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Swedish Intervention and the Krona Float, 1993-2002

Owen F. Humpage and Javiera Ragnartz*

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Abstract

Using a set of standard success criteria, we show that Riksbank foreign-exchange interventions between 1993 and 2002 lacked forecast value; that is, the observed number of successes was not significantly greater—and usually substantially smaller—than the number one would anticipate given the martingale nature of exchange-rate movements. Under some success criteria, the Riksbank exhibited *negative* forecast value, implying that the market could have profited by taking a position opposite that of the bank. Moreover, the likelihood of success was independent of such conditioning factors as the amount of a transaction, the time lapses between interventions, or the number of foreign currencies involved. As such, Riksbank intervention could not operate through an expectations or signaling channel.

Keywords: Intervention, foreign-exchange rates, Swedish Riksbank, krona.

JEL: F3, G15.

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Swedish Intervention and the Krona Float, 1993-2002

1. Introduction

In November 1992, the Swedish Riksbank abandoned its currency peg and allowed the krona to float for the first time since the 1930s. Nevertheless, the Riksbank has often intervened when exchange rates seemed inconsistent with market fundamentals or when exchange rates appeared excessively volatile. With an overnight interest-rate-target guiding its monetary policy, however, the Riksbank automatically sterilizes its foreign-exchange transactions. Because sterilized foreign-exchange intervention has no effect on monetary variables, or other basic macroeconomic determinants of exchange rates, economists have long questioned its effectiveness.

Overall, the existing research has failed to show that sterilized intervention provides monetary authorities with an instrument for systematically determining exchange rates independent of their other monetary-policy objectives, but the empirical literature clearly indicates that intervention *sometimes* provokes the desired exchange-rate response, at least in the short term. (Sarano and Taylor 2001, Baillie, Humpage, and Osterberg 2000, Almekinders 1995, and Edison 1993 survey the literature.) These empirical studies have not isolated the mechanism or channel through which sterilized operations might affect exchange rates, but economists offer two possibilities. Some suggest that because information is costly, official intervention may sometimes affect traders' expectations by "signaling" new information to the market.¹ When a monetary authority takes an open position in a foreign currency, it has—like any speculator—an expectation about an imminent change in that currency, which is based on private information. That information may include priority knowledge of impending monetary-

policy changes or an informed interpretation of generally available data (see Montgomery and Popper, 2001). If the monetary authority has superior information, knowledge that it is intervening will cause private traders to alter their prior estimates of near-term exchange-rate movements. Others suggest that interventions—especially large transactions—might temporarily affect exchange rates as market makers shuffle their inventories to cover their positions in the wake of an official purchase or sale of foreign exchange (see Evans and Lyons 2001 and Lyons 2001). Market makers generally do not like to maintain sizable open positions, especially overnight, and will alter their quotes to eliminate their exposure (see Cheung and Chinn 2001). If the monetary authority sterilizes its transactions, as is typical, this inventory effect should be temporary, at most.

In this paper, we examine the forecast value of official Swedish Riksbank intervention between January 6, 1993, and November 15, 2002. We first present a set of success criteria that link specific near-term exchange-rate movements (e.g., appreciations or depreciations) with same-day interventions. Then, following Henriksson and Merton (1981) and Merton (1981), we test if the number of observed successes exceeds the amount that would randomly occur given the martingale nature of exchange-rate changes. Interventions that prove successful significantly more often than random have *positive forecast value*, implying that private market participants could benefit from observing the central bank in the market. Similarly, interventions that are successful significantly less often than random have *negative forecast value*, implying that private market participants could benefit on average by taking a position opposite that of the central bank.

We find that official Riksbank sales and purchases of foreign exchange had no obvious forecast value. In fact, under some success criteria the Riksbank demonstrated

negative forecast value. Moreover, we find that particular aspects of the operations, such as the size of a transaction, the amount of time that has elapsed since the previous transaction, and the number of foreign currencies simultaneously involved in an intervention, had no bearing on the likelihood of a success. These results suggest that Swedish intervention generally does not affect exchange markets through an expectations (or signaling) channel or through an inventory-adjustment mechanism.

Our overall results are similar to Aguilar and Nydahl (2000), the only other paper to study official Riksbank intervention during the krona float.² They investigated daily interventions in Swedish kronor against German marks and U.S. dollars from January 7, 1993, to December 30, 1996, using a multivariate extension of the GARCH-M model and found little evidence that Riksbank interventions affected either the level or the volatility of day-to-day, krona-dollar or krona-mark exchange rates. Whether they specified intervention in amounts or as a bivariate dummy variable had no bearing on the results. They then isolated one-year subperiods. Using OLS, Aguilar and Nydahl found significant effects for both exchange rates—in a manner consistent with the announced Riksbank objectives—only in 1995. For 1996, they found a significant—but negative—coefficient for intervention against German marks. This coefficient is not inconsistent with the announced policy of leaning against the wind, but it cannot be unambiguously interpreted. Aguilar and Nydahl also find that intervention affects implied volatility as computed from option prices for these currencies. The intervention coefficients are often significant, but their signs change from year to year, indicating that intervention sometimes increases and sometimes decreases implied volatility.

Our paper proceeds as follows: The next section provides a basic description of the official Swedish intervention data. Section 3 discusses the four specific success criteria that we use to evaluate the data and an all-encompassing general success criterion. This section also provides a brief discussion of the timing conventions embodied in our methodology. Section 4 explains the Henderson and Merton test and evaluates the forecast value of Riksbank intervention under our five success criteria. Section 5 uses probit regressions to see if other events or the way in which the Riksbank conducted its interventions influenced the likelihood of success as defined by the general success criterion. Section 6 summarizes our results.

2. Swedish Interventions

The Riksbank executes all of its interventions in the local foreign-exchange market. The Swedish currency market is quite small, amounting to only 2.6% of the global market (Bank for International Settlements, 2002). Banks are the main market participants with interbank transactions accounting for 95% of total trades. Furthermore, the market is highly concentrated; the three largest players—all domestic banks—account for most trading. In contrast to the turnover in the global foreign-exchange market, turnover in the Swedish market has been growing since 1998. Daily turnover in the spot market currently amounts to approximately SEK 36 billion, while daily turnover in the whole market amounts to SEK 185 billion. Normally, traders undertake as much as 85% of the spot transactions via electronic brokering. More than 90% of the spot activity concerns the krona-euro exchange rate, while most forward-market transactions involve the krona-dollar exchange rate.

Between January 6, 1993, and November 15, 2002, the Riksbank intervened in the Swedish market on 179 business days; 165 (91%) of these involved transactions in German marks or—after December 31, 1998—euros (see table 1).³ All of these involved spot market transactions, but on 5 of these 165 days, the Riksbank also intervened in the forward market against German marks. On 17 of the 165 days, the Riksbank also intervened in the spot market against U.S. dollars; and on just 14 other occasions, the Riksbank intervened only in dollars. By far, most interventions were krona purchases, suggesting that overall the Riksbank was more likely to react to krona depreciations, particularly against the key European currency, than to krona appreciations.

The Riksbank maintains its intervention data in U.S. dollar equivalents. The median size of an official transaction—\$30 million—fell substantially below the average, \$68 million, because a relatively small number of very large transactions skewed the distribution. Riksbank interventions against dollars were somewhat smaller than interventions against German marks and euros.

Table 2 provides information about the persistence of Riksbank interventions. Columns 2 through 5 show the probability of an intervention episode lasting one, two, five, or ten days in a row. These columns indicate that Riksbank purchases of Swedish kronor, especially against German marks or euros, were substantially more persistent than Riksbank sales of Swedish kronor. Columns 6 through 9 provide information about the lapse of days between episodes of intervention. These columns show that the typical interval between official purchases of kronor against German marks and euros was much smaller than the lapse of time between sales of kronor. This assessment is also generally

true about transactions against dollars, but a few very large intervals skew the average for purchases of Swedish kronor in this segment of the market.

Figures 1, 2, and 3 provide an overview of Riksbank interventions. Figure 1 presents Riksbank interventions in German marks or euros against movements in the krona-mark exchange rate. (To extend the data beyond 1998, we constructed a notional krona-mark exchange rate from the krona-euro rate.) Figure 2 shows official purchases and sales of U.S. dollars against movements in the krona-dollar exchange rate. The Riksbank also evaluates its interventions in terms of a trade-weighted krona index, which we show in figure 3 along with total Riksbank interventions against German marks, euro, and U.S. dollars. An increase in the trade-weighted krona indicates a krona depreciation.

3. Success Criteria

We investigate the efficacy of Swedish interventions using four specific success criteria and an aggregate criterion that incorporates the first four. We count the number of successes consistent with each criterion and, following Henriksson and Merton (1981) and Merton (1981), evaluate them under the assumption that our success count is a hypergeometric random variable. Leahy (1995) applied the Henriksson and Merton procedure to an analysis of the profitability of U.S. intervention. Humpage (1999, 2000) used it to analyze the success of U.S. interventions, and Chaboud and Humpage (2005) adopted it to study recent Japanese interventions.

The test assumes that the Swedish Riksbank does not directly affect underlying exchange-rate fundamentals when it intervenes. The Swedish Riksbank conducts monetary policy using an overnight repurchase-rate target, a procedure that requires the Riksbank to automatically sterilize any intervention that alters the supply of bank

reserves in breach of the target (see Heikensten and Borg, 2002). To be sure, the monetary authorities could adjust the target interest rate to achieve an exchange-rate objective, but then standard desk operations in domestic securities could achieve the new interest-rate and corresponding exchange-rate targets without creating a foreign-exchange exposure (see Bonser-Neal, et al., 1998 and Humpage 1999). On only one occasion during the krona float, October 9, 1996, did the Riksbank change its target interest rate and intervene in a consistent direction.⁴ On that date the Riksbank bought dollars and lowered its interest-rate target somewhat. The dollar appreciated against the krona.

Although sterilized interventions also alter the currency composition of publicly held government debt, empirical evidence suggests that intervention does not affect exchange rates through a portfolio-balance channel. In studies of this mechanism, the estimated elasticities are either statistically insignificant or too small to be of practical relevance. Dominguez and Frankel (1993) is a noteworthy exception. All in all, our assumption that Riksbank interventions have no direct effect on underlying macroeconomic fundamentals seems valid.

We do not generally know what criteria the Riksbank uses to evaluate its interventions, and these may change from episode to episode. Although our success criteria may not encompass all possibilities, the success criteria that we define below are reasonable, frequently mentioned in intervention literature, and readily verifiable. In accordance with the Henriksson and Merton procedure, we define each success criterion for purchases and sales of foreign exchange separately.

3.1. Appreciate or depreciate the krona.

The first set of success criteria presumes that when the Riksbank buys or sells foreign exchange, it expects the krona to immediately appreciate or depreciate, as the case may be, against an appropriate exchange rate. Accordingly, our first success criterion for official sales of foreign exchange with kronor is:

$$1) \quad W1b_t = \begin{cases} 1 & \text{if } I_t < 0, \text{ and } \Delta S_t < 0, \text{ and} \\ 0 & \text{otherwise.} \end{cases}$$

The corresponding criterion for official purchases of foreign exchange is:

$$2) \quad W1s_t = \begin{cases} 1 & \text{if } I_t > 0, \text{ and } \Delta S_t > 0, \text{ and} \\ 0 & \text{otherwise.} \end{cases}$$

In these expressions, I_t refers to an intervention on day t , with negative and positive values indicating sales or purchases of foreign exchange, respectively. We measure the exchange-rate change, ΔS_t , over the shortest interval that the data permit. For the krona-dollar and the krona-mark exchange rates, we calculate the daily change from the opening of the Stockholm market to its close. All Riksbank interventions occur in this time interval. For the trade-weighted krona index, we measure ΔS_t as the difference between today's closing rate and yesterday's closing rate in the Stockholm market. A rise in the trade-weighted krona index indicates a depreciation of the krona.

3.2. Reverse the direction of the exchange-rate movement.

Our second, more stringent, set of success criteria assumes that when the Riksbank intervenes, it expects the krona to reverse its recent depreciation or appreciation. Accordingly, an intervention sale of foreign exchange is successful if:

$$3) \quad W2b_t = \begin{cases} 1 & \text{if } I_t < 0, \text{ and } \Delta S_t < 0, \text{ and } \Delta S_{t-1} > 0, \text{ and} \\ 0 & \text{otherwise.} \end{cases}$$

An intervention purchase of foreign exchange is successful if:

$$4) \quad W2s_t = \begin{cases} 1 & \text{if } I_t > 0, \text{ and } \Delta S_t > 0, \text{ and } \Delta S_{t-1} < 0, \text{ and} \\ 0 & \text{otherwise.} \end{cases}$$

3.3. Accentuate exchange-rate movements.

Our third set of success criteria assumes that the Riksbank sells or purchases foreign exchange when it believes that a recent krona appreciation or depreciation, as the case may be, will proceed at a faster clip. Reflecting this criterion:

$$7) \quad W3b_t = \begin{cases} 1 & \text{if } I_t < 0, \text{ and } \Delta S_t < \Delta S_{t-1}, \text{ and } \Delta S_{t-1} < 0, \text{ and} \\ 0 & \text{otherwise.} \end{cases}$$

$$8) \quad W3s_t = \begin{cases} 1 & \text{if } I_t > 0, \text{ and } \Delta S_t > \Delta S_{t-1}, \text{ and } \Delta S_{t-1} > 0, \text{ and} \\ 0 & \text{otherwise.} \end{cases}$$

3.4. Moderate exchange-rate movements.

Empirical estimates of intervention reaction functions typically report that monetary authorities attempt to smooth exchange-rate movements or lean against the wind (see Edison 1993, Almekinders 1995). Our final set of individual success criteria tests for this possibility. We assume that the Riksbank takes a position in the foreign-exchange market when it expects that a recent appreciation or depreciation has proceeded too quickly, will subsequently slow, but will not reverse itself. Accordingly,

$$5) \quad W4b_t = \begin{cases} 1 & \text{if } I_t < 0, \text{ and } \Delta S_t < \Delta S_{t-1}, \text{ and } \Delta S_t > 0, \text{ and } \Delta S_{t-1} > 0, \text{ and} \\ 0 & \text{otherwise.} \end{cases}$$

$$6) \quad W4s_t = \begin{cases} 1 & \text{if } I_t > 0, \text{ and } \Delta S_t > \Delta S_{t-1}, \text{ and } \Delta S_t < 0, \text{ and } \Delta S_{t-1} < 0, \text{ and} \\ 0 & \text{otherwise.} \end{cases}$$

3.5. General success criteria.

The following set of general success criteria aggregates the previous criteria:

$$9) \quad W5b_t = \begin{cases} 1 & \text{if } I_t < 0, \text{ and } \Delta S_t < 0, \text{ or } \Delta S_t < \Delta S_{t-1}, \text{ and} \\ 0 & \text{otherwise.} \end{cases}$$

$$10) \quad W5s_t = \begin{cases} 1 & \text{if } I_t > 0, \text{ and } \Delta S_t > 0, \text{ or } \Delta S_t > \Delta S_{t-1}, \text{ and} \\ 0 & \text{otherwise.} \end{cases}$$

We will use these general success criteria primarily in section 5.

3.6. *Timing convention.*

Some researchers may find our timing conventions unduly narrow and prone to miss relevant exchange-rate developments that occur beyond the event window (see Goodhart and Hesse 1993, and Fatum and Hutchison 2002). We might fail to count an intervention successful if the appropriate exchange-rate movement occurs beyond closing on day t . The chances of this type of error seem remote. Chang and Taylor (1998), Chueng and Chinn (2001), and Dominguez (2003), among others, suggest that exchange markets begin to respond to intervention within minutes or hours, not days. So, we should capture this movement in at least one of the success criteria even if complete adjustment extends beyond a single day. Alternatively, we may count an intervention successful even though the exchange-rate movement that led to that conclusion subsequently disappears. This occurrence is more problematic. Opening the event window, however, quickly causes overlap among interventions, making inferences about individual successes impossible. Consequently, we keep the event window narrow.

Because exchange-rate changes approximate martingale processes, we interpret successful interventions as highly persistent, if not permanent, shocks even though interventions often appear to “wear off” in a day or two. A successful intervention will send the exchange rate on an alternate path, but one still consistent with existing and

unchanged market fundamentals. Our methodology cannot answer questions about the duration of exchange-rate shocks.

4. Forecast Value

Given the martingale nature of exchange-rate changes, one would expect to observe a fairly high number of intervention successes merely by chance. To have forecast value, the frequency with which a particular exchange-rate pattern and intervention coincide—a success—must significantly exceed the frequency with which that exchange-rate pattern occurs irrespective of any intervention. If the krona appreciates against the dollar on 50% of the trading days, then one should not be surprised to find that 50% of all Riksbank official dollar sales are associated with krona appreciations.

We evaluate the probability of observing a specific number of successes under the assumption that their occurrence is a hypergeometric random variable. The hypergeometric distribution does not require individual events to be independent and does not depend on the presumed probability of an individual success.⁵ Our null hypothesis compares actual and expected successes. A low p-value indicates positive forecast value, and a very high p-value indicates negative forecast value.

Tables 3 through 6 present our results. The exchange rate, the intervention currencies, and the sample sizes vary across these four tables. The krona-mark exchange rate, for example, begins on February 4, 1993, while our krona-dollar and our trade-weighted krona exchange rates start on January 4, 1993.

The first column of each table lists the five sets of success criteria outlined in the previous section. Notice that the criteria labeled 1a and 1b in the tables create subsets of

the first criterion, although their union is not equal to the set described by criterion 1.

The second column in each table presents a count of the appropriate Riksbank interventions for each case, with foreign-exchange purchases and sales against kronor shown separately. Table 3, for example, shows that the Riksbank sold German marks on 137 days between February 5, 1993, and December 31, 1998, and bought German marks on 14 days.⁶ Column 3 lists the number of Riksbank interventions that were successful according to each criterion, while column 4 records those successes as a percentage of the total interventions. Of the 137 Swedish sales of German marks, for example, only 54, or 39.4%, were associated with a mark depreciation against the krona, indicating success.

The next two columns of tables 3 through 6—labeled *virtual* successes—describe exchange-rate movements independent of intervention. Column 5 records the number of times that the exchange rate moved in conformity with the corresponding success criterion, whether or not intervention took place. Between February 5, 1993, and December 31, 1998, for example, the mark depreciated on 741 days relative to the krona, counting days with and without official interventions (table 3). Column 6 expresses the data in column 5 as a percentage of the total observations in that sample. Table 3 contains 1540 observations, and the mark depreciated 48.1% of the time.

The next three columns of tables 3 through 6 relate to the hypergeometric distribution. Columns 7 and 8 show the expected number of successes and their standard deviations. The last column in each table shows the p-value associated with the null hypothesis: the probability of randomly observing a greater number of successes than we actually found.

The results in tables 3 through 6 unanimously suggest that Riksbank purchases and sales of foreign exchange lacked positive forecast value as measured under any of the success criteria. Because the Riksbank undertook only 14 purchases of marks and euros, only 28 sales of U.S. dollars, and only 3 purchases of U.S. dollars, inferences about the forecast values of these transactions are rather tenuous. Nevertheless, in no case throughout tables 3 to 6 does the p-value associated with the null hypothesis fall below 7%. Usually the p-values are much higher, indicating—as one can see in the tables—that the actual number of successes is far fewer, or at best not significantly higher, than the expected number.

The p-values associated with Riksbank sales of foreign exchange, which by far constitute the majority of interventions, are generally very high. In fact, under the criteria appreciate / depreciate and the general success criteria, the p-values almost always exceed 95%, suggesting *negative* forecast value; that is, the market profits on average by taking a position opposite that of the central bank. For those criteria that involve some inertia in the exchange rate's movement—accentuate or moderate of movements—the p-values drop, but never to a value that might confidently be associated with positive forecast value. Under the criterion of moderate movements, the number of successes usually exceeds the expected number, but the difference is never significant. Using the general success criteria to aggregate across all of the criteria, we find that only about half of the interventions were successful, but this fraction is much smaller than we would expect to randomly observe.

5. Predicting Success

The frequencies presented in tables 3 through 6 correspond to unconditional probabilities. Success, however, may be sensitive to the way in which the Riksbank conducts its operations—for example, the size or frequency of transactions—and to the simultaneous occurrence of other events, such as a change in the central bank's interest-rate target.

We show that successful Riksbank interventions were completely independent of such factors. We base this conclusion on three sets of probit regressions, with sample sizes equal to the total number of relevant interventions: 154 against German marks or euros, 31 against U.S. dollars, and 179 against marks, euros, or dollars. In each case, the bivariate dependent variable measures success according to the general success criterion with purchases and sales now combined. As noted in section 3, the general success criterion subsumes the individual criteria. Table 7 evaluates Riksbank interventions against marks or euros with the krona-mark exchange rate (extended using the euro) as the policy target. (Table 7 corresponds to the counts in table 4.) Table 8 judges Riksbank dollar interventions targeting the krona-dollar exchange rate. (Table 8 corresponds to table 5.) Table 9 considers Riksbank interventions against marks, euros, or dollars with the trade-weighted krona as the policy target. (Table 9 corresponds to table 6.)

The first four independent variables in probit tables refer to specific aspects of the intervention process. One might expect that large interventions or official transactions undertaken after a long period of no activity would have a bigger effect on the market than small, frequent interventions. The large transactions could be important in an

inventory-adjustment mechanism, and both size and lapse time could influence an information-signaling process. This was, however, not the case for Riksbank interventions. In none of the three experiments did either the size of the interventions (measured in kronor) or the time lapsed since the previous intervention (measured in days) have any bearing on the likelihood of success.

Similarly, one might expect that undertaking official transactions simultaneously in more than one segment of the foreign-exchange market could strengthen a signaling or an inventory-adjustment process. Concurrent dollar interventions do not increase the likelihood of success for interventions against marks and euros in table 7 nor for interventions against the trade-weighted krona in table 9. Turning the experiment around (table 8), we found that simultaneously intervening against marks or euros had no influence on the success of the Riksbank's dollar interventions. Similarly, purchasing German marks in the forward market, as the Riksbank did on five occasions, had no bearing on the likelihood of success (tables 7 and 9).

The remaining independent variables in the probit regressions attempt to control for factors that can affect krona exchange rates. These are changes in the repurchase rate, announcements of prospective changes in the repurchase rate, change in relevant money-market interest-rate spreads, and movements in the Stockholm stock index. One might expect that a change in these variables coincident with a Riksbank intervention would increase the chance (or the appearance) of success, but none of these variables had any bearing on the likelihood that Riksbank interventions would appear successful. We obtain this result even though we define each of these independent variables to correspond appropriately with an intervention purchase or sale. For example, we match

increases or announcements of increases in the repurchase rate with intervention sales of foreign exchange, since all of these will promote a krona appreciation. We similarly pair changes in money-market interest-rate spreads and changes in the stock market index with intervention purchases or sales.

6. Conclusions

During the krona float, official Riksbank sales and purchases lacked forecast value; that is, the observed number of successes, as defined under the various criteria listed in this paper, was either smaller or not significantly larger than the number that one would have randomly anticipated given the martingale nature of exchange-rate changes. In some cases, notably intervention sales of foreign exchange in anticipation of a krona appreciation, Riksbank sales had negative forecast value; that is, the market consistently seemed to move against the central bank. These results stand in stark contrast with previous studies using a similar technique: Humpage (1999, 2000) and Chaboud and Humpage (2005). Those papers, which investigated U.S. and Japanese interventions, found evidence of positive forecast value, although the results were not robust across all time periods and definitions of success. They also found—unlike the present paper—that larger interventions had a higher probability of success than small interventions. On the other hand, our results are similar to those of Aguilar and Nydahl (2000), who also found that Swedish interventions were generally ineffective.

The low success count may reflect the interactions between Swedish exchange-rate interventions and monetary policies. During the floating-rate period, Swedish interventions often seemed incompatible with the general thrust of monetary policy, as measured by movements in the repurchase rate (see figure 4). Throughout 1993, for

example, the Riksbank generally sold foreign exchange for kronor while simultaneously lowering the repurchase rate. Although the Riksbank routinely sterilizes its intervention, this apparent incompatibility could raise uncertainties about both policies and reduce the ability of intervention to affect market expectations. To test this hypothesis, we performed a success count, similar to those in tables 3 through 6, for interventions conducted between January 1, 1993, and June 15, 1994, when the Riksbank lowered its repurchase rate. We investigated total intervention in marks and dollars with the trade-weighted krona as the target rate. During this period, the Riksbank undertook 100 sales of foreign exchange and no purchases. Sixty percent of these were successful under the general success criterion, but the observed number of successes was somewhat lower than the expected number. The results for this period were not, however, substantially different from those for the entire sample period; if anything, the success rate was marginally higher. Consequently, the frequent contradiction between the objective of intervention and the thrust of Swedish monetary policy does not seem to explain the lack of positive forecast value.

The low success count may also reflect structural aspects of the Swedish foreign exchange market and the transparency of Riksbank monetary policy actions. The Swedish market for kronor is relative small and highly concentrated, with three large commercial banks dominating the trades. In such a market, a central bank may not possess a particular informational advantage. It may still signal new private information, such as an unanticipated change in monetary policy, but during the floating rate period, the Riksbank may have rendered this mechanism redundant by making frequent announcements of intended policy changes. In a small, concentrated market, moreover,

the monetary authorities may lose their relative advantage in aggregating existing news, a intervention channel that Montgomery and Popper (2001) describe. Market concentration may matter for the success of intervention.

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End Notes

¹ Mussa (1980) first suggested that central banks might signal future, unanticipated changes in monetary policy through their sterilized interventions. This hypothesis, which has not received overwhelming empirical support, may be too narrowly formulated (see Baillie, Humpage, and Osterberg 2000). Intervention could provide information about more than just monetary policy.

² Lindberg (1994) considered Swedish intervention from 1984 through 1990, the pegged-rate period.

³ The counts in the text pertain to the time period January 6, 1993, to November 15, 2002. The data in table 1 pertain to the specific time periods listed there. Table 1 corresponds to the data in tables 3 through 6.

⁴ On two occasions intervention and changes in policy seemed at cross purposes. On February 9, 1993, and May 25, 1993, the Riksbank lowered its target interest rate and bought kronor. Often, the general thrust of policy and intervention seemed at odds (see figure 4).

⁵ The moments of the hypergeometric distribution are defined in a manner that compares days of intervention against the entire sample, rather than against days of no intervention.

⁶ Five of the Riksbank purchases of German marks against Swedish kronor involved forward transactions. We did not remove these transactions from the data, since a

forward transaction could still have a signaling effect in the spot market. Forward operations would not, however, have an inventory effect in the spot market. Removing these five interventions lowers the success count slightly, but not enough to alter the statistical results (see table 3).

Table 1: Intervention Counts and Basic Statistics

Swedish interventions in all currencies <i>January 6, 1993, to November 15, 2002</i>	Count	Average	Median	Minimum	Maximum	Lower 25%	Upper 25%
			<i>(in millions of U.S. dollars)</i>				
Sales of forex; purchases of kronor	163	\$68.98	\$30.00	\$3.00	\$460.00	\$15.00	\$86.00
Purchases of forex; sales of kronor	16	\$62.81	\$41.50	\$3.00	\$251.00	\$29.75	\$89.25
Total (absolute value)	179	\$68.43	\$30.00	\$3.00	\$460.00	\$15.00	\$86.00
No interventions	2394						
Observations	2573						
Swedish interventions in German marks <i>February 4, 1993, to December 31, 1998</i>	Count	Average	Median	Minimum	Maximum	Lower 25%	Upper 25%
			<i>(in millions of U.S. dollars)</i>				
Sales of marks, purchase of kronor	137	\$65.32	\$30.00	\$3.00	\$419.00	\$15.00	\$76.00
Purchases of marks, sales of kronor	14	\$64.43	\$38.00	\$3.00	\$251.00	\$25.50	\$102.50
Total (absolute value)	151	\$65.24	\$31.00	\$3.00	\$419.00	\$15.00	\$78.00
No interventions	1389						
Observations	1540						
Swedish interventions in German marks or euros <i>February 4, 1993, to November 15, 2002</i>	Count	Average	Median	Minimum	Maximum	Lower 25%	Upper 25%
			<i>(in millions of U.S. dollars)</i>				
Sales of marks or euros, purchases of kronor	140	\$68.66	\$30.00	\$3.00	\$419.00	\$15.25	\$84.25
Purchases of marks or euros, sales of kronor	14	\$64.43	\$38.00	\$3.00	\$251.00	\$25.50	\$102.50
Total (absolute value)	154	\$68.28	\$32.00	\$3.00	\$419.00	\$15.75	\$86.50
No interventions	2397						
Observations	2551						
Swedish interventions in U.S. dollars <i>January 5, 1993, to November 15, 2002</i>	Count	Average	Median	Minimum	Maximum	Lower 25%	Upper 25%
			<i>(in millions of U.S. dollars)</i>				
Sales of dollars, purchases of kronor	28	\$43.43	\$28.00	\$3.00	\$240.00	\$12.75	\$50.00
Purchases of dollars, sales of kronor	3	\$34.33	\$33.00	\$30.00	\$40.00	\$30.00	\$40.00
Total (absolute value)	31	\$42.55	\$30.00	\$3.00	\$240.00	\$15.00	\$50.00
No interventions	2543						
Observations	2574						

Note: We chose these sample periods to correspond with those in tables 3 through 6.

Table 2: Probability and Persistence of Intervention

	Number of interventions in a row ¹				Days since last intervention			
	1	2	5	10	Mean	Median	Highest	Lowest
against German marks²								
purchases of Swedish kronor	8.9%	4.5%	2.1%	1.0%	7.8	1.0	279.0	1.0
sales of Swedish kronor	0.9%	0.1%	0.0%	0.0%	21.2	3.0	242.0	1.0
against German marks or euros³								
purchases of Swedish kronor	5.5%	2.8%	1.3%	0.6%	12.7	1.0	702.0	1.0
sales of Swedish kronor	0.5%	0.1%	0.0%	0.0%	21.2	3.0	242.0	1.0
against U.S. dollars⁴								
purchases of Swedish kronor	1.1%	0.5%	0.2%	0%	76.8	2.5	980.0	1.0
sales of Swedish kronor	0.1%	0.0%	0.0%	0.0%	18.3	9.0	42.0	4.0
against any currency⁵								
purchases of Swedish kronor	6.3%	3.3%	1.4%	0.7%	12.5	1.0	702.0	1.0
sales of Swedish kronor	0.6%	0.1%	0.0%	0.0%	3.4	2.0	10.0	1.0

Notes:

1. Probability of intervention conditional on days of consecutive intervention.
2. February 5, 1993, to December 31, 1998, 1540 observations
3. February 5, 1993, to November 15, 2002, 2551 observations
4. January 5, 1991, to November 15, 2002, 2574 observations
5. January 6, 1991, to November 15, 2002, 2573 observations

Table 3: Success Counts for Swedish Intervention against German Marks

February 5, 1993, to December 31, 1998, 1540 observations

Success criteria:	Interventions			Virtual		Hypergeometric Distribution		
	Total #	Successful #	%	Successes #	%	Expected Successes #	Standard Deviation #	p-value
<i>1. Appreciate / depreciate</i>								
Marks sold, kronor purchased	137	54	39.4	741	48.1	65.9	5.6	0.980
Marks sold, kronor purchased ¹	132	51	38.6	741	48.1	63.5	5.5	0.986
Marks purchased, kronor sold	14	1	7.1	791	51.4	7.2	1.9	0.999
<i>1a. Change direction</i>								
Marks sold, Kronor purchased	137	25	18.2	362	23.5	32.2	4.7	0.924
Marks sold, Kronor purchased ¹	132	24	18.2	362	23.5	31.0	4.7	0.922
Marks purchased, kronor sold	14	1	7.1	362	23.5	3.3	1.6	0.877
<i>1b. Accentuate movements</i>								
Marks sold, kronor purchased	137	16	11.7	188	12.2	16.7	3.7	0.513
Marks sold, kronor purchased ¹	132	14	10.6	188	12.2	16.1	3.6	0.665
Marks purchased, kronor sold	14	0	0.0	221	14.4	2.0	1.3	0.887
<i>2. Moderate movements</i>								
Marks sold, kronor purchased	137	19	13.9	202	13.1	18.0	3.8	0.334
Marks sold, kronor purchased ¹	132	18	13.6	202	13.1	17.3	3.7	0.365
Marks purchased, kronor sold	14	3	21.4	188	12.2	1.7	1.2	0.081
<i>3. General success</i>								
Marks sold, kronor purchased	137	73	53.3	947	61.5	84.2	5.4	0.975
Marks sold, kronor purchased ¹	132	69	52.3	947	61.5	81.2	5.3	0.985
Marks purchased, kronor sold	14	4	28.6	983	63.8	8.9	1.8	0.992
Total:	151	77	51.0					

Notes: Target currency is the German mark

1. Five forward mark sales removed.

Table 4: Success Counts for Swedish Intervention against Marks or Euro*February 5, 1993, to November 15, 2002, 2551 observations*

Success criteria:	Interventions			Virtual		Hypergeometric Distribution		
	Total #	Successful #	%	Successes #	%	Expected Successes #	Standard Deviation #	p-value
<i>1. Appreciate / depreciate</i>								
Forex sold, kronor purchased	140	56	40.0	1205	47.2	66.1	5.7	0.954
Forex purchased, kronor sold	14	1	7.1	1336	52.4	7.3	1.9	1.000
<i>1a. Change direction</i>								
Forex sold, kronor purchased	140	25	17.9	599	23.5	32.9	4.9	0.938
Forex purchased, kronor sold	14	1	7.1	598	23.4	3.3	1.6	0.875
<i>1b. Accentuate movements</i>								
Forex sold, kronor purchased	140	17	12.1	298	11.7	16.4	3.7	0.368
Forex purchased, kronor sold	14	0	0.0	382	15.0	2.1	1.3	0.897
<i>2. Moderate movements</i>								
Forex sold, kronor purchased	140	19	13.6	349	13.7	19.2	4.0	0.454
Forex purchased, kronor sold	14	3	21.4	303	11.9	1.7	1.2	0.074
<i>3. General success</i>								
Forex sold, kronor purchased	140	75	53.6	1559	61.1	85.6	5.6	0.963
Forex purchased, kronor sold	14	4	28.6	1644	64.4	9.0	1.8	0.993
Total	154	79	51.3					

Note: Target currency is the German mark, which we extend beyond December 31, 1998, using the euro.

Table 5: Success Counts for Swedish Intervention against Dollars

January 5, 1991, to November 15, 2002, 2574 observations

Success criteria	Interventions			Virtual		Hypergeometric Distribution		
	Total #	Successful #	%	Successes #	%	Expected Successes #	Standard Deviation #	p-value
<i>1. Appreciate / Depreciate</i>								
Dollars sold, kronor purchased	28	7	25.0	1234	47.9	13.4	2.6	0.989
Dollars purchased, kronor sold	3	2	66.7	1335	51.9	1.6	0.9	0.139
<i>1a. Change direction</i>								
Dollars sold, kronor purchased	28	3	10.7	657	25.5	7.1	2.3	0.952
Dollars purchased, kronor sold	3	1	33.3	656	25.5	0.8	0.8	0.162
<i>1b. Accentuate movements</i>								
Dollars sold, kronor purchased	28	2	7.1	286	11.1	3.1	1.7	0.617
Dollars purchased, kronor sold	3	0	0.0	349	13.6	0.4	0.6	0.354
<i>2. Moderate movements</i>								
Dollars sold, kronor purchased	28	5	17.9	325	12.6	3.5	1.7	0.132
Dollars purchased, kronor sold	3	0	0.0	285	11.1	0.3	0.5	0.297
<i>3. General success</i>								
Dollars sold, kronor purchased	28	12	42.9	1560	60.6	17.0	2.6	0.957
Dollars purchases, kronor sold	3	2	66.7	1624	63.1	1.9	0.8	0.251
Total:	31	14	45.2					

Note: Target currency is the U.S. dollar.

Table 6: Success Counts for Swedish Intervention against Marks, Euros, and Dollars

January 6, 1991, to November 15, 2002, 2573 observations

Success criteria:	Interventions			Virtual		Hypergeometric Distribution		
	Total #	Successful #	%	Successes #	%	Expected Successes #	Standard Deviation #	p-value
<i>1. Appreciate / Depreciate</i>								
Forex sold, kronor purchased	163	64	39.3	1250	48.6	79.2	6.2	0.992
Forex purchased, kronor sold	16	3	18.8	1265	49.2	7.9	2.0	0.988
<i>1a. Change direction</i>								
Forex sold, kronor purchased	163	29	17.8	584	22.7	37.0	5.2	0.929
Forex purchased, kronor sold	16	2	12.5	580	22.5	3.6	1.7	0.735
<i>1b. Accentuate movements</i>								
Forex sold, kronor purchased	163	19	11.7	317	12.3	20.1	4.1	0.546
Forex purchaseh, kronor sold	16	0	0.0	322	12.5	2.0	1.3	0.883
<i>2. Moderate movements</i>								
Forex sold, kronor purchased	163	26	16.0	331	12.9	21.0	4.1	0.093
Forex purchased, kronor sold	16	1	6.3	327	12.7	2.0	1.3	0.622
<i>3. General success</i>								
Forex sold, kronor purchased	163	90	55.2	1609	62.5	101.9	6.0	0.971
Forex purchased, kronor sold	16	4	25.0	1615	62.8	10.0	1.9	0.998
Total	179	94	52.5					

Note: Target currency is the Swedish trade-weighted krona index.

Table 7: Individual Factors in the Probit Regressions.

DEPENDENT VARIABLE: Swedish kronor / German mark or euro

INDEPENDENT VARIABLES	Constant	Coefficient	Log Likelihood	Likelihood Ratio Test
Constant only			-106.69	
Amount of intervention (abs. value)	-0.049 -0.37	0.000 0.99	-106.20	0.99
Time since last intervention (days)	0.009 0.09	0.002 0.96	-106.11	1.17
Dollar intervention (dummy)	-0.009 -0.085	0.387 1.172	-105.99	1.40
Forward intervention (dummy)	0.008 0.082	0.833 1.288	-105.78	1.83
Repo rate change (dummy) ¹	<i>none</i>	<i>none</i>	<i>none</i>	<i>none</i>
Announced repo rate change (dummy) ¹	0.016 0.162	5.917 0.003	-105.35	2.70
Interest rate spread (basis points) ^{1,2}	0.035 0.3468	-0.189 -0.21	-106.67	0.04
Stock market changes (index change) ¹	-0.036 -0.32	0.046 1.26	-105.89	1.61
Total observations:	154		<i>Critical</i>	
Successful interventions:	79		<i>Chi-square:</i>	3.84
Unsuccessful interventions:	75			

Notes:

1. Variable defined so that increases correspond with krona purchases and decreases correspond to krona sales.
2. Interest-rate spread is Swedish rate minus German mark rate.

Table 8: Individual Factors in the Probit Regressions.

DEPENDENT VARIABLE: *Swedish kronor / U.S. dollar*

INDEPENDENT VARIABLES	Constant	Coefficient	Log Likelihood	Likelihood Ratio Test
Constant only			-21.34	
Amount of intervention (abs. value)	-0.393 -1.34	0.001 1.28	-20.06	2.57
Time since last intervention (days)	-0.242 -1.00	0.002 1.15	-20.33	2.03
DM or euro intervention (dummy)	-0.566 -1.593	0.789 1.68	-19.89	2.90
Forward intervention (dummy)	<i>none</i>	<i>none</i>	<i>none</i>	<i>none</i>
Repo rate change (dummy) ¹	-0.168 -0.730	5.912 0.004	-20.53	1.63
Announced repo rate change (dummy) ¹	-0.218 -0.928	5.962 0.005	-19.67	3.35
Interest rate spread (basis points) ^{1,2}	-0.122 -0.54	0.007 0.00	-21.34	0.00
Stock market changes (index change) ¹	-0.220 -0.86	0.058 0.80	-21.01	0.66
Total observations:	31		<i>Critical</i>	
Successful interventions:	14		<i>Chi-square:</i>	3.84
Unsuccessful interventions:	17			

Notes:

1. Variable defined so that increases correspond with krona purchases and decreases correspond to krona sales.
2. Interest rate spread is Swedish rate minus U.S. rate.

Table 9: Individual Factors in the Probit Regressions.

DEPENDENT VARIABLE: Trade-weighted kronor

INDEPENDENT VARIABLES	Constant	Coefficient	Log Likelihood	Likelihood Ratio Test
Constant only			-123.85	
Amount of intervention (abs. value)	-0.074 -0.62	0.000 1.84	-121.99	3.72
Time since last intervention (days)	0.046 0.48	0.002 0.83	-123.44	0.82
Dollar intervention (dummy)	0.119 1.15	-0.322 -1.29	-123.01	1.68
Forward interventions (dummy)	0.058 0.61	0.196 0.34	-123.79	0.12
Repo rate change (dummy) ¹	0.070 0.75	-0.599 0.00	-123.10	1.50
Announced repo rate change (dummy) ¹	0.050 0.53	5.888 0.00	-122.55	2.60
Interest rate spread (basis points) ^{1,2}	0.090 0.91	-1.097 -0.87	-123.41	0.88
Stock market changes (index change) ¹	0.058 0.56	0.003 0.10	-123.84	0.01
Total observations:	179		<i>Critical</i>	
Successful interventions:	94		<i>Chi-square:</i>	3.84
Unsuccessful interventions:	85			

Notes:

1. Variable defined so that increases correspond with krona purchases and decreases correspond to krona sales.
2. Interest rate spread is Swedish rate minus trade-weighted rate.

Figure 1: Riksbank Interventions against German Marks or Euros

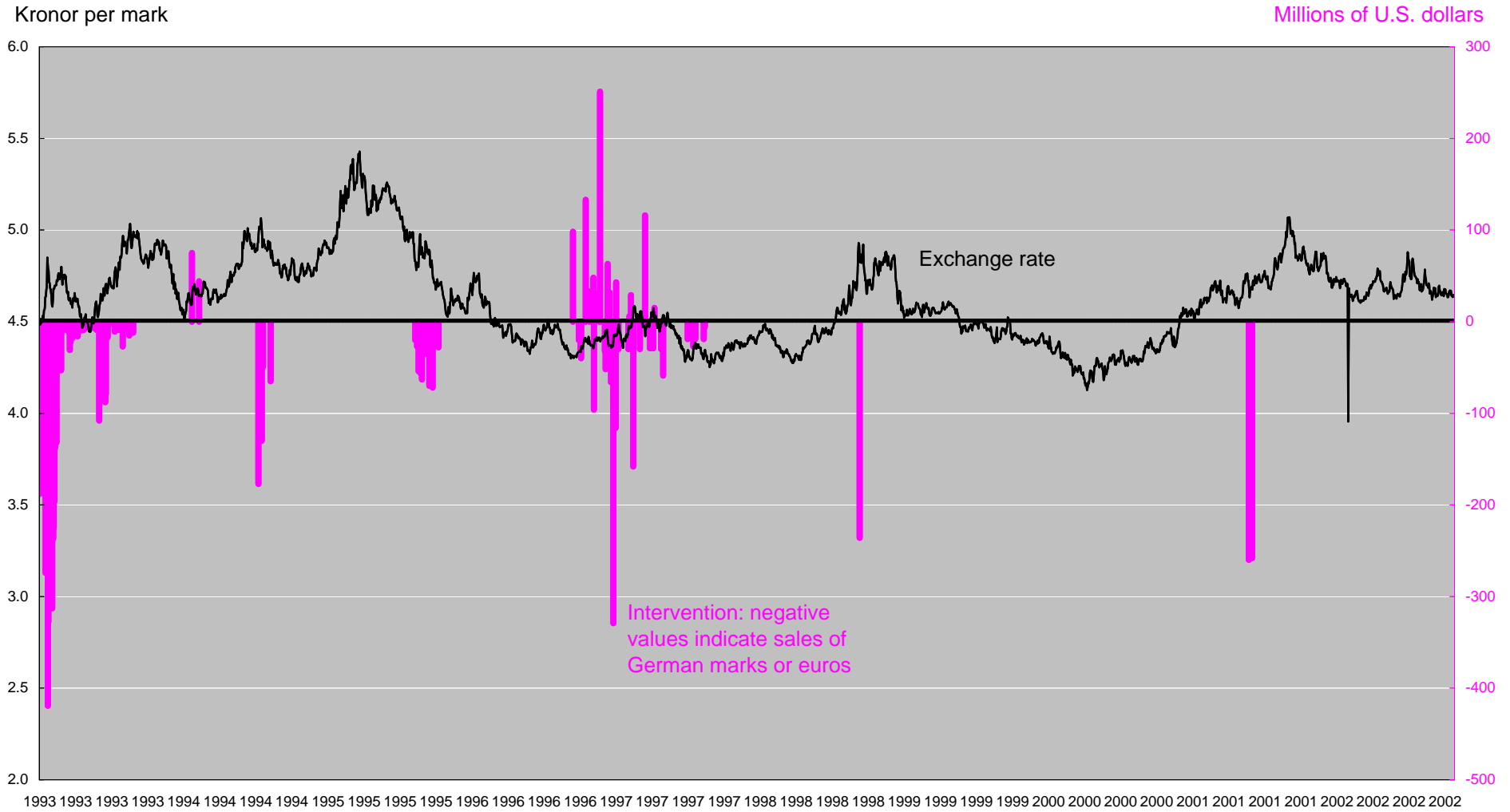


Figure 2: Riksbank Interventions against U.S. Dollars

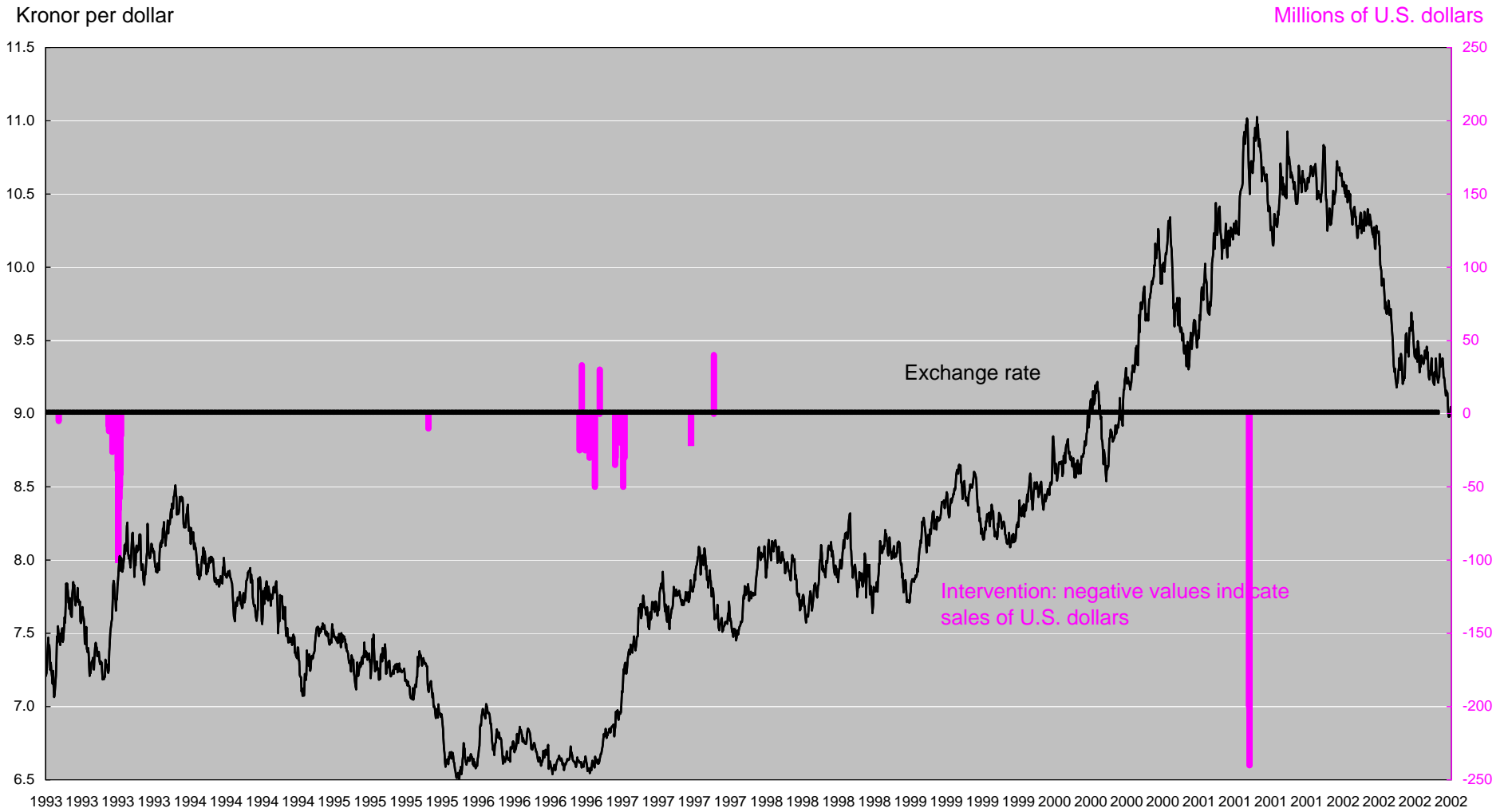


Figure 3: Riksbank Intervention and the Trade-Weighted Krona

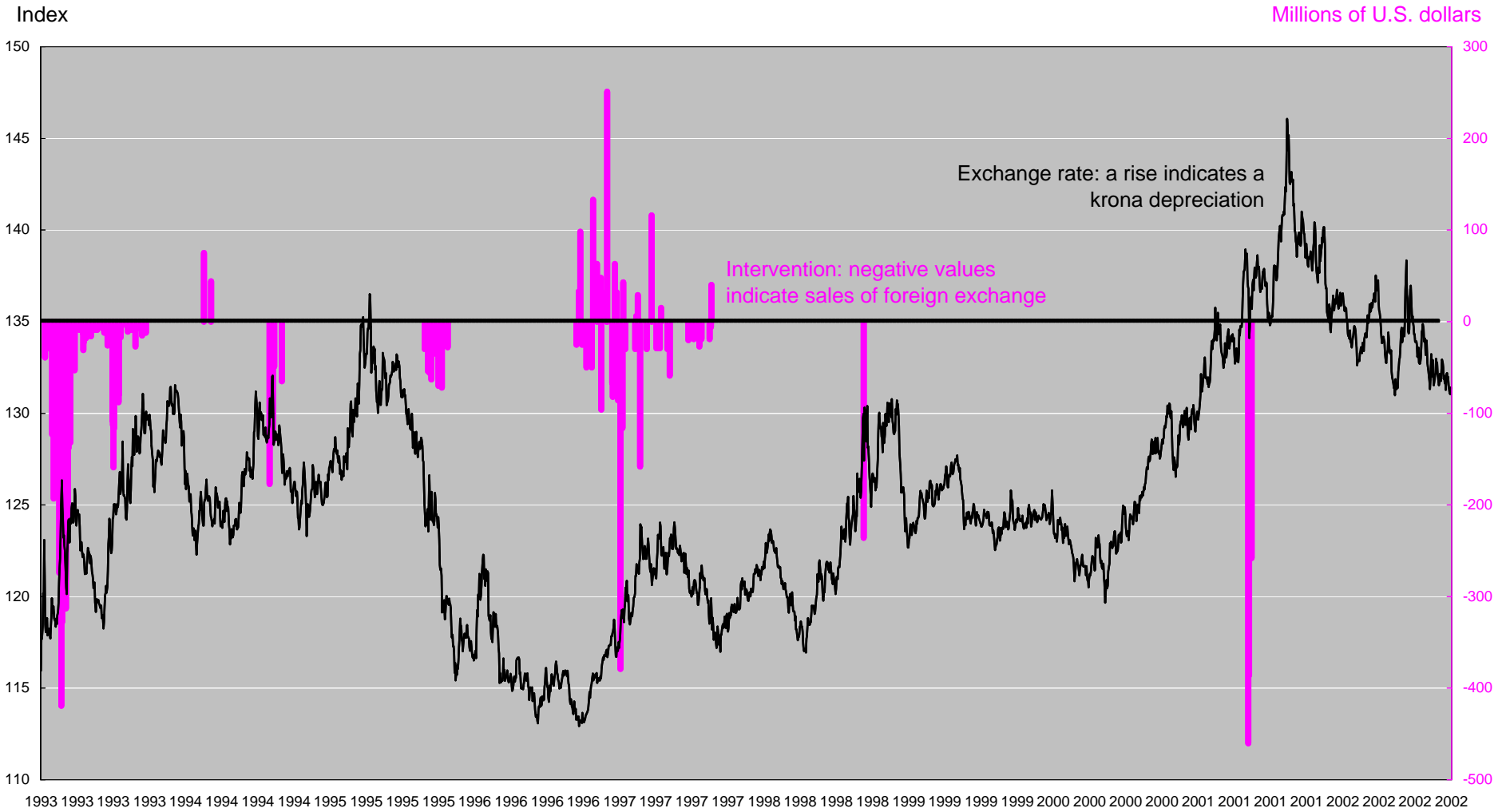
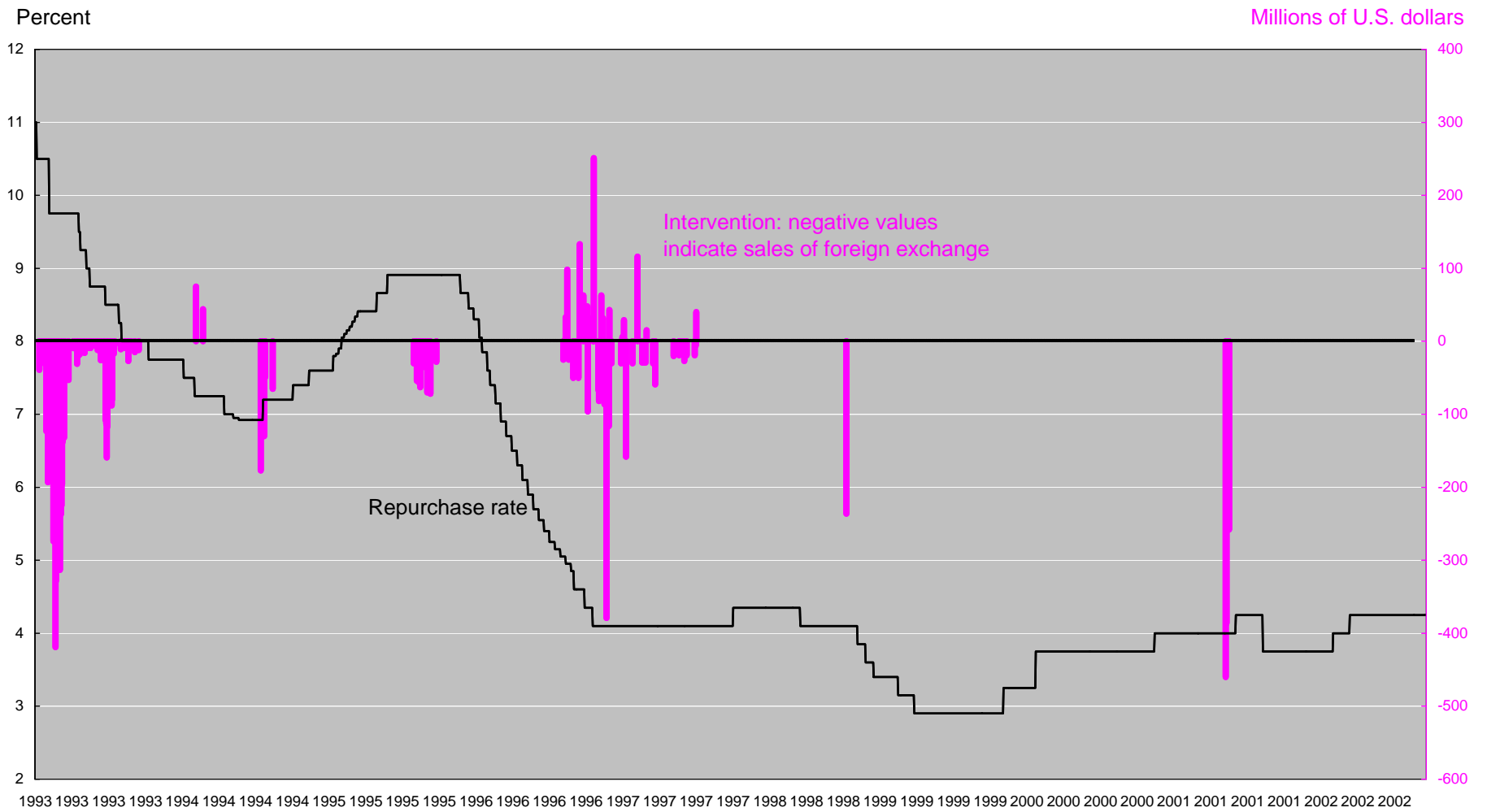


Figure 4: Riksbank Intervention and the Repurchase Rate



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