is indicated by the large absolute value of interventions, and the occurrence of the post-float maximum daily sale of foreign currency (of A$1,305 million).

IV. Evaluation of the Effectiveness of Intervention—An Event Study

There is an extensive literature on the effect of intervention in foreign exchange markets.[9] The bulk of this literature in the 1980s and early 1990s was directed at testing whether intervention affected the exchange rate by influencing market participants' portfolio decisions through changes in the relative supplies of domestic and foreign assets that affect asset returns (referred to as the "portfolio" channel) or by providing information of the possible future stance of monetary policy (referred to as the "signaling" channel). There is now a general consensus in the literature that intervention does not affect the exchange rate through the portfolio channel and some, but by no means conclusive, evidence that intervention works through the signaling channel.[10]

There are many ways in which the effectiveness of official intervention can be evaluated. More recent studies have used an event/case study approach to make such assessments, and they have yielded some evidence that intervention may be effective.[11] These studies assess whether intervention has been successful at stopping or delaying any given trend in the exchange rate. This is the approach adopted in this paper to analyze the effectiveness of official intervention on the level of the exchange rate.

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[9] For comprehensive surveys, see Edison (1993) and Sarno and Taylor (2001).

[10] See, for example, Edison (1993), Dominguez and Frankel (1993), and Galati and Melick (2002).

[11] See, for example, Catti, Gali, Rebeccini (1993), Obstfeld (1995), Edison (1998), Fatum and Hutchison (1999), and Fatum (2000). For a description of the advantages and disadvantages of the event study approach, in comparison with standard time series techniques to analyze the effects of intervention on the behavior of exchange rates, see Fatum (2000).

Table 4. Summary Statistics on RBA Foreign Exchange Market Operations
(January 1984–December 2001)

	January 1984–December 2001	January 1984–June 1986	July 1986–September 1991	October 1991–November 1993	December 1993–June 1995	July 1995–December 2001
Number of trading days	4696	651	1370	566	413	1696
Number of intervention days	1817	322	923	131	0	441
Probability of intervention	0.39	0.49	0.67	0.23	0	0.26
Average absolute value of transactions, $Am	57	14	63	144	0	51
Number of purchases of foreign currency	1283	99	780	15	0	389
Average value of purchases of foreign currency, $Am	47	9	56	35	0	37
Number of sales of foreign currency	534	223	143	116	0	52
Average value of sales of foreign currency, $Am	83	16	100	159	0	158
Maximum daily sale of foreign currency, $Am	1305	90	1026	1305	0	1189
Maximum daily purchase of foreign currency, $Am	661	44	661	150	0	286

Source: Reserve Bank of Australia and authors' calculations.

Notes: Net purchases and sales are of foreign currency (U.S. dollars), valued in millions of Australian dollars ($Am). The full sample begins on January 2, 1984 and ends on December 31, 2001.

In the event study approach, an *episode of intervention* is defined as a period of days with official intervention in foreign exchange in one direction, including up to 10 days of no further intervention activity between the initial and subsequent intervention transactions.[12] To evaluate the effectiveness of intervention, and in line with previous empirical work, two criteria are used: (i) intervention leads to an immediate reversal of the exchange rate trend (referred to as a "short-term" effect); and (ii) intervention leads to a continued reversal of the exchange rate trend one month after the intervention episode has ended (referred to as a "long-term" effect). Given these two criteria, there are four possible outcomes:

- *Definite success (DS).* Both a short-term and long-term reversal of trend in the exchange rate occur after an intervention episode.

- *Failure (F).* There is neither a short-term nor a long-term reversal in the trend in the exchange rate after an intervention episode.

- *Short-term success (SS).* There is only a short-term effect on the exchange rate, but no long-term effect after an intervention episode.

- *Long-term success (LS).* There is no short-term effect on the exchange rate, but there is a long-term effect after an intervention episode.

Reflecting the perceived shift in Australia's approach to official intervention, the empirical analysis in this Section is limited to the period January 1997 to December 2001. Table 5 shows that, during this period, the RBA has engaged in 31 distinct intervention episodes for a total of 173 days.[13] Slightly more than half of these operations were in support of the Australian dollar. The length of the intervention episodes varied, with 9 cases consisting of one-day operations and the remaining 22 cases consisting of multiple days of intervention. The longest episodes occurred in 1999, when the RBA was trying to rebuild its stock of net foreign reserves following heavy official intervention during 1998.

Table 6 provides a detailed description of the 18 episodes of intervention directed at supporting the Australian dollar over the period January 1997 to December 2001. For over half of these episodes, the total size of intervention was less than A$250 million; however there was one episode in June 1998 when the RBA intervened by in excess of A$2.5 billion.

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[12] This relatively wide window is used so that "reasonably" close intervention transactions are treated as single episodes, on the assumption that they are undertaken as a result of the same policy decision.

[13] A shift in Reserve Bank intervention (becoming less frequent and involving larger amounts) started to occur in the early 1990s. However, this event study focuses only on the most recent period (1997-2001) and thus limits the number of intervention episodes to 31.

Table 5. Total Episodes of Daily Intervention in the Australian Dollar Market
(January 1997 - December 2001)

Episode	Dates	Initial Intervention (A$m)	Total Amount of Intervention (A$m)	Number of Days of Intervention	Number of Days of Episode	Type of Intervention
1	2/26/97–3/4/97	53	404	6	13	Build
2	5/2/97–5/2/97	20	20	1	1	Build
3	5/22/97–5/22/97	150	150	1	1	Build
4	12/17/97–12/17/97	-250	-250	1	1	Support
5	1/5/98–1/9/98	-50	-100	2	5	Support
6	2/27/98–3/27/98	40	367	12	21	Build
7	4/22/98–4/24/98	29	87	3	3	Build
8	5/13/98–5/19/98	-343	-577	2	5	Support
9	6/4–18/98	-936	-2628	4	11	Support
10	8/26–31/98	-100	-665	4	4	Support
11	4/20/99–7/8/99	12	1507	46	58	Build
12	8/5/99–8/18/99	8	56	4	10	Build
13	9/6/99–10/26/99	9	770	24	37	Build
14	11/9–16/99	21	90	4	6	Build
15	12/6/99–12/6/99	2	2	1	1	Build
16	12/20/99–1/21/00	9	461	17	25	Build
17	9/6/00–9/28/00	-82	-556	6	17	Support
18	10/26/00–11/20/00	-50	-1140	8	18	Support
19	11/22/00–11/22/00	250	250	1	1	Build
20	11/23/00–11/23/00	-20	-20	1	1	Support
21	12/13/00–12/13/00	-50	0	1	1	Support
22	1/11–17/01	-100	-150	4	5	Support
23	1/19–23/01	30	50	2	3	Build
24	1/24/01–1/24/01	-50	-50	1	1	Support
25	2/5–6/01	-100	-115	2	2	Support
26	3/6–14/01	-150	-400	3	7	Support
27	4/2/01–4/2/01	-100	-100	1	1	Support
28	4/22/01–4/24/01	-75	-225	2	2	Support
29	7/6–12/01	-30	-286	2	5	Support
30	7/27–31/01	-11	-31	2	3	Support
31	9/4–27/01	-335	-781	5	18	Support

Source: Authors' calculations.

Notes: In column (7), "Build" denotes intervention (net purchases of foreign currency) in order to increase net foreign reserves; "Support" denotes intervention (net sales of foreign currency) in order to appreciate the Australian dollar.

Table 6. Success of Individual Intervention Operations—Net Sales of Foreign Currency
(January 2, 1997—December 31, 2001)

Dates	Initial Amount of Intervention (A$m)	Total Amount of Intervention (A$m)	Level of Exchange rate (US$/A$)	Direction of Exchange Rate Prior to Intervention 1/	Direction of Exchange Rate on Day of Intervention 2/	Direction of Exchange Rate After Intervention 3/	Number of Days of Intervention	Number of Days of Episode	Short-Term Effectiveness 4/	Long-Term Effectiveness 5/	Overall Assessment 6/
12/17/97–12/17/97	-250	-250	0.66	-5.70	1.20	-0.91	1	1	Yes	No	SS
01/05–09/98	-50	-100	0.65	-3.55	-0.20	4.69	2	5	No	Yes	LS
05/13–19/98	-343	-577	0.63	-2.47	-0.39	-5.40	2	5	No	No	F
06/04–18/98	-936	-2628	0.61	-4.66	-0.36	2.99	4	11	No	Yes	LS
08/26–31/98	-100	-665	0.58	-5.94	-0.90	4.60	4	4	No	Yes	LS
09/06–28/00	-82	-556	0.57	-3.47	-1.17	-5.51	6	17	No	No	F
10/26/00–11/20/00	-50	-1140	0.52	-5.43	-1.56	4.51	8	18	No	Yes	LS
11/23/00–11/23/00	-20	-20	0.52	-0.46	2.40	5.91	1	1	Yes	Yes	DS
12/13/00–12/13/00	-50	-50	0.54	3.89	0.44	2.38	1	1	No	No	F
01/11–17/01	-100	-150	0.55	2.38	-0.32	-5.01	4	5	Yes	Yes	DS
01/24/01–01/24/01	-50	-50	0.55	-0.50	-0.68	-5.08	1	1	No	No	F
02/05–06/01	-100	-115	0.55	-3.43	-0.38	-6.81	2	2	No	No	F
03/06–14/01	-150	-400	0.52	-5.44	-0.87	-6.59	3	7	No	No	F
04/02/01–04/02/01	-100	-100	0.49	-7.85	-0.67	5.56	1	1	No	Yes	LS
04/22–24/01	-75	-225	0.50	2.08	-2.08	2.47	2	2	Yes	No	SS
07/06–12/01	-30	-286	0.51	-0.83	-1.18	1.96	2	5	No	Yes	LS
07/27–31/01	-11	-31	0.51	-1.80	-0.33	5.34	2	3	No	Yes	LS
09/04–27/01	-335	-781	0.52	1.35	-0.38	3.47	5	18	Yes	No	SS

Source: Authors' calculations.

1/ Percentage change in exchange rate 21 days prior to intervention episode.
2/ Percentage change in exchange rate on day of intervention.
3/ Percentage change in exchange rate 21 days after the intervention episode.
4/ Short-term effectiveness determined by whether direction of change in exchange rate on day of intervention reverses trend in exchange rate from previous 21 days.
5/ Long-term effectiveness determined by whether direction of change in exchange rate 21 days after intervention reverses trend in exchange rate from trend prior to intervention.
6/ Assessment: DS = Definitely successful; F = Failure (no reversal of exchange rate trend); SS= Short-term success (reverses exchange rate trend over day); LS = Long-term success (trend in exchange rate reverses after intervention).

Identification of the success of each episode is based on whether the depreciating trend in the exchange rate (as catalogued in Table 6) was halted. The results suggest that the RBA has been reasonably successful, with 12 of the 18 episodes classified as either a definite, short-term, or long-term success. Two of the episodes are classified as definitely successful (DS)—the Australian dollar appreciated immediately and continued to appreciate in the month following intervention. However, 6 intervention episodes are judged to be outright failures (F)—the exchange rate failed to appreciate on the day of intervention and failed to appreciate in the subsequent month. In the remaining episodes, the currency strengthened either immediately (SS) or reversed its depreciating trend (LS). Four of the episodes are somewhat unique, in that it appears that the RBA intervened by selling foreign currency while the Australian dollar was appreciating. These intervention episodes might be best characterized as "leaning with the wind" (intervention in support of the Australian dollar while the dollar is appreciating), as opposed to the more traditional supportive intervention ("leaning against the wind") that was employed in the other episodes.

In summary, we have found some support for the notion that the RBA has been effectively "leaning against the wind" in changing the trend movement in the Australian dollar exchange rate. However, it will also be of interest to determine whether this effective altering of the level of the exchange rate has affected the volatility of exchange rate movements, which is the object of the following section.

V. The Effects of Intervention on the Volatility of the Exchange Rate

Another common motive for central bank intervention is to try to calm disorderly exchange markets. In the empirical literature, this motive has generally been interpreted as suggesting that the objective of intervention is to dampen exchange rate volatility. Until relatively recently little research was devoted to examining the effects of central bank intervention on the volatility of exchange rates.[14] To address this issue, it is necessary to measure volatility. There are broadly two ways to measure exchange rate volatility: using time series econometric techniques (see Dominguez, 1997 and 1998; and Kim, Kortian, and Sheen, 2001) or using market-determined option prices (see Bonser-Neal and Tanner, 1996; Murray et al., 1997; and Edison, 1998). Both approaches have their merits, but owing to the lack of readily available options data, the effects of RBA intervention are modeled by investigating the statistical properties of changes in the daily exchange rate on the days of intervention, using a GARCH model. The null hypothesis in this analysis is that intervention has no effect on volatility of the exchange rate with two alternative possibilities:

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[14] The main reason for this is the lack of daily data on amounts of central bank intervention. Many central banks have been reluctant to release these figures, and most researchers have had to rely on imperfect, low frequency proxies (such as the change in central bank reserve holdings), which makes studying volatility more difficult. The Reserve Bank of Australia, the U.S. Federal Reserve Board, and the Bank of Japan are among those few central banks that have released this daily intervention data to researchers.

(i) intervention is associated with lower volatility; or (ii) intervention is associated with higher volatility.[15]

Figure 2 looks at the daily intervention operations and the unconditional volatility of the exchange rate (as measured by the square of the percentage change in the logarithm of the exchange rate). Periods of high volatility in the exchange rate appear to match up well with large net sales of foreign currency by the RBA, particularly in 1998 and 2001.

Since the expected sign on the impact of intervention is ambiguous, Table 7 examines the basic trends of exchange rate volatility (as measured by the square of the percentage change in the logarithm of the exchange rate) around intervention days. In particular, it examines the percentage of days volatility increases following intervention; the percentage of days volatility increases above the previous trend average prior to intervention; and the percentage of days volatility increases both prior to and following intervention. The results indicate that volatility increases about 60 percent of the time following RBA intervention, and that RBA intervention occurs less than half of the time in the presence of increasing exchange rate volatility.

It has long been observed that exchange rate changes tend to be leptokurtic (that is, they exhibit "fat tails"). Volatility clustering is also common, whereby large changes in exchange rates tend to be followed by further large changes, and small changes tend to be followed by further small changes—visual inspection of Figure 2 reveals this volatility clustering quite clearly. In this paper, we follow Baillie and Bollershev (1989) and Dominguez (1998) and use a univariate generalized autoregressive conditional heteroskedastic (GARCH) model to account for time-varying conditional variance structure of the errors in the first-differenced exchange rate series. The hypothesis of interest is the extent to which changes in the conditional mean and conditional variance of the Australian dollar exchange rate are associated with changes in the intervention variables.

The basic regression model, with GARCH(1,1) errors, is as follows:

$$\Delta s_t = \varphi_0 + \sum_{i+1}^{4} \varphi_i D_{it} + \varphi_5 INT_t + \varepsilon_t \tag{1}$$

$$\varepsilon_t \mid I_{t-1} \sim N(0, h_t) \tag{2}$$

[15] It is also plausible that central bank intervention may have no impact on exchange rate volatility, given the magnitude of the Australian dollar foreign exchange market. For example, in 2001 the average net daily volume of trading in the U.S. dollar-Australian dollar market was about US$47 billion, while the average amount of U.S. dollars bought and sold by the RBA was about US$48 million (A$92 million). Central bank intervention of typically 0.10 percent of the overall market is not likely to have a major impact on equilibrium exchange rate.

$$h_t = \delta_0 + \sum_{i+1}^{4} \delta_i D_{it} + \delta_5 \mid INT_t \mid + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1} \tag{3}$$

where Δs_t is the log change in the U.S. dollar-Australian dollar exchange rate between period t and t-1 (a positive value is an appreciation of the Australian dollar); D_{it} are day of the week dummy variables (that is, D_{it}= 1 on Mondays); INT_t is the variable capturing RBA reported intervention operations (a positive value indicates net purchases of foreign currency); $\mid\ \mid$ is the absolute value operator; I_t is the information set through time t-1; and ε_t is the disturbance term. Equation (1) measures the direct effect of official intervention on exchange rate changes; equation (2) states that regression residuals will be modeled as a GARCH process; and equation (3) describes the conditional variance. Following Dominguez (1998), in the GARCH conditional mean equation the intervention variables are included in a manner such that a negative coefficient on intervention indicates that a net purchase of foreign currency depreciates the Australian dollar. In the GARCH conditional variance equation, intervention variables appear in absolute value form. The parameters of the model were estimated using the quasi-maximum likelihood approach of Bollerslev and Wooldridge (1992), which yields standard errors that are robust to nonnormality in the density function underlying the residuals.

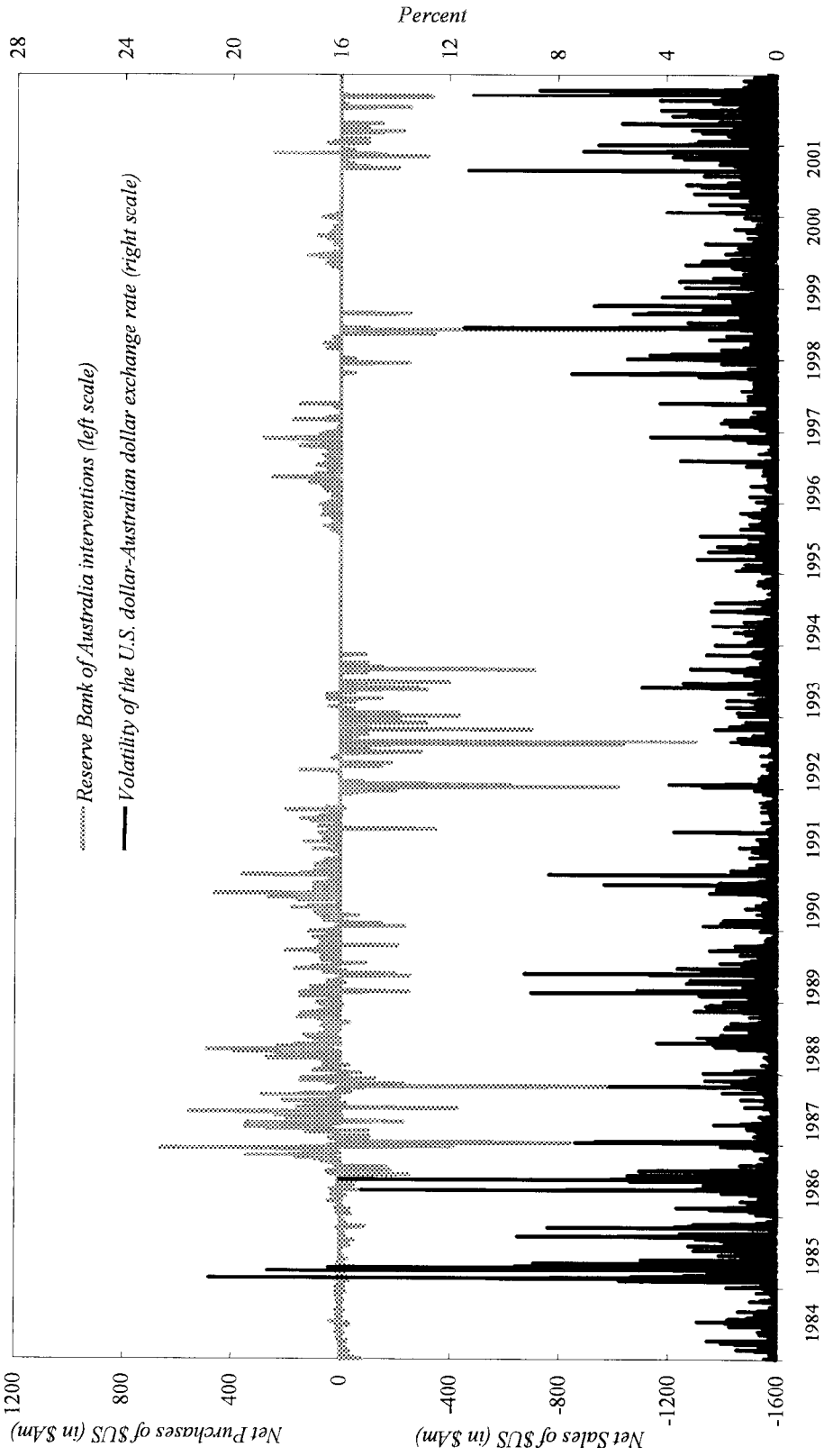
Table 7. Trends in Exchange Rate Volatility 1/
(percent of sample)

	Does Volatility Increase Following Intervention? 1/	Does Volatility Increase Prior to Intervention? 2/	Does Volatility Increase throughout the 'Event' Window? 3/
Whole sample (1814 observations)	62	46	10
1995–2001 (438 observations)	63	44	9
1997–2001 (180 observations)	62	43	5

Source: Authors' calculations.

1/ Volatility is measured as unconditional volatility, and is the square of the percentage change in the logarithm of the exchange rate).
2/ Measured as the percentage of days average volatility over the subsequent five days is higher than volatility on the day of intervention.
3/ Measured as the percentage of days average volatility on the five days prior to intervention is higher than the previous 'local' trend in volatility.
4/ Measured as the percentage of days average volatility continues to increase (that is, volatility increases both prior and subsequent to intervention).

Figure 2. Australia: Foreign Currency Operations and Volatility of Exchange Rate, 1984-2001



Source: Reserve Bank of Australia

Table 8 reports the coefficients of the conditional mean and conditional variance equations for the GARCH model estimated for the whole sample period (January 1984–December 2001) and for the subperiods that represent distinct phases of RBA intervention (see Section III). The results provide strong support for the ability of the GARCH models to correct the heteroskedasticity in the exchange rate data. Standard model diagnostic statistics reveal far less evidence of autocorrelation in the standardized residuals (relative to the decisive rejection of the null hypothesis of white noise in the exchange rate series), and the extent of nonnormality in the standardized residuals is much less than in the unadjusted residuals.

Has RBA intervention been effective at altering the level of the exchange rate? If net U.S. dollar-purchasing intervention by the RBA ($|INT_t| > 0$) depreciated the Australian dollar ($\Delta s_t < 0$) the sign on the intervention coefficient in the conditional mean equation would be negative. However, the estimates of the conditional mean equation reveal that the coefficient on the contemporaneous intervention variable is positive and statistically significant, for the full sample and all subsamples. This indicates that on those days when official net purchases of U.S. dollars in the foreign exchange market occur, the U.S. dollar-Australian dollar exchange rate tends to be rising—sales of Australian dollars by the RBA tend to be associated with an *appreciation* of the Australian dollar. One interpretation of these results is that RBA intervention was not "effective" at moderating exchange rate movements.

An alternative interpretation of this result might be that while interventions by the Reserve Bank were ineffective in reversing the direction of movement of the exchange rate, its intervention actions succeeded in dampening the current trend movement of the exchange rate. In this sense, the RBA's intervention actions were consistent with "leaning against the wind" behavior, in that its net purchases (sales) of foreign assets coincided with an appreciation (depreciation) of the Australian dollar (see also Baillie and Osterberg, 1997). That is, the RBA's interventions have tended to stabilize the conditional mean of daily changes in the U.S. dollar-Australian dollar exchange rate—these results broadly support the findings garnered from the event analysis of Section IV.[16] In addition, there is little evidence of statistically significant day-of-the-week effects (not reported in Table 8)—this is consistent with few differences in the volume of trading information affecting the conditional mean on particular days.

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[16] When official interventions were carried out the Australian dollar was typically depreciating quite heavily, and so it is reasonable to conclude that the depreciation was largely independent of the RBA's intervention activities. However, while the effect of official intervention on the level of the exchange rate is statistically significant, it is not economically significant. In particular, for the full sample period a A$100 million purchase of foreign currency is associated with a rather small 0.15 percent appreciation of the Australian dollar (Table 8).

Table 8. Daily Exchange Rate GARCH Model: Results for the Conditional Mean and Conditional Variance Equations

	January 1984–December 2001		January 1984–June 1986		July 1986–September 1991		October 199–November 1993		December 1993–June 1995	July 1995–December 2001	
	Coeff.	(*p*-value)	Coeff.	(*p*-value)	Coeff.	(*p*-value)	Coeff.	(*p*-value)		Coeff.	(*p*-value)
Conditional mean equation											
φ_0	-0.016	(0.313)	-0.036	(0.271)	-0.019	(0.452)	-0.012	(0.697)		-0.033	(0.302)
φ_5	0.0015*	(0.000)	0.031*	(0.000)	0.002*	(0.000)	0.0011*	(0.000)		0.002*	(0.000)
Conditional variance equation											
δ_0	-0.033	(0.094)	0.013	(0.678)	-0.048*	(0.039)	-0.012	(0.635)		-0.048	(0.386)
δ_1	0.085*	(0.011)	0.162	(0.158)	0.082*	(0.028)	0.046	(0.369)		0.067	(0.431)
δ_2	0.009	(0.739)	-0.166	(0.054)	0.085*	(0.016)	-0.011	(0.778)		0.005	(0.937)
δ_3	0.063*	(0.033)	0.047	(0.351)	0.065	(0.078)	0.027	(0.429)		0.157*	(0.034)
δ_4	0.022	(0.543)	-0.013	(0.858)	0.054	(0.248)	-0.002	(0.967)		0.014	(0.893)
α	0.074*	(0.000)	0.138*	(0.050)	0.161*	(0.000)	0.049*	(0.000)		0.021*	(0.001)
β	0.918*	(0.000)	0.701*	(0.000)	0.792*	(0.000)	0.941*	(0.000)		0.978*	(0.000)
$\delta_5 \times 10^2$	0.0055*	(0.038)	0.733*	(0.009)	0.02*	(0.009)	0.007*	(0.045)		0.002	(0.559)
Diagnostics for standardized residuals											
Log *L*	-4007.937		-566.676		-1054.412		-318.607			-1592.62	
$Q(20)$	26.606	(0.147)	32.586*	(0.037)	14.608	(0.798)	34.128*	(0.025)		34.450*	(0.023)
$Q^2(20)$	26.759	(0.142)	23.120	(0.283)	24.078	(0.239)	14.014	(0.830)		20.601	(0.421)
M_3 (skewness)	-0.405		0.181		-0.275		-0.482			-0.143	
M_4 (kurtosis)	5.782		5.776		4.967		4.185			4.966	
Iterations	20		15		26		55			25	
Included observations	4696		651		1370		566			1696	

Source: Authors' calculations.

Notes: The model of equations (1) – (3) was estimated with Bollerslev-Wooldridge (1992) robust standard errors; numbers reported in parenthesis are *p*-values. An asterisk (*) indicates significance at the 5 percent level. Log *L* denotes the value of the log-likelihood function; $Q(20)$ and $Q^2(20)$ denote the Box-Pierce *Q*-statistic with 20 lags of the standardized residuals and squared standardized residuals; m_3 and m_4 denote the standard measures of skewness and kurtosis—a value of zero corresponds to the normal distribution; "Iterations" is the number of iterations taken to converge to the final maximum likelihood estimates; and "Included observations" is the number of days with intervention transactions. There was no exchange intervention by the Reserve Bank of Australia during the December 1993-June 1995 subperiod. The numbers in parentheses are asymptotic *p*-values.

The conditional variance equation satisfies the standard tests of robustness (well-defined variance and covariance), in that ARCH(α) and GARCH(β) terms are both positive and statistically significant (Table 8). In addition, ($\alpha+\beta$) is typically close to unity, indicating that volatility shocks are rather persistent. Unlike the conditional mean results, there is some evidence of significant day-of-the-week effects of intervention on the volatility of the exchange rate—for the full sample, exchange rate volatility increased by 0.08 and 0.06 on Mondays and Wednesdays, respectively. The estimated coefficients on the absolute value of intervention (δ_5) are positive and statistically significant for all estimation subsamples except for the last—indicative that on days of official intervention (either the purchase or sale of U.S. dollars for foreign exchange) the volatility of the exchange rate increased.[17] This result suggests that the (typically-secret) intervention operations of the RBA may have sent ambiguous signals (of both its intervention operations and future monetary policy) to the foreign exchange market, and consequently added some uncertainty to the market (Diebold and Nerlove 1989).

However, while it appears that official intervention has had a *statistically* significant effect on exchange rate volatility, it is of interest to assess its *economic* significance. In particular, how large is the impact of official intervention on the volatility of the exchange rate? One method of assessing the impact of intervention on exchange rate volatility is to calculate the percentage of the conditional variance that can be explained by RBA intervention (see Cuddington and Liang (2000)). The initial impact of intervention operations on the conditional volatility of the Australian dollar exchange rate in equation (3) is: $impulse_t = \delta_5 * |INT_t|$. These impulses are then perpetrated through the AR(1) process in the conditional variance equation to determine the cumulative effect on the conditional variance: $cum_t = \delta_5 * |INT_t| + \beta * cum_{t-1}$. The calculations show that, on average, the initial impact of intervention operation ($impulse_t/h_t$) explains 0.48 percent of the conditional variance over the full sample, while the cumulative effects of dollar purchases (cum_t/h_t) explain only 1.29 percent of the conditional variance over the same period. Based on these results, reducing the intervention operations of the RBA would be expected to yield only modest

[17] The absolute value of intervention is used, such that no distinction is made between purchases and sales of dollars. In testing the robustness of these results, different model specifications (EGARCH and GARCH-in-Mean) were tried, as well as different ways of specifying intervention such as a dummy variable, size of intervention, and whether this was the first day of intervention or part of a series of intervention. The results generally were consistent across the various specifications. In addition, very similar results were obtained for the conditional mean and conditional variance models when the log change in the trade-weighted index-Australian dollar exchange rate was used as Δs_t in equation(1) instead of the log change in the U.S. dollar-Australian dollar exchange rate.

gains in terms of reduced exchange rate volatility. In contrast, Figure 3 shows the cumulative effects of intervention as a percentage of the conditional variance over the January 1984—December 2001 period. During those periods when the RBA intervened heavily in support of the Australian dollar, in particular 1986-87, 1992 and 1998, intervention explains about 30, 40 and 20 percent of the conditional variance (using the cum_t/h_t measure), respectively.

The results from the various volatility equations indicate that intervention and exchange rate volatility are often highly correlated, but it is not clear if there is a causal relationship, that is, if volatility causes intervention or rather the other way around. This raises the issue of whether official intervention is exogenous, or whether past exchange rate changes influence the RBA's decision to intervene. Table 9 shows the results of pairwise Granger-causality tests and indicates that intervention tends to "cause" (help predict) the increase in exchange rate volatility, while exchange rate volatility does not Granger-cause intervention. The finding that intervention tends to increase exchange market volatility may be consistent with an alternative interpretation of how official intervention works to calm disorderly markets. By raising market uncertainty, intervention would increase the risk associated with taking a large open position in the exchange market, and thereby, force market participants to reconsider their positions.

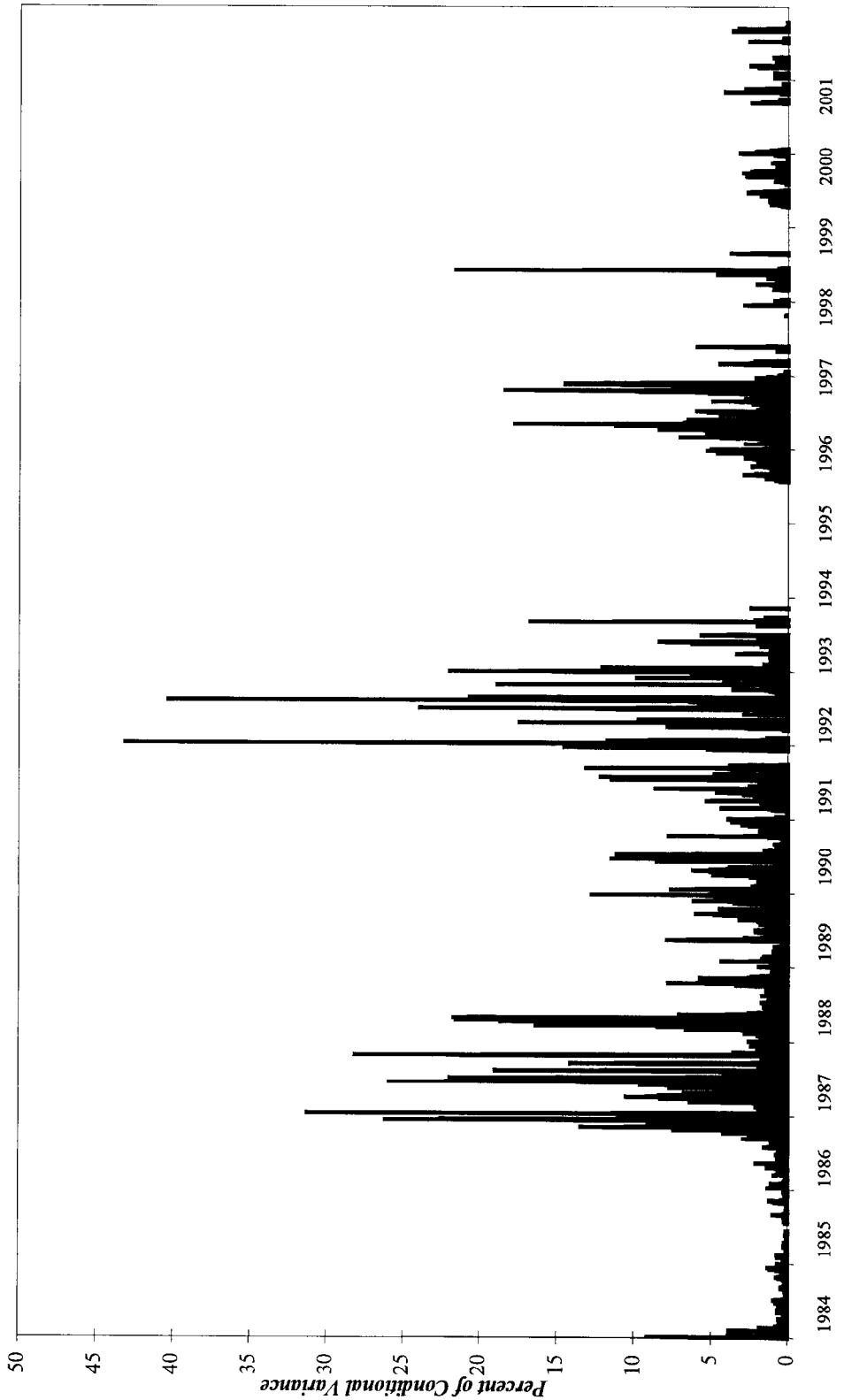
Table 9. Pairwise Granger Causality Test 1/
(p-values)

	January 1984–December 2001	January 198–June 1986	July 1986–September 1991	October 1991–November 1993	July 1995–December 2001
Intervention → Volatility 2/	0.00	0.00	0.00	0.00	0.00
Volatility → Intervention 3/	0.08	0.05	0.62	0.03	0.54

Source: Authors' calculations.

1/ The table reports the p-values for Granger-causality test (with ten lags); large values indicate that one cannot reject the relevant null hypothesis.
2/ Null hypothesis is that (absolute) intervention does not Granger-cause (help predict) exchange rate volatility.
3/ Null hypothesis is that exchange rate volatility does not Granger-cause (help predict) absolute intervention.

Figure 3. Percent Contributions of Cumulative Intervention to Conditional Exchange Rate Volatility, 1984-2001



VI. Conclusion

In this paper we examine the effects of official intervention by the Australian central bank on the level and variability of the U.S. dollar-Australian dollar exchange rate. We consider daily Reserve Bank of Australia intervention and exchange rate data over the 18-year period since the floating of the Australian dollar in December 1983. Using an event study and estimation of a model with time-varying conditional variance, we have two main findings. First, the empirical evidence suggests that the intervention activities of the Reserve Bank of Australia (Australian dollar-support intervention) do not consistently influence the level of the exchange rate. However, there is some indication that intervention is carried out to "lean against the wind," with Australian dollar sales tending to coincide with an appreciating Australian dollar. Second, we find that the conditional variance of the exchange rate is positively related to the magnitude of official intervention operations (there is little evidence of successful "market calming"). An important caveat is that while official intervention is found to be statistically significant in affecting exchange rate volatility, the actual share of exchange rate volatility attributable to official intervention is very small. The empirical evidence also supports the hypothesis that Granger causality is unidirectional from intervention to exchange rate volatility. The apparent success of official intervention in affecting the level of the Australian dollar exchange rate appears to have come at the expense of increased volatility of exchange rate movements, which may be indicative of greater uncertainty in the foreign exchange market regarding future official intervention operations.

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