Title
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Publication Date
2007-11-07

How should we think about markets for foreign exchange?*

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As support for traditional asset models of the foreign exchange market fades, there is growing interest in more general models that include flows from international trade and international investment. One advantage of flow models is that they fit naturally into the recent literature on microstructure, particularly the work on order flow. My objective here is to use intervention data to help discriminate between traditional asset models of the foreign exchange market and more general flow models. The evidence supports a flow approach.

JEL classification number: F31
Keywords: exchange rates, foreign exchange markets, intervention

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* I would like to thank Gabriele Galati, Carol Osler and participants at various seminars for their comments and/or help.

There is a growing realization that conventional asset models of the foreign exchange market have failed.[1] After over 30 years, asset models have not improved our understanding of the short-run behavior of exchange rates. This failure is particularly evident in the intervention literature where the empirical results have been at best inconsistent.[2]

As confidence in conventional asset models fades, interest is growing in more general flow models where asset markets, international investment and trade flows all affect exchange rates in the short run.[3] An attractive aspect of flow models is that they fit naturally into the work on microstructure, particularly work on order flow.[4]

My objective here is to provide some evidence that discriminates between conventional asset models and flow models. If the conventional asset approach is correct, intervention should have either no effect or a permanent effect. Flow models advocated by Pippenger (2003), Evans and Lyons (2006) and Osler (2006) imply that intervention can have a temporary effect. The evidence indicates that intervention has a temporary effect.

Section 1 discusses the effect of intervention in the different approaches. Section 2 uses Section 1 to derive some implications about the effects of intervention that can help discriminate between conventional asset approaches and a flow approach. To exploit these implications, Section 3 provides estimates of bank reaction functions for intervention. Using the results from Section 3, Section 4 examines the behavior of exchange rates without and with intervention to help discriminate between alternative approaches. Using the results from Sections 3 and 4, Section 5 analyzes the effects of intervention in more detail.

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[1] See for example Bacchetta and van Wincoop (2006), Dominguez (2006) and Osler (2006).
[2] For reviews of this literature see Humpage (1991), Edison (1993), Sarno and Taylor (2001) and Neely (2005).
[3] See for example Pippenger (2003), Bacchetta and van Wincoop (2006), Evans and Lyons (2006) and Osler (2006)
[4] For a discussion of the microstructure approach see Lyons (2001). For a discussion of order flows see Evans and Lyons (2006).

The intervention data for Canada, Germany, Japan and Switzerland have all been analyzed elsewhere, but not in an attempt to discriminate between conventional asset models and a more general flow approach.[5] This is, I believe, the first analysis of the newly released data on intervention by the Bank of England.

1. Alternative Responses to Intervention

Section 1.1 describes a typical asset model for exchange rates. A similar model applies to signaling. In both models, foreign exchange markets and order flows disappear into the background. Section 1.2 describes a more general approach that also includes flows from importers, exporters and international investors. An Appendix describes these markets in more detail and shows how asset models are a special case of the general flow approach.

1.1. Asset Models

In asset models, the stock of financial assets is fixed in the short run. At each moment, asset prices, including exchange rates, are such that portfolio managers are willing to hold the existing stock of financial assets. There is an implicit assumption that these markets are all auction markets. They do not include markets for assets like stock in closely held corporations.

The typical asset model in the Appendix is from Edison (1993). In that model there are two countries, the United States and Great Britain. There are four assets: U.S. money, British money, dollar bonds, and sterling bonds. Domestic residents do not hold foreign money. With appropriate restrictions, these six equations determine equilibrium values for the stocks of financial assets, the two interest rates and the exchange rate.

Both portfolio balance models like the one in Edison (1993) and monetary models like Dornbusch (1976) are open economy versions of the LM schedule described in Tobin (1969). In this approach, bond and money markets are mirror images of each other. Interest rates and exchange rates consistent with equilibrium in one market must be consistent with equilibrium in the other. Portfolio balance concentrates on bond markets.

[5] Canadian and Swiss intervention are used in this way in Pippenger (2003).

Monetary models concentrate on the 'money' market. If intervention affects asset markets, it alters exchange rates permanently. If intervention is too small to affect asset markets, it does not affect exchange rates.

The intervention literature has been moving away from asset models to signaling models. But conventional signaling models are usually based on an asset approach.[6] As a result, signaling models imply either nor response to intervention or a permanent response. If intervention signals future monetary policy, the change in the exchange rate is permanent. That is it does not disappear in a day or two. If intervention does not convey any information about future monetary policy, intervention does not affect the exchange rate.

In his review of the recent literature on intervention, Neely (2005) describes a standard asset model for intervention as follows:

$$\Delta S_t = c_r + \beta I_t + Ax_{1t} + e_t. \qquad (1)$$

Where Δ is the difference operator, $\{c_r, \beta, A\}$ is the coefficient vector, S_t is the dollar price of sterling and x_{1t} is an appropriate set of regressors that contains the expected future exchange rate. I_t is sterilized intervention. Positive intervention is a purchase of sterling.

Equation 1 summarizes the asset model described in the Appendix. If β is positive, intervention raises the exchange rate permanently. If intervention is not effective, β is zero and the exchange rate does not change.

1.2 A General Flow Approach

Consider the eight external sources for orders placed with foreign exchange dealers to either buy or sell pound sterling: (1) Importers who want to buy sterling. (2) Exporters who want to sell sterling. (3) Savers who want to buy sterling bonds out of current dollar income. (4) Savers who want to buy dollar bonds out of current sterling income. (5) Firms who want to sell dollar bonds to finance investment projects in the U.K. (6) Firms who want to sell sterling bonds to finance investment projects in the United States. (7) Central banks who want to intervene. (8) Portfolio managers who want to switch between dollar and sterling assets. This list

[6] See for example the review of signaling in Sarno and Taylor (2001).

does not imply that these are different individuals or firms. Ignoring central banks, a single individual or firm could engage in all seven of the other transactions.

Before the mid 1970s, standard models ignored everyone but importers and exporters. After the mid 1970s, standard models ignored everyone but portfolio managers. Flow models include all sources.

In discussing persistent changes in exchange rates, Lyons (2001, 17) points out that "Order flow is a proximate cause. The underlying cause is information." Orders change exchange rates permanently when they contain information. In both conventional asset approaches and a flow approach, if order flows generated by intervention contain information about asset markets or future monetary policy, then intervention should have a permanent effect on exchange rates. The effect of the information should not disappear in a day or two.

But if intervention does not contain useful information, conventional models and flow models imply different responses to intervention. In that case, asset models imply that exchange rates do not change even temporarily because typical asset models assume instantaneous adjustment. As the Appendix points out, that assumption implies that any inventory disequilibrium among foreign exchange dealers caused by intervention would be resolved instantaneously. As a result, there would be no incentive for dealers to change the exchange rate even temporarily.

In a flow approach, even when intervention provides no useful information, it can have a temporary effect. As Bacchetta and van Wincoop (2006) show, when traders have different information, or interpret that information differently, non-informative trades affect exchange rates temporarily. The reason is that it takes time for dealers as a whole to discriminate between informative and non-informative orders.

Using a format similar to equation 1, equation 2 summarizes the flow model in the Appendix. Asset markets do not adjust instantaneously. As a result, trade flows and international investment affect exchange rates. Equation 2 assumes that intervention does not contain any information. If intervention did contain information, intervention would have a permanent effect as it does in equation 1.

$$S_r = k_r + \beta I_t + Aw_{1t} + \varepsilon_t. \quad (2)$$

Now the coefficient vector is $\{k,\beta,A\}$ and w_{1t} is an appropriate set of regressors.

In equation 2 asset markets do not swamp the order flows from trade and foreign investment because portfolio adjustment is not instantaneous. Here portfolios can be in disequilibrium in the sense that, given all current information, the combination of assets in portfolios at this instant is not what managers plan to hold tomorrow or even an hour from now.[7] Of course, in full equilibrium, the exchange rate must be consistent with equilibrium in asset markets, international trade, and foreign investment.[8]

A comparison of equation 1 and equation 3, which is equation 2 in first differences, illustrates the crucial difference regarding intervention between the conventional asset approach and a more general flow approach. In asset models, intervention has a permanent effect.

$$\Delta S_t = c_r + \beta I_t + Ax_{1t} + e_t. \quad (1)$$

In a flow approach, intervention has only a temporary effect.

$$\Delta S_t = + \beta I_t - \beta I_{t-1} + A\Delta w_{1t} + \Delta\varepsilon_t, \quad (3)$$

Note that equation 3 assumes that sterilized intervention does not contain any relevant information about asset markets or future monetary policy. If intervention did contain such information, there would be a permanent change in one of the elements of w_{1t} and a permanent change in the exchange rate. For example, suppose intervention signaled a future monetary policy that would change relative price levels in the future. In addition to its impact through asset markets, such information would affect current exchange rates through leads and lags in trade flows.[9]

As an example of the difference between the two approaches, consider the following mental experiment first for asset models and then for the more general approach. With everything else constant indefinitely, suppose the central bank buys dollars on Monday and then stops intervening forever. In both approaches, what happens depends on the information in intervention. If intervention contains relevant information, the exchange rate S_t rises on Monday and does not fall on Tuesday. But if the intervention does not contain any useful

[7] As long as the cost associated with portfolio adjustment is greater than the expected return, such disequilibria are optimal.

[8] With growth, these are all equilibrium flows as wealth increases and portfolios expand.

[9] Importers in the country with the depreciating currency would import more now and less later. Importers in the country with the appreciating currency would do the opposite.

information, the responses differ. In asset models and conventional signaling models, S_t does not change on Monday. In the flow model, S_t rises on Monday, but then falls on Tuesday.

Intervention either has no effect or a permanent effect in asset models and with conventional signaling. Intervention always has an effect in a flow model. If intervention conveys information, the effect is permanent. If intervention does not convey any information, the effect is only temporary.

If we could persuade some central bank to intervene on a purely random basis without any signal intended, it would be relatively easy to discriminate between the two approaches. With purely random intervention the issue of simultaneity would disappear and simple tests could resolve the issue. If such intervention had a temporary effect, that would support a flow approach. If it had no effect, that would support an asset approach. Since such intervention is unlikely, we have to develop other ways to discriminate between alternative approaches. As long as intervention responds to exchange rates, such efforts will be plagued with the problem of simultaneity. But consistent results from a variety of tests should provide a foundation for a general consensus.

The following model of sterilized intervention is a crucial part of the tests performed here. Those tests assume that sterilized intervention does not contain any information about asset markets or future monetary policy. If intervention does contain such information, the tests are biased in favor the conventional approach.

2. Intervention and Exchange Rates

Section 2.1 develops a reaction function for intervention. Sections 2.2 and 2.3 use that reaction function to show in more detail how sterilized intervention affects exchange rates in the two approaches.

2.1. Modeling Intervention

In their reviews of the literature, Edison (1993) and Sarno and Taylor (2001) identify “leaning against the wind” as a major objective of intervention.[10] In his “Looking under the Hood”, Neely (2001) agrees. Other

[10] Over time the meaning of the term “leaning against the wind” has changed. I use the original meaning: buying as the price falls or selling as the price rises.

objectives these articles identify include correcting "medium-term misalignments" and "defense of an exchange rate target". The following model for sterilized intervention denoted I_t includes all three objectives:

$$I_t = - \alpha_0 \Delta S_t - \alpha_1 \Delta S_{t-1} + \gamma_0 (T_t - S_t) + \gamma_1 (T_{t-1} - S_{t-1}) + \varepsilon_t \qquad (4)$$

The error term ε_t reflects any intervention not associated with either the level or the change in the exchange rate. When α_0 is positive, central banks systematically lean against the wind. They buy sterling as the price of sterling falls. Central banks also can lean against the wind to resist what they see as inappropriate movements in exchange rates. For example, a central bank might lean against the wind when the exchange rate moves away from a target, but not when the rate moves toward a target. When α_1 is positive, central banks systematically lean against the wind, but with a lag. Most studies of intervention ignore the effect of a lagged response. As shown below, a lagged response alters the effect of leaning against the wind.

When α_0 or α_1 is negative, central banks lean with the wind. They systematically buy sterling as the price rises. Central banks might lean with the wind to correct what they see as a misalignment or to move an exchange rate toward a target. A central bank also might appear to be leaning with the wind when it simply leaned against the wind a little too hard.

When γ_0 or γ_1 is positive, central banks respond to a target denoted T that can change over time. As the exchange rate moves away from the target, the Bank will appear to be leaning against the wind. When the exchange rate moves toward the target, the Bank will appear to be leaning with the wind. If a central bank intervenes aggressively enough to move the rate toward some target, it will appear to be leaning with the wind. Unlike the response to changes in the exchange rate captured by α_0 and α_1, as shown below, current and lagged responses to a target have similar effects.

Unfortunately, with the exception of Canada, central banks do not say much about why they intervene. We only observe that a bank is leaning with or against the wind. Not knowing the objective of intervention further complicates empirical work that is already difficult due to simultaneous equations.

All the later tests assume that intervention is sterilized. Unsterilized intervention would bias those tests in favor of an asset model or signaling. Unsterilized intervention affects exchange rates by affecting interest rates and money. Presumably those effects are permanent, not temporary. In the context of the literature on order flow, unsterilized intervention would provide information.

2.2. Intervention in Asset Models

Equation 5 combines the asset model described by equation 1 with the model of intervention described by equation 4. Equation 5 shows how intervention affects exchange rates in asset and signaling models. If intervention is too small to affect asset markets and does not convey any information about future monetary policy, then β is zero. Otherwise β is positive.

$$\Delta S_t = [1/(1+\beta\alpha_0)][\Delta R_t - \beta\alpha_1\Delta S_{t-1} + \beta\gamma_0(T_t - S_t) + \beta\gamma_1(T_{t-1} - S_{t-1}) + \beta\varepsilon_t]. \quad (5)$$

ΔR_t is the change in the exchange rate in the absence of intervention. ΔR_t equals $c_r + Ax_{1t} + e_t$. As shown later in Table 3, in the absence of intervention, daily exchange rates are approximately martingales.

In equation 5, if intervention is effective either because of signaling or an asset effect, leaning against the wind (LAW) without a lag reduces the variance in ΔS_t denoted $\sigma^2_{\Delta S}$. Systematically leaning with the wind (LWW) without a lag increases $\sigma^2_{\Delta S}$. Both leaning against and with the wind with a lag increase $\sigma^2_{\Delta S}$.

Leaning against or with the wind without a lag does not affect the correlation in ΔS_t. Leaning against the wind with a lag introduces negative autocorrelation. Leaning with the wind with a lag does the opposite.

Both with and without a lag, a stable target introduces positive serial correlation. As long as T is above S_t, the bank buys sterling and the exchange rate tends to rise. As long as T is below S_t, the bank sells sterling and the exchange rate tends to fall. Unfortunately, from outside the central bank, we usually cannot distinguish between when γ_i is positive and a central bank has a target or when a bank is leaning against or with the wind. All we see is the bank buying or selling foreign exchange as exchange rates change.

2.3. Intervention in the Flow Model

Equation 6 describes how intervention affects exchange rates in the flow model. Equation 6 combines equations 3 and 4. Here β is positive when intervention contains no information. If intervention contains information, there is a permanent change in ΔR_t that is not captured by equation 6.

$$\Delta S_t = [1/(1+\beta\alpha_0+\beta\gamma_0)][\Delta R_t - \beta(\alpha_1-\alpha_0+\gamma_1)]\Delta S_{t-1} + \beta\alpha_1\Delta S_{t-2}+\beta\gamma_0\Delta T_t + \beta\gamma_1\Delta T_t + \beta\Delta\varepsilon_t] \quad (6)$$

Now ΔR_t equals $A\Delta z_{1t} + \Delta\varepsilon_t$.

Leaning against the wind without a lag introduces positive serial correlation. Leaning against the wind with a lag introduces negative serial correlation. Leaning with the wind does the opposite. Responding to a target does not affect the autocorrelation in ΔS_t. If a central bank drives the exchange rate toward some target it will look as though it is leaning with the wind, but the intervention will introduce positive serial correlation. Here intervention has only a short run effect on $\sigma^2_{\Delta S}$.[11]

3. Estimated Reaction Functions

As long as central banks lean against the wind and intervention does not contain any information, it is possible to discriminate between asset models or signaling and the flow approach. Except for Japan, which appears to respond to a target, the central banks studied here appear to primarily lean against the wind.

3.1. The Data

The Bundesbank (DBB), the Swiss National Bank (SNB) and the Bank of Japan (BOJ) all provide daily data on intervention.[12] The Bank of England (BOE) has just released data on daily intervention for 1977 to 1981 and 1990:01 to 1993:02.[13] As of early 2007, the only time the Bank of England has intervened after 1993:02 was on 22 September, 2000. The Bank of Canada (BOC) supplies daily data for the holdings of gold

[11] See Pippenger and Phillips (1973).

[12] Data from the Bank of Japan are available on their web site. The other data are all confidential, but the banks routinely supply them to *bona fide* researchers.

[13] It is not clear why the BOE has not released data on intervention from 1982:01 to 1989:12. The intervention in the later period includes all BOE intervention.

and dollars in the Exchange Fund Account. Changes in that Account are a good proxy for intervention.[14] Since intervention is usually not posted to the account until the following day, or in some cases the second, day, changes in the Account's holdings of dollars and gold need to be aligned properly with changes in exchange rates. When intervention is not posted until the second day, it will appear as lagged intervention in an estimated reaction function even when there is no lagged response.

For Canada the daily exchange rates are closing rates supplied by the BOC. For Germany and Switzerland, the daily rates are noon buying rates in New York supplied by the Federal Reserve Bank of New York.[15] For England the exchange rates are closing rates in London supplied by the Bank of England. The rates for Japan are from Galati, Melick and Micu (2005) and are for noon London time. All empirical work uses the logarithm of the exchange rate.

Of all the intervention data, the data for Canada during the 1950s are probably the most important. That is the one episode where a central bank has publicly declared a simple policy for intervention. [16] As the estimated reaction functions below show, the Bank of Canada apparently kept its promise to just lean against the wind.

3.2. Estimates

The objective here is to estimate a parsimonious reaction function for intervention with white noise errors and no conditional heteroscedasticity. The search for a parsimonious reaction function begins with equation 4. Additional lagged changes in the exchange rate are added as needed. Lagged values for intervention are added to obtain white noise errors. These lagged values serve as proxies for unobserved determinants of intervention. Since targets are usually unknown, no attempt is made to estimate T_t. However the level of the exchange rate is included as a separate variable. A reasonably stable target should produce a significant constant and a significant negative coefficient for the level of the exchange rate.

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[14] The BOC does not release information about intervention. However the BOC re-estimated some equations in Phillips and Pippenger (1993) with actual intervention data and the two results are similar.

[15] For Germany, when the New York rate was not available, I was able to substitute the 1:00 rate in Frankfurt.

[16] Shepherd (1973, 174) describes that intervention as follows: "…intervention by the Bank of Canada (on behalf of the Exchange Fund Account) in the foreign exchange market was undertaken only to smooth out extreme day-to-day rate fluctuations, and not to bring about or to block a definite rate movement. This had been a matter of firm, declared policy."

Table 1 reports the estimates for the reaction functions. Most central banks primarily lean against the wind. For all countries except Japan, the coefficient for ΔS_t is negative and significant at well beyond the 1 percent level. For all countries including Japan, the coefficient for ΔS_{t-1} is negative and significant at well beyond the 1 percent level. These two results provide the basis for the tests in the following sections.

For all countries but Japan, the flow model implies that leaning against the wind introduces positive correlation into ΔS_t. Asset models or conventional signaling models imply that leaning against the wind without a lag does not affect the correlation in ΔS_t. Since the coefficients for ΔS_{t-1} are all negative and highly significant, any positive autocorrelation in ΔS_t cannot be attributed to lagged leaning with the wind in the conventional approach.

Table 1 indicates that the Bank of Japan did not systematically lean against the wind without a lag. The coefficient for ΔS_t is positive and highly significant. The Bank of Japan apparently responded primarily to a target. For Japan the constant is significant and the coefficient for S_t is negative and significant at well beyond the 1 percent level. These results are consistent with Ito and Yabu (2007).

According to Ito and Yabu (2007), Japan had a stable target during this period of between 124 and 125 yen per dollar. That target would cause the Bank to appear to lean with the wind when the rate moves toward the target and lean against the wind when the rate moves away from the target. Using a target of 124.5 yen per dollar as suggested by Ito and Yabu (2007), it is possible to divide ΔS_t into changes that are moving away from the target, ΔSA_t, and those moving toward the target, ΔST_t. If the positive coefficient for S_t is solely the result of bias and there is no target, the coefficients for ΔSA_t and ΔST_t should be the same as the coefficient for ΔS_t in Table 1. If the Bank is responding to a target, the coefficients for ΔSA_t and ΔST_t should be different.

Table 2 reports the results of re-estimating the equation for Japan with ΔS_t replaced with ΔSA_t and ΔST_t, and ΔS_{t-1} replaced with ΔSA_{t-1} and ΔST_{t-1}. In addition to the tests reported in Table 1, Table 2 also reports the Wald Chi Square tests for ΔSA_t equals ΔST_t and ΔSA_{t-1} equals ΔST_{t-1}.

The test for ΔSA_t equals ΔST_t rejects the restriction at well beyond the 1 percent level. The test for ΔSA_{t-1} equals ΔST_{t-1} rejects the restriction at the 5 percent level. In addition, while the significance of the lagged intervention terms remain largely unchanged, both the constant and the coefficient for S_t are insignificant in Table 2. It appears that, when the Bank of Japan did intervene, it did so primarily by leaning with the wind when the exchange rate moved towards its target. The coefficient for ΔSA_t is insignificant while the coefficient for ΔST_t is positive and significant.

Except for the Bank of Japan, central banks leaned against the wind. How exchange rates respond to leaning against the wind and a target can be used to discriminate between traditional asset models and signaling on the one hand and a flow model on the other. These tests assume that intervention contains no information. If intervention contains information, the tests are biased in favor of the conventional approach.

4. Responses to Sterilized Intervention

All of the tests in this section and the next assume that intervention is sterilized. Unsterilized intervention would bias the results in favor of the conventional approach. Canada sterilizes now and sterilized in the 1950s. See Pippenger (2003) and www.bank-banque-canada.ca/en/backgrounders/bg-e2.htm. Intervention by the Bank of England presumably was routinely sterilized. German and Japanese intervention is generally considered to be sterilized. See Baillie and Osterberg (1997). The SNB often did not sterilize. See Gartner (1987).

This section examines the behavior of exchange rates without and with intervention. Section 5 examines the behavior of exchange rates with intervention in more detail.

Table 3 reports the results from estimating the following AR(10) equation for daily changes in the logarithm of exchange rates over intervals where a central bank did not report intervention:

$$\Delta S_t = c + \sum_{i=1}^{10} \lambda_i \Delta S_{t-i} + u_t \qquad (7)$$

The choice of 10 lags was made before the regressions were run. When u_t is correlated, additional lags are added until the error is white noise.

Table 4 shows the results of estimating the same equation over intervals where the central bank reported intervention. Those intervals were chosen because they were analyzed earlier or because they cover the available data. Canada from 1952:01 to 1960:11 covers Canada's first experiment with flexible rates. Canada from 1975:01 to 1986:12 starts after the collapse of Bretton Woods. It ends where Phillips and Pippenger (1993) ends. Canada from 1987:01 to 1998:09 covers the remaining time up to the point where Canada ended intervention. British data from 1977:01 to 1981:12 and 1990:01 to 1993:02 cover all the intervention data supplied to date by the BOE. Germany 1976:01 to 1995:12 covers all the intervention data supplied to me by the DBB up to the time the DBB ended intervention. Japan 1994:02 to 2000:04 covers the intervention analyzed in Galati, Melick and Micu (2005). Switzerland 1975:01 to 1995:08 starts with the earliest daily intervention data supplied to me by the SNB and ends when they end intervention.

To save space in Tables 3 and 4, the estimate for the first lag is always reported, but only the two most significant of the remaining lags are reported.[17] Tests for serial correlation in the residuals (Q) and conditional heteroscedasticity (Arch) were calculated from 1 to 25 lags.[18] Again to save space, only the most significant estimates are reported. If they are not significant, no test is significant. In addition to the results reported in Table 3, Table 4 reports the percentage of days the central bank intervened.

When there is no reported intervention, daily exchange rates are approximately martingales. Of the 60 estimates of λ_i behind Table 3 only one is significant at the 1 percent level, another is significant at the 5 percent level and a third is almost significant at the 5 percent level.

The results in Table 4 are very different. The more central banks lean against the wind, the more structure there is in daily exchange rates. For all countries other than Japan, the coefficient for ΔS_t is positive as implied by a flow approach. One coefficient is significant at only the 10 percent level, but all others are significant at 5 percent or better. Canada in the 1950s leaned against the wind the most consistently and the coefficient for that

[17] All estimates here and later use EViews4.
[18] There is no test for normality because, like all daily financial data, these price changes are highly leptokurtotic.

episode is the largest and it is significant at well beyond the 1 percent level. These results support a flow approach and are difficult to reconcile with a conventional asset approach.

Although they do not necessarily reject a conventional asset approach, the results for Japan are consistent with a flow approach.[19] A flow approach implies that leaning against the wind should affect the exchange rate, which Tables 3 and 4 support for the other countries. A flow approach implies that a target should not affect the autocorrelation in exchange rates, which Tables 3 and 4 support for Japan.

Tables 3 and 4 provides substantial evidence that intervention has just a temporary effect on exchange rates. For all countries other than Japan, leaning against the wind introduces positive autocorrelation as implied by a flow approach. For Japan, intervening with a target does not introduce autocorrelation as implied by a flow approach. These results are difficult to reconcile with a conventional asset approach.

Tables 3 and 4 only look at the behavior of exchange rates during periods with and without intervention. Using the same intervals as in Table 4, the next section looks at intervention in more detail. It distinguishes between leaning against the wind and leaning with the wind.

5. A Closer Look at the Effects of Intervention.

To have a closer look at the effect of intervention, this section divides ΔS_t into four regimes. The first regime captures the effects of leaning against the wind. When a central bank leans against the wind, $I_t\Delta S_t$ is negative. When the price of dollars rises, the bank sells dollars. If both $I_t\Delta S_t$ and $I_{t-1}\Delta S_{t-1}$ are negative, ΔS_{t-1} is in the first regime. I use two days of leaning against the wind because the models developed above assume that intervention is continuous. Two days assures some continuity while providing a relatively large sample. There is no restriction on the direction that the bank leans against the wind. The bank could buy with a falling rate on Monday and sell with a rising rate on Tuesday.

[19] Intervention that is too small to affect asset markets or intervention that contains no relevant information would also not affect the exchange rate with a target.

The second regime captures the effect of leaning with the wind or possibly a target. When a central bank leans with the wind, $I_t\Delta S_t$ is positive. When the price of dollars rises, the bank buys dollars. If both $I_t\Delta S_t$ and $I_{t-1}\Delta S_{t-1}$ are positive, ΔS_{t-1} is in the second regime. Again there is no restriction on the direction that the bank leans with the wind. The bank could buy with a rising rate on Monday and sell with a falling rate on Tuesday.

When ΔS_{t-1} is zero, I place it in a third regime. The reason for this regime is that there seems to be an unusual number of zero changes when there is intervention. If a central bank leans strongly enough against the wind, it can stop the exchange rate from changing. This appears to be a real possibility because for each country the percentage of zero changes usually more than triples when there is intervention.[20] This increase in the number of zero changes in ΔS_t is additional evidence that intervention affects exchange rates.

Any changes in the exchange rate that are not in the first three regimes are in a fourth regime. Regime four serves as a benchmark against which to compare regimes one and two.

5.1. Test Equation

With these four regimes, the test equation is the following:

$$\Delta S_t = C_{LAW} + C_{LWW} + C_{OTHER} + C_{ZERO} + a_1\Theta_{t-1}\Delta S_{t-1} + a_2\Omega_{t-1}\Delta S_{t-1} + a_4X_{t-1}\Delta S_{t-1} + \mu_t \qquad (8)$$

C_{LAW} and Θ_{t-1} are one when ΔS_{t-1} is in the first regime and zero otherwise. C_{LWW} and Ω_{t-1} are one when ΔS_{t-1} is in the second regime and zero otherwise. C_{ZERO} is one when ΔS_{t-1} is zero and zero otherwise. C_{OTHER} and X_{t-1} are one when ΔS_{t-1} is in the fourth regime and zero otherwise. If μ_t is correlated, additional lags are added without regard to regime. Since this regression uses only changes in exchange rates, the estimates should avoid most of the bias due to simultaneous equations.[21]

[20] The percentage of zeros is very high for the first Canadian interval, 17.8. For the second interval, the percentage drops to 2.6. For Canada after 1986 the percentage is 0.7 without intervention and 2.0 with. For Japan, Germany and Switzerland the comparisons are respectively 0.1 without intervention versus 4.1 with, 0.00 without versus 1.30 with, and 0.6 without versus 1.80 with.

[21] Equation 8 does not completely avoid that bias. For example, suppose the central bank leans against the wind with a rising rate on Tuesday. If the bank's decision to LAW or not intervene on Wednesday depends on the change in the exchange rate on Wednesday, there could be bias. LAW on Wednesday when the rate rises, but not when it falls, would introduce evidence of positive serial correlation with LAW in equation 8 even if intervention did not affect exchange rates.

Estimates of a_1 (LAW) that are significantly larger than a_4 (OTHER) indicate that leaning against the wind increases the correlation in ΔS_t. That result is consistent with the flow approach and inconsistent with asset models and signaling. Estimates of a_1 that are not significantly different from a_4 support the conventional approach. Estimates of a_1 that are significantly less than a_4 are inconsistent with a flow approach, an asset approach and signaling. Fortunately a_1 is never less than a_4.

Estimates of a_2 (LWW) that are significantly different from a_4 (OTHER) suggest that intervention is effective, but have no discriminatory power. Estimates of a_2 that are not significantly different from a_4 have no discriminatory power. They are consistent with both approaches and cannot discriminate between effective and ineffective intervention.[22]

5.2 Empirical Results

Table 5 reports the results from applying equation 8 to the data used in Table 4. In addition to the tests reported earlier, Table 5 also reports the following: (1) The total number of observations (N) and the number in each regime (N_i). (2) Chi-squared tests for the equality between the estimates for LAW=OTHER (a_1=a_4) and LWW=OTHER (a_2=a_4).

In only two cases, Germany and Switzerland, is the coefficient for leaning with the wind statistically different from the coefficient for other. In both cases the coefficient for leaning with the wind is positive. This result is consistent with intervention affecting exchange rates, but it does not effectively discriminate between a flow approach and the conventional asset approach. A positive coefficient could be the result of a central bank moving the exchange rate toward some target. It is the coefficient for leaning against the wind that best discriminates between the different approaches.

For every country and interval other than for Japan, the coefficient for LAW is positive and larger than the coefficient for OTHER at well beyond the 1 percent level. That result indicates that leaning against the wind

[22] Since we cannot distinguish between LWW and moving toward a target, under a flow approach a_2 can be larger or smaller than a_4.

has only a temporary effect on exchange rates. A temporary effect supports the flow model while rejecting asset models and signaling.

Since Japan responded mainly to a target rather than leaning against the wind to reduce short-run fluctuations, the absence of a significant difference between LAW and OTHER for Japan is consistent with a flow approach. In the flow approach, intervening in response to a stationary target does not affect the persistence in exchange rates because the effect of intervention is only temporary.

The results in Tables 1 through 5 strongly support the idea that leaning against the wind increases the correlation in exchange rates. Sterilized intervention apparently has no permanent effect on the level of the exchange rate, but it does have a temporary effect. This result has been observed in other research, but it is has not been generally recognized as inconsistent with the conventional asset approach.

In her review of the literature after 1982, Edison (1993) concludes the following: "Nevertheless, the empirical evidence, although allowing for the possibility of short-lived effects, does not ascribe to intervention a long-lasting effect on the foreign-exchange market." More recent research reinforces Edison's conclusion that intervention only has a temporary effect. See for example Fatum and Hutchison (2003) and (2006), Payne and Vitale (2003) and Kearns and Rigobon (2005). But none of this work, or the reviews of the literature in footnote 2, recognizes that a temporary effect is inconsistent with the conventional asset approach and suggests a switch to a flow approach.

6. Summary and Conclusions

There is growing dissatisfaction with conventional asset models of the foreign exchange market and a growing interest in more general flow models. One important advantage of a flow model is that it fits naturally into the work on order flow in the microstructure literature.

The primary purpose of this paper is to provide some evidence that can help discriminate between the two approaches. Asset models or signaling imply that sterilized intervention should have either no effect or a 'permanent' effect. When combined with the assumption that intervention contains no information, a flow approach implies that sterilized intervention only has a temporary effect.

The empirical evidence indicates that intervention only has a temporary effect. When central banks do not intervene, daily exchange rates are approximately martingales. When central banks lean against the wind, there is positive serial correlation in daily exchange rates. A closer examination of daily exchange rates supports that conclusion. These results are consistent with a flow approach, but not consistent with asset models or signaling. Unlike most of the results in the intervention literature, these results are robust. They hold over a variety of time periods and for several countries.

These results support the growing interest in flow models as a replacement for conventional asset approaches to the foreign exchange market.

APPENDIX

In the portfolio balance model in Edison (1993), W is financial wealth for the United States:

$$W = M + B_{US} + SB^{*}_{US}.$$

B_{US} is the dollar value of dollar bonds U.S. residents hold. SB^{*}_{US} is the dollar value of sterling bonds they hold. M is the stock of money in the United States. A similar equation defines foreign wealth W* in terms of sterling.

$$W^{*} = M^{*} + (1/S)B_{UK} + B^{*}_{UK}.$$

M* is the stock of money in Britain.

Two equations describe equilibrium in markets for dollar assets where B and M are the actual market value of the stock of dollar bonds and money respectively.

$$B = B_{US} + B_{UK} = b_{US}(r,r^{*},S,S^{E},Y,W) + b_{UK}(r,r^{*},S,S^{E},Y^{*},W^{*}).$$

$$M = b_{M}(r,r^{*},S,S^{E},Y,W).$$

Where r is the domestic interest rate, r* is the foreign interest rate and S^{E} is the expected future exchange rate. Y and Y* are domestic and foreign income respectively. Two similar equations describe equilibrium in markets for foreign assets.

$B^* = B^*_{UK} + B^*_{US} = b^*_{UK}(r,r^*,S,S^E,Y^*,W^*) + b^*_{US}(r,r^*,S,S^E,Y,W)$.

$M^* = b^*_M\,(r,r^*,S,S^E,Y^*,W^*)$.

With appropriate restrictions, these six equations determine equilibrium values for W, W*, r, r* and S. [23] In this and similar models, the purchase of one asset must be financed by the sale of another asset.[24]

A general flow model considers all potential orders by customers of foreign exchange dealers including orders generated by international trade and international investment.

Let T(y) represent net order flows for sterling from importers and exporters where y is a vector of relevant explanatory variables that includes the exchange rate and expected exchange rate. Let F(z) represent net order flows for sterling from savers and investors where z is a vector of relevant explanatory variables that includes the exchange rate and expected exchange rate. Let I represent official intervention. Let A(x) represent net order flows for sterling generated by portfolio managers as they move between dollar and sterling assets.

From the asset model above, the total excess demand for sterling bonds is the following:

$$b^*_{US}(r,r^*,S,S^E,Y,W) + b^*_{UK}(r,r^*,S,S^E,Y^*,W^*) - B^*.$$

Part of that excess demand comes from a purchase of sterling bonds financed by a sale of dollar bonds. Part comes from British residents who want to shift out of sterling deposits into sterling bonds. That part of the excess demand for sterling bonds does not directly affect the market for foreign exchange. With the simplifying assumption that the shift from money to bonds is restricted to domestic bonds, the net order flow for sterling from asset markets is the following:

$$A(x) = \lambda[b^*_{US}(r,r^*,S,S^E,Y,W) + b^*_{UK}(r,r^*,S,S^E,Y^*,W^*) - B^*] - \lambda[M^* - b^*_M(r,r^*,S,S^E,Y,W)].$$

Where λ reflects the speed of adjustment that, for simplicity, is the same for money and bonds.[25]

The next equation describes the flow excess demand for sterling. That schedule describes the customer order flow from all sources.

$$T(y) + F(z) + I + A(x) = £/t.$$

When £/t is positive, dealers as a group sell more sterling than they buy.

23 For additional restrictions and definitions see Tobin (1969). In Edison (1993) wealth, income and the expected exchange rate are given. Here wealth is endogenous.

24 In Monetarist and many other approaches, households and firms can use money balances to finance the purchases of goods.

25 A demand for sterling bonds that reflects only a supply of dollar bonds does not generate a net demand for sterling. Since sellers of sterling bonds want dollars to buy dollar bonds, they sell the sterling they receive to buy dollars. For there to be a net external order flow from asset markets, there must be an excess demand for or supply of money.

Dealers try to end each day with no open positions. With no net open positions for dealers at the end of the day, the daily equilibrium exchange rate is the rate that sets this excess demand equal to zero.[26]

$$T(y) + F(z) + I + A(x) = 0$$

Portfolio balance and monetary models are special cases of this general flow model.[27] Taking the limit as λ goes to infinity converts that equilibrium condition into the following:

$$b^*_{US}(r,r^*,S,S^E,Y,W) + b^*_{UK}(r,r^*,S,S^E,Y^*,W^*) - B^* = M^* - b^*_M(r,r^*,S,S^E,Y^*,W^*)$$

With continuous equilibrium in all asset markets, both sides of that equation are zero. Foreign exchange markets disappear into the background. In that special case, typical asset models determine all asset prices and the exchange rate.

Portfolio balance models concentrate on the left-hand-side of the last equation.

$$B^* = b^*_{US}(r,r^*,S,S^E,Y,W) + b^*_{UK}(r,r^*,S,S^E,Y^*,W^*)$$

Monetary models concentrate on the right hand side.

$$M^* = b^*_M(r,r^*,S,S^E,Y^*,W^*)$$

The exchange rate consistent with equilibrium on one side must be consistent with equilibrium on the other.

The economic interpretation of taking the limit as λ goes to infinity is important for understanding the effects of intervention in portfolio balance and monetary models. As λ goes to infinity, it takes only an infinitely small deviation from the equilibrium exchange rate to provide instantaneously the finite amount of dollars or sterling necessary to rebalance the inventories of dealers. That instantaneous response is why intervention in these models has either no effect or a permanent effect. Dropping the assumption of instantaneous adjustment, and therefore continuous equilibrium in asset markets, returns us to a flow approach where trade and international investment can affect exchange rates.

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[26] As a group, dealers will usually have open positions because the foreign exchange market is usually open somewhere.

[27] Portfolio and monetary models are extensions of the conventional LM schedule that emphasize the role of money as a store of wealth. Monetarists and many others view money as a productive asset that reduces the information and transaction costs associated with production and exchange. From that perspective monetary equilibrium is rare because, as part of that role, money acts as a buffer for when income and expenditures do not match.

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Table 1
Estimated Reaction Functions

	Canada 1952:01-1960.11	Canada 1975:01-1986:12	Canada 1987:01-1998:09	England 1977:01-1981:12	England 1990:01-1993:02
Constant [Probability]	-0.009 [0.913	-1.977 [0.004]	-38.701 [0.000]	25.040 [0.000]	-20.987 [0.084]
ΔS_t [Probability]	-2114.721 [0.000]	-163.054 [0.000]	-2271.201 [0.000]	-498.658 [0.000]	-1136.843 [0.000]
ΔS_{t-1} [Probability]	-481.130 [0.000]	-25.096 [0.000]	-737.948 [0.000]	-1349.407 [0.000]	
ΔS_{t-2} [Probability]		-28.149 [0.000]	-386.497 [0.000]		-436.294 [0.041]
ΔS_{t-3} [Probability]		-15.710 [0.000]	-434.783 [0.000]	-245.729 [0.013]	
ΔS_{t-4} [Probability]			-294.657 [0.000]		747.832 [0.000]
ΔS_{t-5} [Probability]			-110.412 [0.038]		
ΔS_{t-6} [Probability]			-217.609 [0.000]		
ΔS_{t-7} [Probability]			-162.023 [0.000]		
S_{t-1} [Probability]		62.528 [0.000]			
I_{t-1} [Probability]		-0.034 [0.026]	0.191 [0.000]	-12.614 [0.000]	35.549 [0.096]
I_{t-i} [Probability]			0.047 (5) [0.010]	0.274 [0.000]	0.222 [0.000]
I_{t-j} [Probability]			0.048 (10) [0.000]	0.058 (2) [0.011]	0.109 (3) [0.002]
I_{t-j} [Probability]				0.075 (3) [0.002]	0.079 (4) [0.024]
I_{t-j} [Probability]				0.097 (5) [0.000]	
I_{t-j} [Probability]					
I_{t-j} [Probability]					
I_{t-j} [Probability]					
Garch(p,q)	0,0	3,3	4,4	2,2	0,0
Q(Lag) [Probability]	7.828 (8) [0.450]	16.184 (9) [0.063]	10.202 (9) [0.334]	25.287 (17) [0.088]	2.785 (2) [0.248]
Arch(Lag) [Probability]	0.020 [0.887]	1.156 (2) [0.561]	0.058 (1) [0.809]	0.390 (1) [0.532]	1.234 (1) [0.267]
$\bar{R}^2$	0.261	0.251	0.506	0.227	0.126

* Unable to remove conditional heteroscedasticity without introducing autocorrelated errors.

Table 1 Continued

	Germany* 1976:01-1995:12	Japan 1994:02-2000:04	Switzerland 1975:01-1995:08
Constant [Probability]	14.075 [0.011]	2762.869 [0.003]	-2.190 [0.128]
ΔS_t [Probability]	-10.962 [0.000]	138.785 [0.000]	-4.565 [0.000]
ΔS_{t-1} [Probability]	-17.098 [0.000]	-121.761 [0.000]	-4.827 [0.000]
ΔS_{t-2} [Probability]	-4.942 [0.040]		
ΔS_{t-3} [Probability]	-7.909 [0.001]		
ΔS_{t-5} [Probability]			
ΔS^3_t [Probability]			0.251 [0.042]
ΔS^3_{t-1} [Probability]			0.815 [0.000]
ΔS^3_{t-2} [Probability]			
ΔS^3_{t-3} [Probability]	-0.281 [0.000]		
S_{t-1} [Probability]	0.323 [0.000]	-5.714 [0.003]	0.058 [0.013]
I_{t-1} [Probability]	0.144 (2) [0.000]	0.086 [0.001]	0.309 [0.000]
I_{Lag} [Probability]	-0.028 (3) [0.049]	0.093 (5) [0.001]	0.079 (2) [0.000]
I_{Lag} [Probability]	0.054 (5) [0.000]	0.066 (10) 0.012]	0.037 (3) [0.010]
I_{Lag} [Probability]	0.123 (6) [0.000]		0.122 (4) [0.000]
I_{Lag} [Probability]	-0.066 (7) [0.000]		0.048 (5) [0.001]
I_{Lag} [Probability]	0.058 (8) [0.000]		0.108 (8) [0.000]
I_{Lag} [Probability]	0.062 (19) [0.000]		
Garch(p,q)		0,0	0,0
Q(Lag) [Probability]	0,0	3.667 (2) [0.160]	20.344 (13) [0.087]
Arch(Lag) [Probability]	32.156 (25) [0.154]	0.155 (1) [0.693]	90.149 (1) [0.000]
$\bar{R}^2$	16.294 (1) [0.000]	0.049	0.261
	0.256		

Table 2

Re-estimated Reaction Function for Japan

Constant [Prob.]	ΔSA_t [Prob.]	ΔST_t [Prob.]	ΔSA_{t-1} [Prob.]	ΔST_{t-1} [Prob.]	S_t [Prob.]	I_{t-1} [Prob.]	I_{t-5} [Prob.]	I_{t-10} [Prob.]
-488.573 [0.639]	-46.309 [0.283]	343.318 [0.000]	-181.166 [0.000]	-29.337 [0.546]	1.004 [0.647]	0.070 [0.004]	0.087 [0.001]	0.057 [0.028]

GARCH= (0,0), Q(Lag)=3.908 (2), ARCH(Lag)=0.091 (1) , $\bar{R}^2$=0.073,
Wald Chi Square Tests[Probability]: $\Delta SA_t = \Delta ST_t$ [0.000], $\Delta SA_{t-1} = \Delta ST_{t-1}$ [0.038]

Table 3

AR(10) for Daily Log Differences without Intervention

	Canada 1999:01-2005:12	England 1993:03-2007:09	Germany 1996:01-1998:12
$\lambda_{(1)}$ [Probability]	-0.008 [0.755]	0.026 [0.128]	0.013 [0.720]
$\lambda_{(Lag)}$ [Probability]	-0.041 (5) [0.095]	-0.047 (3) [0.006]	0.071 (10) [0.051]
$\lambda_{(Lag)}$ [Probability]	-0.023 (3) [0.325]	-0.027 (6) [0.121]	-0.067 (5) [0.064]
Garch(p,q)	(1,1)	1,1	(1,2)
Q(Lag) [Probability]	12.12 (20) [0.912]	20.815 (22) [0.532]	9.581 (20) [0.975]
Arch(Lag) [Probability]	4.040 (3) [0.257]	35.495 (25) [0.080]	21.376 (21) [0.436]
$\bar{R}^2$	-0.005	0.000	-0.003

Table 3 Continued

AR(10) for Daily Log Differences without Intervention

	Japan 1993:09-1994:02	Japan 2000:05-2001:08	Switzerland 1996:01-2005:12
$\lambda_{(1)}$ [Probability]	-0.024 [0.821]	-0.063 [0.247]	-0.006 [0.781]
$\lambda_{(Lag)}$ [Probability]	0.212 (9) [0.080]	-0.123 (3) [0.023]	0.036 (4) [0.074]
$\lambda_{(Lag)}$ [Probability]	0.123 (10) [0.309]	0.087 (5) [0.107]	-0.027 (8) [0.192]
Garch(p,q)	0,0	0,0	1,2
Q(Lag) [Probability]	0.006 (1) [0.938]	0.001 (1) [0.982]	21.345 (25) [0.673]
Arch(Lag) [Probability]	25.656 (17) [0.081]	1.337 (1) [0.248]	20.542 (21) [0.487]
$\bar{R}^2$	-0.049	0.014	-0.002

Table 4
AR(10) for Daily Log Differences with Intervention

	Canada 1952:01-1960.11	Canada 1952:01-1960:11	Canada 1975:01-1986:12	Canada 1987:01-1998:09
$\lambda_{(1)}$ [Probability]	0.224 [0.000]	0.176 [0.000]	0.050 [0.035]	0.036 [0.063]
$\lambda_{(Lag)}$ [Probability]	-0.074 (6) [0.001]	-0.080 (2) [0.001]	-0.055 (2) [0.011]	0.049 (10) [0.011]
$\lambda_{(Lag)}$ [Probability]	0.059 (5) [0.006]	0.062 (5) [0.007]	0.044 (3) [0.053]	-0.039 (9) [0.034]
Garch(p,q)	0,0	1,1	1,1	(1,1)
Q(Lag) [Probability]	16.468 (25) [0.900]	16.882 (2) [0.000]	8.501 (5) [0.131]	0.091 (1) [0.763]
Arch(Lag) [Probability]	145.928 (1) [0.000]	16.799 (13) [0.209]	13.510 (8) [0.095]	30.418 (24) [0.171]
Percentage of Intervention	97.7	97.7	99.7	35.9
$\bar{R}^2$	0.058	0.047	0.006	-0.003
Additional Lag	15			

Table 4 Continued

	United Kingdom 1977:01-1981:12	United Kingdom 1990:01-1993:02	Germany 1976:01-1995:12	Japan 1994:02-2000:04	Switzerland 1975:01-1995:08
$\lambda_{(1)}$ [Probability]	0.076 [0.036]	0.136 [0.000]	0.028 [0.061]	-0.028 [0.374]	0.031 [0.038]
$\lambda_{(Lag)}$ [Probability]	-0.070 (2) [0.027]	0.064 (8) [0.097]	0.033 (9) [0.024]	0.043 (10) [0.105]	0.043 (9) [0.002]
$\lambda_{(Lag)}$ [Probability]	-0.033 (9) [0.309]	0.058 (4) [0.122]	0.025 (5) [0.074]	-0.028 (8) [0.269]	0.014 (4) [0.342]
Garch(p,q)		1,1	1,1	2,2	1,1
Q(Lag) [Probability]	0.147 (1) [0.147]	16.026 (18) [0.591]	24.130 (16) [0.087]	22.419 (23) [0.495]	1.567 (1) [0.211]
Arch(Lag) [Probability]	0.076 (1) [0.783]	2.331 (2) [0.312]	14.287 (10) [0.161]	3.881 (5) [0.567]	17.894 (17) [0.396]
Percentage of Intervention	89.0	8.9	23.4	8.1	16.9
$\bar{R}^2$	-0.004	0.021	0.001	-0.009	-0.001
Additional Lag			20		

Table 5

Estimates from $\Delta S_t = C_{LAW} + C_{LWW} + C_{OTHER} + C_{ZERO} + a_1 \Theta_{t-1} \Delta S_{t-1} + a_2 \Omega_{t-1} \Delta S_{t-1} + a_3 X_{t-1} \Delta S_{t-1} + \mu_t$

	Canada 1952:01-1960.11	Canada 1952:01-1960:11	Canada 1975:01-1986:12	Canada 1987:01-1998:09
C_{LAW} [Probability]	-0.000 [0.861]	-0.000 [0.000]	0.008 [0.098]	-0.007 [0.597]
C_{LWW} [Probability]	-0.000 [0.986]	0.000 [0.535]	0.011 [0.547]	0.012 [0.938]
C_{OTHER} [Probability]	0.000 [0.991]	0.000 [0.806]	0.002 [0.811]	0.001 [0.831]
C_{ZERO} [Probability]	0.000 [0.954]	-0.000 [0.084]	-0.002 [0.885]	0.049 [0.043]
a_1 or LAW [Probability]	0.290 [0.000]	0.267 [0.000]	0.138 [0.000]	0.460 [0.000]
a_2 or LWW [Probability]	0.241 [0.024]	-0.056 [0.553]	-0.174 [0.272]	0.736 [0.665]
a_3 or OTHER [Probability]	0.086 [0.013]	0.068 [0.134]	-0.077 [0.105]	-0.095 [0.000]
Garch(p,q)	0,0	5,3	1,1	1,1
Q(Lag) [Probability]	14.693 (9) [0.100]	19.697 (2) [0.000]	8.571 (5) [0.127]	8.847 (7) [0.264]
Arch(Lag) [Probability]	110.025 (1) [0.000]	14.154 (16) [0.587]	11.482 (8) [0.176]	32.278 (24) [0.120]
$\bar{R}^2$	0.062	0.042	0.023	0.060
Additional Lags	5,6,15	2,5	2,3,4,5	10,11,16
N	2241	2241	2957	2939
N_{LAW}	824	824	1472	372
N_{LWW}	123	123	236	11
N_{OTHER}	896	896	1172	2494
N_{ZERO}	398	398	77	62
Wald Tests Chi-Squared				
LAW=OTHER [Probability]	21.929 [0.000]	14.351 [0.000]	15.307 [0.000]	163.751 [0.000]
LWW=OTHER [Probability]	1.904 [0.168]	1.483 [0.223]	0.341 [0.560]	0.239 [0.625]

Table 5 Continued

	England 1977:01-1981:12	England 1990:01-1993:02	Germany 1976:01-1995:12	Japan 1994:02-2000:04	Switzerland 1975:01-1995:08
C_{LAW} [Probability]	0.000 [0.009]	-0.000 [0.973]	0.041 [0.113]	-0.502 [0.008]	-0.163 [0.000]
C_{LWW} [Probability]	-0.004 [0.000]	-0.001 [0.981]	-0.117 [0.076]	0.428 [0.308]	0.127 [0.096]
C_{OTHER} [Probability]	0.000 [0.365]	0.000 [0.270]	-0.010 [0.197]	0.021 [0.262	0.009 [0.315]
C_{ZERO} [Probability]	-0.000 [0.894]	0.004 [0.045]	-0.074 [0.128]	0.072 [0.287]	-0.092 [0.036]
a_1 or LAW [Probability]	0.264 [0.000]	0.905 [0.001]	0.607 [0.000]	0.096 [0.572]	0.485 [0.000]
a_2 or LWW [Probability]	0.101 [0.620]	0.333 [0.990]	0.548 [0.000]	1.027 [0.200]	0.655 [0.000]
a_3 or OTHER [Probability]	-0.077] [0.185]	0.117 [0.004]	-0.037 [0.018]	-0.065 [0.031]	-0.013 [0.380]
Garch(p,q)	1,1	1,1	1,1	2,2	1,1
Q(Lag) [Probability]	3.625 (1) [0.057]	2.106 (2) [0.349]	3.079 (1) [0.079]	22.051 (23) [0.517]	2.775 (1) [0.096]
Arch(Lag) [Probability]	0.257 (1) [0.612]	21.922 (25) [0.640]	14.190 (12) [0.289]	3.929 (5) [0.560]	20.527 (17) [0.248]
$\bar{R}^2$	0.010	0.015	0.029	0.016	0.029
Additional Lags	2	4	16,20		9,15
N	1263	800	5179	1600	5174
N_{LAW}	512	17	299	32	195
N_{LWW}	80	5	97	7	68
N_{OTHER}	669	776	4718	1496	4817
N_{ZERO}	17	6	65	65	94
Wald Tests Chi-Squared					
LAW=OTHER [Probability]	27.694 [0.000]	8.064 [0.004]	160.809 [0.000]	0.895 [0.344]	47.327 [0.000]
LWW=OTHER [Probability]	0.681 [0.409]	0.000 [0.994]	37.394 [0.000]	1.852 [0.174]	29.209 [0.000]