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Bank of England

Discussion Paper No.2

Exchange flows and the gilt-edged security market: a causality study

by

B.C.Hilliard

February 1979

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The object of this series is to give a wider circulation to research work being undertaken in the Bank and to invite comment upon it; and any comments should be sent to the author at the address given below. The views expressed are his, and not necessarily those of the Bank of England.

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Introduction[1]

1 This paper sets out to test whether there is any statistically-defined causal relationship between external inflows and sales of gilt-edged securities by the authorities, thereby implying a causal relationship between external flows and domestic credit expansion (DCE). While it is possible to define the change in the money stock in terms of a domestic component (DCE) and a foreign component (reserve changes), it is not necessarily the case that DCE is independent of reserve changes, as is frequently suggested by the monetary approach to the balance of payments. Even if the exchange rate is allowed to float, this still does not ensure that DCE will be independent of external influences, and it is important to be clear what linkages may exist.

2 The paper is divided into four sections. The first discusses the statistical techniques used, the second the data to which they are applied and the third the results obtained; the fourth section deals with the conclusions to come out of the study.

3 Although the results are not uniform, they suggest that there is a two-way causal relationship between exchange flows and the gilt-edged market. This would imply that DCE is not independent of reserve changes.

[1] I should like to thank R.T.Coghlan, C.A.E.Goodhart and other members of the Economic Intelligence Department of the Bank for their many helpful comments.

The methodology employed

4 The causality tests developed over the last decade all rely on a definition of causality proposed by Granger (1969). A version of this due to Pierce and Haugh (1977) is given below:

x causes y if

$$\sigma^2(y|\bar{A}) < \sigma^2(y|\overline{A-x})$$

where

A = the past and present information available including values of x

$-$ = all values for periods prior to the current period

$\sigma^2(y|\bar{A})$ = the mean square error of $P(y|\bar{A})$

$P(y|\bar{A})$ = the minimum mean square error one step ahead predictor of y given $\bar{A}$

likewise for $\overline{A-x}$ where x is past and present values of x and A-x is all past and present information except for information on x.

In other words, x causes y if the prediction of y using all present and past information <u>including x</u> is better (in the sense of having a lower mean square error) than the prediction of y using all present and past information <u>excluding x</u>.

5 Before applying tests for the presence of causality defined in the above way, it will be useful to be aware of the limitations of the approach. These have already been noted by several authors, e.g. Sims (1972), but are sufficiently important to be stated again here:

(i) The method as usually applied only includes values of x and y in A. If there is some other important determinant besides these two, then the conclusions of the test may be incorrect. For example, as Granger points out, if a third variable causes both x and y, then applying the test using only values of x and y may indicate a causal relationship between x and y when none exists.

(ii) It does not admit of the possibility that future values of one variable may affect past values of another variable. This point is likely to worry philosophers more than practitioners since it is hard to think of actual cases where this would arise.

(iii) If the variables under consideration are influenced by some sort of optimal control policy, then the test will be invalid.

6 Although there is a variety of different ways in which this type of causality can be tested, there are two that are widely used; both of which will be applied in this study. I will refer to these as the regression and ARIMA (auto-regressive integrated moving average) approaches. These are defined in the following paragraphs.

7 The regression approach, first used by Sims, involves regressing y on past, current and future values of x. If x causes y, then the coefficients on future values of x should be insignificant in this regression. Conversely, in a regression of x on past, current and future values of y, some of the future values of y will have significant coefficients. It is of prime importance in this method to allow for any residual autocorrelation that may be present (and so ensure that the error term is white noise) in order that the significance tests carried out are valid. Each regression was therefore estimated by autoregressive least squares. This is preferable to Sims' method of prefiltering the x and y series by a fairly arbitrary filter, because then only by chance is the regression error term reduced to white noise as required.

8 In contrast, the ARIMA approach specifically aims to reduce both the x and y series to white noise. For each series this is done by fitting an ARIMA model[1] to it and then applying that model to filter it to white noise. The test of causality is then to correlate the filtered x and y series, a and b respectively; x then causes y

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[1] That is, a model of the form:

$$\theta(L)(1-L)^d Z_t = \phi(L)u_t$$

where

$\theta(L)$ and $\phi(L)$ are finite distributed lags; Z_t is the series to be modelled; u_t is an error term distributred as $N(0,\sigma^2)$; and d is the degree of differencing.

if $\rho_{ab}(k) \neq 0$ for at least one $k > 0$ and $\rho_{ab}(k) = 0$ for all $k < 0$, where $\rho_{ab}(k)$ is the correlation between the kth lag of a and the current value of b.

9 It should be emphasised that in theory the two approaches should both yield the same causality results.[1] However, each has individual features so that it is worthwhile employing both approaches. With the ARIMA approach, a test of independence can be applied to see whether there is any causality to examine. It does, however, have the disadvantage that ARIMA modelling is a fairly vague process and one can never be sure that the true model has been found. On the other hand, the regression method has the advantage that as well as giving information on the direction of causality it allows the relationship between the two variables to be modelled and the degree of explanation to be found. This is useful information because the causality results could not really be said to tell the whole story if the relationship examined only explained 5%, say, of the variance of the dependent variable.

[1] For a discussion of this point see Pierce and Haugh.

The data used in the tests

10 The first point of interest is that daily data have been used. One reason for so doing is that many of the interactions that take place between the gilt-edged and foreign exchange markets are expected to occur very rapidly and may only be picked up by data observations of this frequency. Related to this, simultaneity between the variables should be lessened the shorter the observation period, and thus the clearer should the relationships become.

11 A consequence of using daily data for these markets is that a few observations will be extremely large in comparison to the rest. However, high variability in series is not necessarily a bad thing since it may, in fact, allow a better relationship to be fitted; see, for example, the improvement in the fit of M_1 demand equations when the post-1971 period is included in the sample - Coghlan (1978). There may still, of course, be some periods when the fitted equation does have large errors, but under the usual assumption that the errors are normally distributed, one would expect a certain number of these large errors to occur. It should also be pointed out that four definitions of gilt-edged sales are used and some of these do not give rise to many large errors.

12 For exchange flows (EF), the sterling value of market spot transactions plus central bank spot transactions conducted by the Exchange Equalisation Account (EEA) were used. To express gilt-edged market conditions, the gross redemption yield on a representative stock or the level of official sales could be used. Several definitions of both these variables were used and they are discussed below. The time period considered was the 250 working days from 23rd May 1976 to 17th March 1977. This number of observations is the maximum that the ARIMA modelling program used would allow. To permit valid comparison of the ARIMA and regression results, it was decided to use the same data period for the regression tests. The end of the sample period was chosen to be immediately before the first part-paid issue, to avoid any possibility that the introduction of such issues might have altered the structure of the gilt-edged market in some way.

13 During the sample period, there was intense activity in the foreign exchange market with sterling falling sharply and then recovering accompanied by substantial intervention at certain times. Given this, one might expect some difficulty in identifying relationships during this period but even so some reasonable results were obtained.

Gross redemption yields

14 Ideally one would like to be able to use a figure that represents some form of weighted average of many long-term gilt-edged stocks in order to obtain a truly representative series. Such a series is constructed within the Bank but it is only available for Monday, Wednesday and Thursday of each week together with the last day of the month. Since the aim is to use daily data this would mean that the series would have to be interpolated in some way. This might be justifiable for a descriptive exercise but for an analysis of the statistical properties of the series it is preferable to use individual series because any interpolation is likely to distort those properties in an unpredictable way.

15 To impart some degree of generality to the results, the yields of three securities were analysed. The securities used were chosen to be fairly large issues, out of tap, so that they would be influenced by general market conditions. In addition, two were high-coupon stocks (12 3/4% Treasury Stock 1995 and 9 1/2% Treasury Stock 1999) since it was thought that some flows might be into securities attractive to the low or zero rate taxpayer.

16 Foreign investors fall into the latter category, but for most government securities the tax is deducted at source, unless exemption is specifically applied for. Since this is a somewhat cumbersome process, it is in the interest of such investors to buy a security for which tax is not deducted. For this reason they display a marked preference for 3 1/2% War Loan 1952 or after and so this series was also analysed. In the remainder of the paper the series are known as T95, T99, and WAR respectively.

17 Having decided on the securities to be used, there is one feature that requires examination. This is the behaviour when the security goes ex-dividend. If the typical investor buying or holding that

security pays no tax, then the price of the security might be expected to fall by the amount of the dividend when it goes ex-dividend, ceteris paribus. The gross redemption yield would then be unaffected. In actual fact the average price appears to fall by about 90% of the dividend.[1] This implies that the gross redemption yield is negligibly affected when the security goes ex-dividend and so no adjustment need be made to it in such periods.

18 To ensure that this conclusion was true for the particular securities chosen, their gross redemption yields were plotted together against time. Since they went ex-dividend at different times, a comparison of the series during their respective ex-dividend periods should show up any distortions caused by the dividend. From a qualitative examination of the series no distortions were found.

Official gilt-edged sales variables

19 Four variants were tried. Each excluded official sales to the Commissioners for the Reduction of the National Debt on the grounds that these transactions are aside from the market and have no effect on it. The variants were constructed from the following four series:

(i) general sales - official sales excluding new issues, next maturities and redemptions (increase +);

(ii) next maturities - these are securities that are within about six months of maturity and so one might treat their purchase as a redemption (increase -);

(iii) redemptions (increase -); and

(iv) new issues - the quantity of a new issue sold on the day of its issue (increase +).

These were formed as follows:

S1 = (i)

S2 = (i) + (ii)

S3 = (i) + (ii) + (iii)

S4 = (i) + (ii) + (iii) + (iv).

[1] This result is drawn from a study carried out by the Capital Markets Group of the Bank's Economic Intelligence Department.

Timing of the variables

20 In such an exercise it is particularly important to be clear about the timing of the variables since this will affect the interpretation of the length of the delays found between cause and effect in the relationships. The data used in this exercise record the amount of an exchange flow on the day of the exchange deal rather than the day of its settlement (which would usually be two days after the deal). On the other hand, the amount of a gilt-edged sale is recorded on the day of the settlement of the transaction (usually one day after the deal).[1]

21 Gilt-edged yields used were those ruling at the close of business on the date for which they were recorded.

22 The timing used must be borne in mind when interpreting the results. Different hypotheses imply different timings of the variables and so any timing chosen is essentially a compromise. In this context, the ARIMA causality tests can easily accommodate changes in timing since all that need be done is to shift the origin of the cross-correlogram. It will be seen in Section 4 that shifts of several days in the timing do not affect the causality results.

[1] It was thought desirable not to adjust the exchange flow data to be recorded on the day of its settlement because, although the average delay between deal and settlement is known to be two days, the actual delay varies around this and so any adjustment made would only be approximate.

The results obtained

23 Prior to estimating the relationships, some likely processes at work determining causality are listed below:

(i) A high rate on gilt-edged stocks (relative to world interest rates) attracts foreign capital into the country. For this to be the cause of the inflows, the rate must not only be high relative to comparable world interest rates but also relative to other UK rates.

(ii) High gilt-edged sales may increase foreign confidence that the PSBR can be financed without an adverse effect on money supply growth. This may in turn lead to an optimistic view of the future rate of inflation in the United Kingdom and (given the expected average world rate of inflation and views about the UK exchange rate) lead to exchange inflows.

(iii) A high inflow of foreign funds into the UK money market may cause an improvement in UK investors' confidence. This might lead to a general increase in demand for government debt, the demand for gilt-edged increasing as part of this. If supply does not change, then the gilt-edged rate will fall. If, however, the Government wish to sell more debt or to regulate the change in the interest rate, then they will respond by selling gilt-edged stocks thereby offsetting any possible effects of these inflows on the money supply.

The signs on the coefficients in these relationships are shown in Table A overleaf.

Table A

Hypothesis	Regression	Sign of coefficient
(i)	I on R	+
(ii)	I on S	+
(iii)(a)	R on I	-
(b)	S on I	+

where

I = inflows

R = gilt-edged rate

S = gilt-edged sales.

In practice it is likely that many of the hypotheses jointly or separately will apply at one time or another. If one is suggested from the tests carried out, this will only be taken to mean that that particular explanation predominated during the sample period chosen.

The Regression tests

24 The causality tests described in Section 2 require the series being tested to be stationary. To test for stationarity, the autocorrelation function (ACF) and partial ACF were calculated for each series. If a series is stationary then the ACF should die out fairly rapidly (Box and Jenkins 1970, page 174). If it does not, then the series may be non-stationary.

25 From this procedure it was thought that the three-yield series were non-stationary and that the sales series were all stationary. To verify this an AR(1) process[1] was fitted to each of the series. The results are shown opposite in Table B. The estimated coefficient should be below unity if the series is stationary.

[1] That is, a process of the form $(1 - \theta_1 L)\ Z_t = u_t$ with Z_t and u_t as defined in the footnote on page 7.

Table B

AR(1) Estimates

$(1 - 0.3567L)\ EF_t = u_t$
(0.06)

$(1 - 0.9319L)\ T95_t = u_t$
(0.02)

$(1 - 0.9950L)\ T99_t = u_t$
(0.01)

$(1 - 0.9950L)\ WAR_t = u_t$
(0.01)

$(1 - 0.2975L)\ S1_t = u_t$
(0.06)

$(1 - 0.2681L)\ S2_t = u_t$
(0.06)

$(1 - 0.2389L)\ S3_t = u_t$
(0.06)

$(1 - 0.2465L)\ S4_t = u_t$
(0.06)

where

L = lag operator
u = error term.

Standard errors are shown in brackets beneath the estimates.

26 These results confirm the information obtained from the ACFs. The first five variables are clearly stationary. T95, T99, and WAR have coefficients very close to unity, suggesting that they are non-stationary. Although, given the standard error shown, the estimate of the coefficient on T95 is significantly below unity with 5% probability of type 1 error, the value of 0.9319 can still be taken as strong evidence of non-stationarity.[1] In the light of this, the yield series were first-differenced to induce stationarity.

27 Because the suggested economic processes determining the causality are likely to act quickly if they act at all, it was decided to limit the maximum time lag between cause and effect to ten days. This meant that the regressions would include (besides a constant) ten leads, the current value, and ten lags of the explanatory variable. In preliminary estimation it was found that with this number of variables the t statistics of each of the coefficients were generally insignificant and little information was gained. It was therefore decided to reduce the number of variables in the regression. Two sets were run - one with five lags and ten leads, the other with ten lags and five leads of the explanatory variable. Since the object of the exercise is to test the significance of the leads as a group, the corresponding regressions without the leads were also run, i.e. with five lags and ten lags respectively.

[1] The more detailed ARIMA modelling carried out later in this section showed these conclusions to be correct.

28 As stated earlier, the tests require that any autocorrelation in the residuals be allowed for in the estimation procedure. The program used allows the modelling of autoregressive error processes up to and including the fourth order. The procedure adopted was therefore to estimate the regressions specifying all error processes up to the fourth order and then examine the results to see which order was appropriate. This was decided by considering the significance of the autoregressive parameters.

29 When carrying out tests of the significance of a group of coefficients, an F test is normally used, but, in this case, an χ^2 test is more appropriate. This is because the presence of the autoregressive error term necessitates the use of a likelihood ratio test, the statistic for which is asymptotically distributed as a χ^2 variable. The test statistic is

$$T \log_e \frac{RSS1}{RSS2}$$

where

T = the number of observations

RSS1 = the residual sum of squares of the model excluding the particular group of n variables

RSS2 = the residual sum of squares of the model that is the same except that it includes the n variables.

The test statistic is then distributed as χ^2 with n degrees of freedom under the null hypothesis that the n variables have no influence as a group. In applying the test it is important to specify the same order of autoregressive error process in the two equations being compared; otherwise the competing hypotheses will not be nested[1] and so this test cannot be performed. Therefore whenever the two equations (i.e. that including leads and its counterpart without leads) had error processes of different orders, the maximum of the two orders was chosen and the estimates of the two equations with that maximum order specified were compared.

30 The tests were carried out for each of the gilt-edged market variables discussed in Section 3, the test statistics being shown in Table C. If causality runs uniquely from variable A to variable B,

[1] One hypothesis is nested inside another if the former can be obtained by placing some specified restrictions on the parameters of the latter.

then in a regression of A on leads and lags of B the leads and lags will be significant, whereas in a regression of B on leads and lags of A the leads of A will be insignificant. From Table C we can then see that causality appears to run uniquely from exchange flows to interest rates. For the five leads case, exchange flows also seem to cause S1 and S2, the official sales variables excluding redemptions and new issues, but for the ten leads case, the leads in neither direction are significant. For S3 and S4 there is inconclusive evidence on the direction of causality.

Table C

χ^2 test statistics for significance of leads

	Five leads	Ten leads
T95 on EF	3.67	6.87
EF on T95	11.73[a]	21.13[a]
T99 on EF	1.57	4.90
EF on T99	9.09	17.58
WAR on EF	4.33	12.71
EF on WAR	10.63	18.44[a]
S1 on EF	1.35	9.19
EF on S1	12.23[a]	14.08
S2 on EF	2.62	12.14
EF on S2	11.50[a]	12.13
S3 on EF	10.19	24.04[a]
EF on S3	15.14[a]	20.60[a]
S4 on EF	9.94	23.70[a]
EF on S4	12.09[a]	16.30

The five leads statistic is distributed as $\chi^2(5)$
The ten leads statistic is distributed as $\chi^2(10)$

$\chi^2(5)$ 5% = 11.07
$\chi^2(10)$ 5% = 18.31

[a] Significant with 5% probability of type 1 error.

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31 To examine these results further, the regressions are shown in Table D on the following pages for a representative member of each of the

Table D

Dependent variable: WAR
Explanatory variable: EF
Number of observations: 225

Regression number:	1	2	3	4
Lag on explanatory variable				
+ 10	-0.00025 (1.05)	-0.00026 (1.09)		
+ 9	+0.00055 (2.10)	+0.00055 (2.16)		
+ 8	-0.00009 (0.34)	-0.00015 (0.60)		
+ 7	+0.00005 (0.19)	+0.00008 (0.32)		
+ 6	-0.00006 (0.23)	-0.00015 (0.56)		
+ 5	-0.00040 (1.53)	-0.00046 (1.79)	-0.00029 (1.19)	-0.00040 (1.71)
+ 4	-0.00028 (1.09)	-0.00027 (1.05)	-0.00011 (0.43)	-0.00020 (0.78)
+ 3	-0.00022 (0.88)	-0.00027 (1.06)	-0.00023 (0.85)	-0.00026 (1.02)
+ 2	-0.00002 (0.07)	-0.00007 (0.27)	+0.00009 (0.33)	-0.00004 (0.14)
+ 1	+0.00004 (0.18)	+0.00004 (0.15)	+0.00012 (0.46)	+0.00003 (0.10)
0	+0.00007 (0.29)	+0.00002 (0.10)	+0.00014 (0.28)	+0.00012 (0.49)
- 1	+0.00002 (0.09)		+0.00022 (0.85)	
- 2	-0.00031 (1.24)		-0.00033 (1.26)	
- 3	+0.00025 (1.00)		+0.00031 (1.22)	
- 4	-0.00023 (0.92)		-0.00044 (1.72)	
- 5	-0.00018 (0.77)		-0.00007 (0.29)	
- 6			-0.00044 (1.70)	
- 7			+0.00013 (0.51)	
- 8			-0.00009 (0.36)	
- 9			-0.00023 (0.90)	
- 10			+0.00015 (0.63)	
Constant	-0.00287 (0.36)	-0.00375 (0.47)	-0.00230 (0.28)	-0.00462 (0.56)
ρ^1	-0.21038 (3.13)	-0.20722 (3.14)	-0.20242 (2.98)	-0.19682 (2.97)
ρ^2				
ρ^3				
ρ^4				
RSS	4.321617	4.405730	4.570718	4.836423
R^2	0.129	0.112	0.123	0.072

ρ^i = ith order autoregressive coifficient

RSS = residual sum squares

t statistics in brackets

Table D (continued)

Dependent variable: EF

Explanatory variable: WAR

Number of observations: 225

Regression number:	5		6		7		8	
Lag on explanatory variable								
+ 10	- 2.936	(0.15)	- 6.941	(0.35)				
+ 9	-26.423	(1.27)	-36.683	(1.74)				
+ 8	-30.056	(1.44)	-38.461	(1.82)				
+ 7	-29.72	(1.43)	-36.655	(1.73)				
+ 6	-63.005	(2.99)	-69.616	(3.24)				
+ 5	-46.816	(2.21)	-56.778	(2.62)	-20.476	(1.06)	-16.440	(0.85)
+ 4	-53.830	(2.56)	-59.070	(2.74)	-38.815	(1.87)	-37.667	(1.80)
+ 3	-21.208	(1.00)	-19.934	(0.93)	- 5.284	(0.25)	- 0.899	(0.04)
+ 2	-46.045	(2.19)	-44.804	(2.08)	-27.561	(1.33)	-20.778	(1.01)
+ 1	-28.060	(1.34)	-21.872	(1.01)	-13.255	(0.63)	+ 3.749	(0.18)
0	-23.234	(1.08)	-12.311	(0.60)	-13.379	(0.63)	+ 7.143	(0.36)
- 1	-13.562	(0.63)			-17.045	(0.81)		
- 2	-16.215	(0.75)			-26.676	(1.26)		
- 3	-38.016	(1.74)			-52.764	(2.51)		
- 4	-51.242	(2.32)			-62.044	(2.96)		
- 5	-52.486	(2.53)			-63.979	(2.97)		
- 6					-41.626	(1.94)		
- 7					-14.507	(0.68)		
- 8					-16.952	(0.78)		
- 9					+ 7.495	(0.34)		
- 10					-17.463	(0.86)		
Constant	+ 1.058	(0.25)	+ 2.326	(0.47)	+ 0.385	(0.08)	+ 2.810	(0.47)
ρ^1	+ 0.16555	(2.34)	+ 0.21302	(3.07)	+ 0.22165	(3.20)	+ 0.28527	(4.25)
ρ^2	- 0.05322	(0.74)	- 0.02719	(0.38)	- 0.06702	(0.95)	- 0.03077	(0.44)
ρ^3	+ 0.03194	(0.44)	+ 0.05933	(0.81)	+ 0.05320	(0.74)	+ 0.08005	(1.13)
ρ^4	+ 0.16264	(2.26)	+ 0.15976	(2.24)	+ 0.18079	(2.61)	+ 0.20169	(2.95)
RSS	386582		405282		369617		401189	
R^2	0.259		0.223		0.260		0.196	

ρ^i = ith order autoregressive coefficient

RSS = residual sum of squares

t statistics in brackets

Table D (continued)

Dependent variable: S1

Explanatory variable: EF

Number of observations: 226

Regression number:	9	10	11	12
Lag on explanatory variable				
+ 10	- 0.11898 (1.04)	- 0.13545 (1.21)		
+ 9	- 0.07018 (0.61)	- 0.08730 (0.79)		
+ 8	+ 0.08392 (0.73)	+ 0.07491 (0.68)		
+ 7	- 0.07941 (0.70)	- 0.06284 (0.58)		
+ 6	+ 0.02389 (0.21)	+ 0.01283 (0.12)		
+ 5	- 0.04555 (0.39)	- 0.05258 (0.48)	- 0.08119 (0.72)	- 0.07597 (0.71)
+ 4	+ 0.01878 (0.17)	+ 0.00958 (0.09)	- 0.04359 (0.38)	+ 0.00857 (0.08)
+ 3	+ 0.23355 (2.07)	+ 0.21898 (2.01)	+ 0.18292 (1.60)	+ 0.19169 (1.83)
+ 2	+ 0.27329 (2.46)	+ 0.27011 (2.51)	+ 0.24917 (2.21)	+ 0.27278 (2.63)
+ 1	+ 0.12929 (1.17)	+ 0.13638 (1.27)	+ 0.13024 (1.14)	+ 0.13929 (1.31)
0	+ 0.00092 (0.01)	+ 0.01359 (0.13)	- 0.02346 (0.21)	- 0.01488 (0.14)
- 1	- 0.07404 (0.66)		- 0.14948 (1.34)	
- 2	- 0.07101 (0.65)		- 0.13030 (1.16)	
- 3	+ 0.06372 (0.58)		+ 0.01634 (0.15)	
- 4	- 0.00899 (0.08)		- 0.02916 (0.27)	
- 5	+ 0.02160 (0.20)		+ 0.03632 (0.33)	
- 6			+ 0.19327 (1.74)	
- 7			+ 0.06933 (0.64)	
- 8			+ 0.21618 (1.99)	
- 9			- 0.01389 (0.13)	
- 10			- 0.06859 (0.63)	
Constant	+27.82627 (4.49)	+27.56842 (4.51)	+27.75563 (4.54)	+28.55520 (4.69)
ρ^1	+ 0.24654 (3.64)	+ 0.24648 (3.71)	+ 0.24130 (3.58)	+ 0.24932 (3.79)
ρ^2				
ρ^3				
ρ^4				
RSS	1006952	1012969	987814	1028819
R^2	0.148	0.142	0.170	0.135

ρ^i = ith order autoregressive coefficient

RSS = residual sum of squares

t statistics in brackets

Table D (continued)

Dependent variable: EF

Explanatory variable: S1

Number of observations: 226

Regression number:	13		14		15		16	
Lag on explanatory variable								
+ 10	-0.00948	(0.22)	-0.01374	(0.32)				
+ 9	+0.03202	(0.74)	+0.01630	(0.37)				
+ 8	+0.11116	(2.58)	+0.09645	(2.22)				
+ 7	+0.02350	(0.54)	+0.01438	(0.33)				
+ 6	+0.05475	(1.22)	+0.04227	(0.92)				
+ 5	+0.01779	(0.40)	+0.00411	(0.09)	+0.00530	(0.13)	-0.01350	(0.32)
+ 4	+0.02190	(0.49)	+0.01479	(0.32)	+0.00048	(0.01)	-0.02107	(0.50)
+ 3	+0.05438	(1.21)	+0.03437	(0.78)	+0.04395	(1.04)	+0.01402	(0.35)
+ 2	+0.00953	(0.21)	-0.03468	(0.78)	-0.00627	(0.15)	-0.05254	(1.31)
+ 1	-0.01340	(0.30)	-0.04609	(1.04)	-0.02203	(0.50)	-0.06020	(1.43)
0	-0.01433	(0.32)	-0.01254	(0.28)	-0.01223	(0.28)	-0.01856	(0.44)
- 1	+0.04767	(1.06)			+0.04952	(1.13)		
- 2	+0.10815	(2.49)			+0.10429	(2.36)		
- 3	+0.06559	(1.52)			+0.07126	(1.61)		
- 4	-0.01276	(0.30)			+0.00308	(0.07)		
- 5	-0.01543	(0.36)			-0.01157	(0.26)		
- 6					+0.02569	(0.58)		
- 7					+0.01854	(0.44)		
- 8					+0.05681	(1.35)		
- 9					-0.02225	(0.53)		
- 10					-0.04914	(1.16)		
Constant	-9.56134	(1.10)	+1.33291	(0.15)	-4.24621	(0.48)	+8.23032	(0.96)
ρ^1	+0.20260	(2.91)	+0.24247	(3.53)	+0.24129	(3.54)	+0.28528	(4.31)
ρ^2	+0.01866	(0.26)	+0.01919	(0.27)	+0.00170	(0.02)	+0.00998	(0.14)
ρ^3	+0.08368	(1.15)	+0.08301	(1.13)	+0.09134	(1.29)	+0.09865	(1.41)
ρ^4	+0.20936	(2.94)	+0.21800	(3.05)	+0.21602	(3.13)	+0.24097	(3.58)
RSS	397717		419828		380595		405058	
R^2	0.238		0.195		0.241		0.192	

ρ^i = ith order autoregressive coefficient

RSS = residual sum of squares

t statistics in brackets

Table D (continued)

Dependent variable: S3

Explanatory variable: EF

Number of observations: 228

Regression number:	17	18	19	20
Lag on explanatory variable				
+ 10	- 0.06642 (0.51)	- 0.09315 (0.72)		
+ 9	- 0.10932 (0.84)	- 0.13770 (1.08)		
+ 8	+ 0.07526 (0.58)	+ 0.13126 (1.03)		
+ 7	- 0.02974 (0.23)	+ 0.00297 (0.02)		
+ 6	+ 0.03789 (0.29)	+ 0.07250 (0.57)		
+ 5	+ 0.01509 (0.12)	- 0.02755 (0.22)	- 0.03106 (0.25)	- 0.05799 (0.47)
+ 4	- 0.09596 (0.75)	- 0.10135 (0.80)	- 0.15775 (1.25)	- 0.10879 (0.88)
+ 3	+ 0.37267 (2.91)	+ 0.38500 (3.04)	+ 0.28792 (2.27)	+ 0.37549 (3.10)
+ 2	+ 0.12815 (1.02)	+ 0.14234 (1.14)	+ 0.07294 (0.58)	+ 0.15706 (1.31)
+ 1	+ 0.28855 (2.31)	+ 0.33075 (2.67)	+ 0.32597 (2.55)	+ 0.35727 (2.89)
0	- 0.07487 (0.59)	- 0.04462 (0.35)	- 0.09946 (0.78)	- 0.05290 (0.43)
- 1	- 0.19295 (1.53)		- 0.26999 (2.17)	
- 2	+ 0.05426 (0.44)		+ 0.03831 (0.31)	
- 3	+ 0.08534 (0.69)		+ 0.00676 (0.05)	
- 4	+ 0.30221 (2.44)		+ 0.27367 (2.25)	
- 5	- 0.08564 (0.69)		- 0.06662 (0.54)	
- 6			- 0.00911 (0.07)	
- 7			+ 0.24246 (2.01)	
- 8			+ 0.32282 (2.67)	
- 9			- 0.01357 (0.11)	
- 10			- 0.05223 (0.43)	
Constant	+29.23583 (4.44)	+29.24467 (4.44)	+29.37209 (4.70)	+31.06183 (4.78)
ρ^1	+ 0.19533 (2.89)	+ 0.19209 (2.86)	+ 0.17376 (2.55)	+ 0.19123 (2.87)
ρ^2				
ρ^3				
ρ^4				
RSS	1311782	1371758	1250173	1389213
R^2	0.188	0.151	0.227	0.141

ρ^i = ith order autoregressive coefficient

RSS = residual sum of squares

t statistics in brackets

Table D (concluded)

Dependent variable: EF

Explanatory variable: S3

Number of observations: 229

Regression number:	21	22	23	24
Lag on explanatory variable				
+ 10	+ 0.00404 (0.11)	+ 0.01252 (0.35)		
+ 9	+ 0.01672 (0.47)	+ 0.02100 (0.58)		
+ 8	+ 0.10667 (3.01)	+ 0.11329 (3.14)		
+ 7	+ 0.10693 (3.01)	+ 0.10872 (3.01)		
+ 6	- 0.01147 (0.32)	- 0.01181 (0.33)		
+ 5	- 0.00848 (0.24)	- 0.00827 (0.23)	- 0.00264 (0.07)	+ 0.00098 (0.03)
+ 4	+ 0.10986 (3.05)	+ 0.11731 (3.24)	+ 0.11370 (3.21)	+ 0.12322 (3.47)
+ 3	+ 0.02764 (0.77)	+ 0.04243 (1.17)	+ 0.05198 (1.47)	+ 0.06868 (1.93)
+ 2	+ 0.00410 (0.11)	+ 0.01469 (0.41)	+ 0.02749 (0.78)	+ 0.03826 (1.08)
+ 1	- 0.03372 (0.94)	- 0.03034 (0.84)	- 0.03645 (1.03)	- 0.03250 (0.91)
0	+ 0.00550 (0.15)	- 0.00512 (0.14)	+ 0.00285 (0.08)	- 0.01397 (0.38)
- 1	+ 0.07501 (2.11)		+ 0.08279 (2.30)	
- 2	+ 0.04410 (1.23)		+ 0.04557 (1.27)	
- 3	+ 0.09407 (2.64)		+ 0.10210 (2.84)	
- 4	- 0.02302 (0.65)		+ 0.00021 (0.01)	
- 5	- 0.01922 (0.54)		+ 0.00405 (0.11)	
- 6			+ 0.02585 (0.73)	
- 7			+ 0.01658 (0.47)	
- 8			+ 0.03491 (0.98)	
- 9			- 0.02812 (0.79)	
- 10			- 0.02766 (0.78)	
Constant	-12.45186 (2.45)	- 8.55221 (1.70)	-11.81340 (2.18)	14.64485 (0.91)
ρ^1	+ 0.22558 (3.30)	+ 0.25108 (3.68)	+ 0.28565 (4.32)	+ 0.32754 (5.04)
ρ^2				
ρ^3				
ρ^4				
RSS	383121	409316	380742	416574
R^2	0.274	0.224	0.257	0.187

ρ^i = ith order autoregressive coefficient

RSS = residual sum of squares

t statistics in brackets

three groups of variables discussed above, i.e. WAR, S1 and S3. A general observation is that although the R^2 for each of the regressions shown is rather low, the highest value being 0.274, they are quite good considering that daily data have been used and thus there is a large amount of noise in the series. In addition the regressions with EF as the dependent variable generally outperform those with a gilt-edged market variable as dependent variable.

32 For the regressions of WAR on EF, there is only one significant coefficient and generally the relationship seems weak. In regressions 2 and 4 the sum of coefficients is negative which accords with hypothesis (iv), but given the lack of significance of the coefficients no weight can be put on this result. For the complementary regressions 6 and 8, the sum of the coefficients is strongly negative but this does not conform with any of the suggested hypotheses. This is unfortunate since regression 6 appears to express quite a strong relationship. If high interest rates attract foreign exchange inflows, then one would expect a positive sum of coefficients. What is also rather surprising is that the tests recorded in Table C indicate causality running from exchange flows to the War Loan interest rate, whereas the best-defined relationship of the first eight is regression 6 where changes in the War Loan interest rate cause exchange flows.

33 For the regressions using gilt-edged sales, when only lagged values of the explanatory variables were used, the sum of the coefficients on those lagged values was positive in all but one case (16). These positive signs accord with hypotheses (iii)(b) for the regressions of S on EF and with (ii) for the regressions of EF on S. In addition the regressions of S1 and S3 on EF displayed a pronounced positive effect at one, two and three lags. Given the delay between the deal and settlement of an exchange transaction, this timing could be accounted for by a simultaneous decision to buy gilt-edged stocks and the sterling with which to purchase them, or simultaneous settlement of the deals. Of this set of regressions, the strongest result is the two-way causality indicated between S3 and EF in the case where ten leads were tested.

The ARIMA tests

34 To gain further information, ARIMA causality tests were carried out on the three gilt-edged variables for which the regressions were

shown. The first stage in this procedure is to fit ARIMA models to the series under examination. The aim in the ARIMA modelling procedure was to obtain a parsimonious representation that satisfied the usual diagnostic checks of overfitting, Q statistics etc. The models chosen are shown in Table E.

Table E

The preferred ARIMA models

EF $$(1 - L)Z_t = (1 - \underset{(0.0617)}{0.7486}L - \underset{(0.0624)}{0.1931}L^2)u_t$$

RSS = 0.4690E6 Q(17) = 25.57

WAR $$(1 - L)Z_t = (1 + \underset{(0.0629)}{0.1419}L)u_t$$

RSS = 0.5410 Q(18) = 19.93

S1 $$Z_t = (1 + \underset{(0.0650)}{0.2815}L + \underset{(0.0633)}{0.1522}L^2)u_t$$

RSS = 0.1101E7 Q(17) = 21.23

S3 $$Z_t = (1 + \underset{(0.0635)}{0.2361}L + \underset{(0.0629)}{0.1546}L^2)u_t$$

RSS = 0.1537E7 Q(17) = 26.69

where
RSS = residual sum of squares
Q(n) = Box-Pierce Q statistic distributed as χ^2 with n degrees of freedom
$\chi^2(17)$ 5% = 27.59
$\chi^2(18)$ 5% = 28.87
Standard errors are shown in brackets below the coefficients.

35 All these specifications pass the diagnostic checks mentioned. The model for EF has a root of (1 - 0.9515L) in the moving average part, which might be thought to cancel approximately with the (1 - L) in the autoregressive part to give a (0, 0, 1) model. However, on fitting a (0, 0, 1) model, the Q test is failed so that the (0, 1, 2) specification is still preferred.

36 The next stage was to use the fitted ARIMA models to form within-sample predictions of the series and thus the within-sample residuals, i.e. to filter the series by their estimated ARIMA representations to reduce them to white noise. Lastly, past, current and future values of the filtered series were cross-correlated. This technique is more flexible than the regression technique in that the number of leads and

lags between the two series under consideration can more easily be varied. Because of this, twenty leads and lags were chosen, rather than the ten leads and lags chosen for the regressions.

37 To use the cross-correlogram data to infer causality, first, a test of the independence of the two series is required (if they are independent then there is no causal relationship present), and, secondly, standard errors for each of the cross-correlation coefficients. The formulae used to compute these are taken from Haugh (1976). The independence test statistic is:

$$S_M^* = T^2 \sum_{k=-M}^{M} (T - |k|)^{-1} \rho_{12}(k)^2 \sim \chi^2(2M + 1)$$

where

M = maximum lead and lag

T = number of observations

$\rho_{12}(k)$ = cross-correlation coefficient between series 1 lagged k periods and series 2.

If S_M^* is less than the χ^2 value, then the two series are independent.

The variance of the cross-correlation coefficient $\rho_{12}(k)$ is:

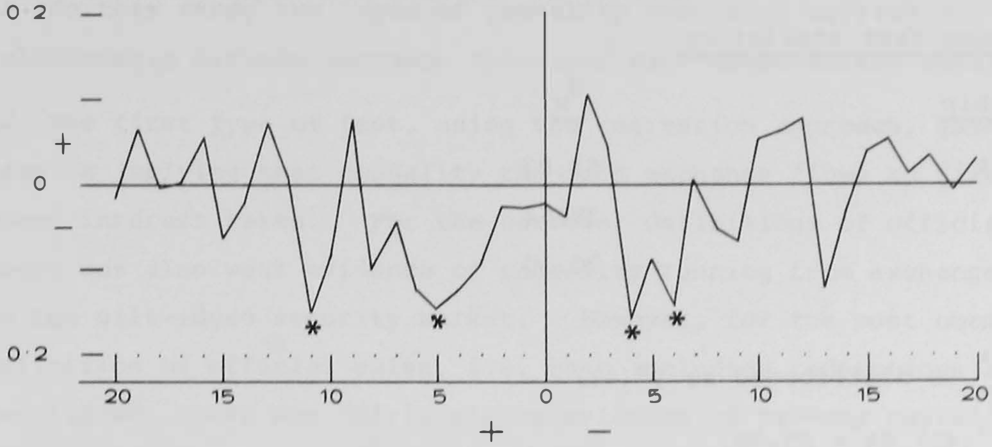
$$\text{var } \rho_{12}(k) = (1 - |k/T|)T^{-1}$$

38 The cross-correlograms showing the correlation between EF and WAR, S1 and S3 are shown in Charts A, B and C respectively. Using the above formula, the confidence interval for each correlation coefficient was computed and where a coefficient was found to be significant this was marked on the chart. The relevant S_M^* statistics are shown in Table F on page 28.

39 From this table we see that only between EF and S3 is a significant relationship indicated and so only for that can we carry out a causality test. From Chart C we see that there are several significant (positive) coefficients for both leads and lags of EF and thus we conclude that there is two-way causality between EF and S3. This is still true even if the timing of EF is moved back by two days. This result agrees with the result obtained for S3 by the regression method when ten leads were used. This is noteworthy since the latter was the strongest result obtained using the regression method.

Chart A

Cross Correlogram of War Loan and EF

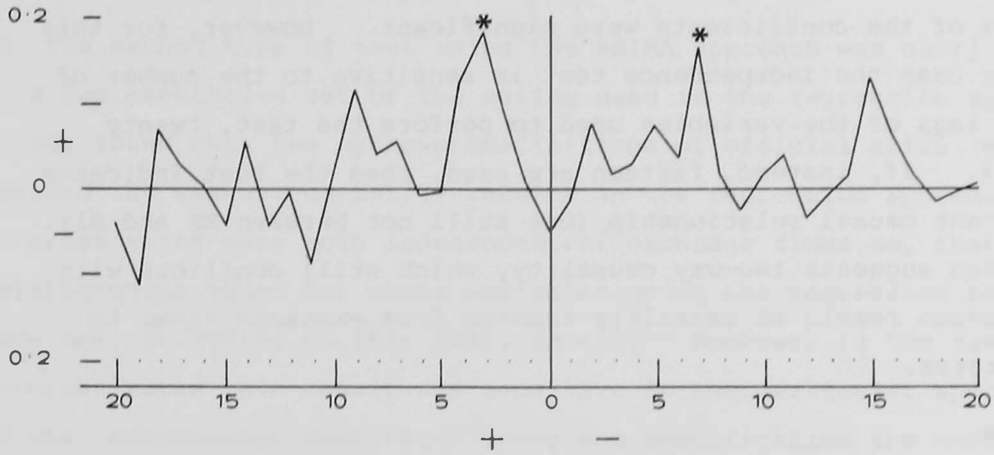


Number of days lag on EF relative to WAR (+ = lag, − = lead)

* Significant with 5 % probability of Type 1 error

Chart B

Cross Correlogram of S1 and EF

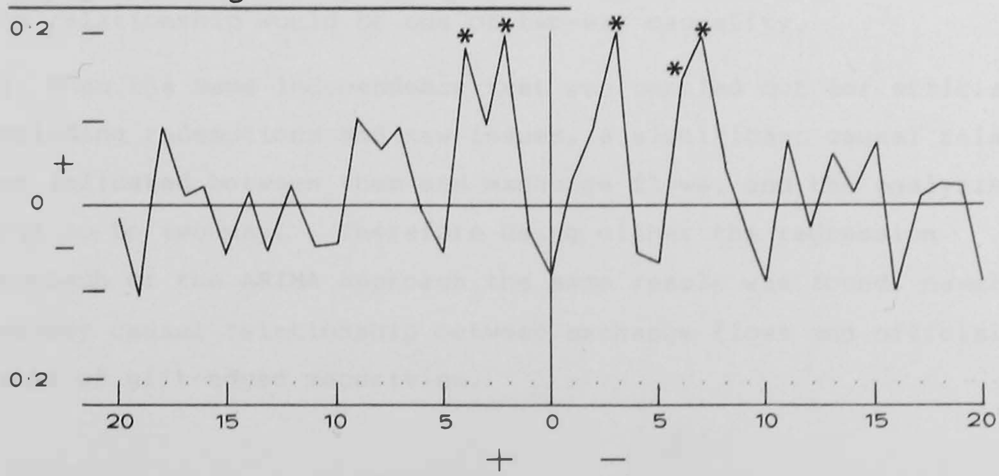


Number of days lag on EF relative to S1 (+ = lag, − = lead)

* Significant with 5 % probability of Type 1 error

Chart C

Cross Correlogram of S3 and EF



Number of days lag on EF relative to S3 (+= lag, − = lead)

* Significant with 5 % probability of Type 1 error

Table F

Independence test statistics

Relationship	S^*_M
EF and WAR	51.87
EF and S1	39.54
EF and S3	70.10

where

S^*_M is distributed as $\chi^2(41)$

$\chi^2(40)$ 5% = 55.76.

40 The fact that no causality is indicated between EF and WAR conflicts with the regression results where in several cases the t statistics of the coefficients were significant. However, for this particular case the independence test is sensitive to the number of leads and lags of the variables used to perform the test, twenty being used. If, instead, fifteen are used, then the test indicates a significant causal relationship (but still not between EF and S1). Chart A then suggests two-way causality, which still conflicts with the regression result of causality running from exchange flows to interest rates.

Conclusions

41 In this study two types of causality test were carried out on the relationship between exchange flows and gilt-edged market conditions.

42 The first type of test, using the regression approach, gave some results implying that causality ran from exchange flows to gilt-edged interest rates. For the narrower definitions of official sales there was also weak evidence of causality running from exchange flows to the gilt-edged security market. However, for the most normal definition of official sales, i.e. that including redemptions and new issues, there was fairly strong evidence of two-way causality. There was also a pronounced positive effect of exchange flows on sales of gilt-edged with a lag of one to three days, suggesting that a reasonable amount of automatic sterilisation of exchange inflows rapidly takes place.

43 The second type of test using the ARIMA approach was carried out on a representative set of the series used in the regression approach. It was found that the narrower definitions of official sales (which yielded the weakest causality results in the regression approach) and interest rates were both independent of exchange flows so, that the relationships found for those variables using the regression approach were not, according to this test, causal. However, in the case of interest rates this result was sensitive to the particular specification of the independence test used (using one specification the test suggested independence, in the other it did not) and so it is possible that a causal relationship does exist between exchange flows and interest rates. The appropriate cross-correlogram then suggests that the relationship would be one of two-way causality.

44 When the same independence test was carried out for official sales including redemptions and new issues, a significant causal relationship was indicated between them and exchange flows, and the analysis showed this to be two-way. Therefore using either the regression approach or the ARIMA approach the same result was found, namely a two-way causal relationship between exchange flows and official sales of gilt-edged securities.

45 In the monetary theory of the balance of payments, the assumption is made that DCE is exogenous with respect to exchange flows. Although, as has been mentioned above, the results obtained in this paper are not entirely uniform between the two testing approaches used, they both produce the result that there is two-way causality between official gilt-edged sales and exchange flows. Since some official gilt-edged sales will affect DCE, there is therefore some weak evidence that DCE is not exogenous and that that assumption made in the monetary theory of the balance of payments may not be correct.

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CORRECTION

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Page 11 Paragraph 19

In the definition of variables at the foot of the page, variable S3 should read:

$$S3 = (i) + (iii) + (iv)$$