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The interaction between trading volume of stocks and options: some statistical evidence

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The finance literature provides several examples of research into the interaction between stock and option prices. This paper examines the feedback hypothesis for trading volume on the Amsterdam stock and options markets using a generalized Granger–Sims framework.

The most important finding of this paper is that very often causality runs from options trade to the stock market which seems to support the feeling of the business profession and the main hypothesis of this paper. Statistically it is interesting that the results indicate very convincingly that the relations reveal no stability over time. (JEL C13, C52).

The finance literature—see *e.g.* Black (1975), Jennings and Starks (1986), Manaster and Rendleman (1982)—provides several examples of research into the interaction between stock and option prices. This research examines the hypothesis that option prices include incremental information on stock prices. Other researchers, *e.g.* Copeland (1976) and more recently Anthony (1988), have analyzed trading volume on stock and option markets to test the sequential-information-arrival hypothesis using trading volume as a proxy for the rate of information arrival. The main difference between these two studies concerns both the markets considered and the statistical methodology employed. As to the latter, Anthony employs Granger–Sims causality tests based on regression analysis and univariate autoregressive time series models. Unlike finance theorists practitioners have no doubt that option trading encourages stock trading although they are less unanimous on the feedback. To study this question the multivariate time series model or vector ARIMA model offers an appropriate framework to examine the Granger–Sims causality. The feedback or causality question became of paramount practical importance in discussions on the October 1987 stock market crash when options and futures trading were blamed for causing part of the trouble and serious doubts were raised on the market mechanisms for financial derivatives as options. In the US this led to the well-known Brady report of January 1988. Similar studies were made for European financial centers like Amsterdam.

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This article addresses the feedback hypothesis by postulating a general bivariate autoregressive time series model as a tool for analysis which was applied to daily data for the Amsterdam stock and option markets. Thus it enables one to operationalize the feedback assumption and to derive conclusions on the type of causality in a generalized Granger–Sims framework.

As indicated above the present paper is akin to and an extension of Anthony. The results are generally consistent with Anthony's findings, *i.e.* that option trading often leads stock trading. However, this paper offers several incremental contributions. These are both technical and substantial. As to the first they are the use of the bivariate ARMA model, the evidence from a different market than the US market and the coverage of a more extensive sample period. As a matter of substance the finding that the results are unstable over the longer time period considered here is of particular interest. Unlike Anthony, the reported results include all traded options and not only near the money options. Thus the results offer corroborating evidence from a European market.

Section I introduces the statistical model and discusses the data used in estimating this model. Section II summarizes the results of this statistical analysis of the transactions volume data of the stock and option market. The final section draws the main conclusions of this exercise.

I. Statistical methodology

I.A. The stochastic multivariate time series model

The behavior of a univariate time series x_t is often described by stochastic difference equations or ARIMA (p, d, q) models of the form:

$$\langle 1 \rangle \qquad \phi_p(B)\nabla^d x_t = \theta_0 + \theta_q(B)a_t,$$

where $\phi_p(B) = 1 - \phi_1 B - \phi_2 B^2 - \cdots - \phi_p B^p$, $\theta_q(B) = 1 - \theta_1 B - \theta_2 B^2 - \cdots - \theta_q B^q$ are scalar polynomials in B, θ_0 is a constant. B is the backshift operator such that $Bx_t = x_{t-1}$, ∇ the difference operator such that $\nabla = 1 - B$, and p, d, q are non-negative integers. In $\langle 1 \rangle$ the a_t are stochastically independent, normally distributed random shocks with zero mean and constant variance σ_a^2.

Apart from differencing the straightforward generalization of $\langle 1 \rangle$ is the $m \times m$ vector or multivariate stochastic difference equation:

$$\langle 1\text{a} \rangle \qquad \phi(B)x_t = \theta_0 + \theta(B)a_t,$$

where $\phi(B) = I - \phi_1 B - \phi_2 B^2 - \cdots - \phi_p B^p$, $\theta(B) = I - \theta_1 B - \theta_2 B^2 - \cdots - \theta_q B^q$ are matrix polynomials in the backshift operator B, the ϕ and θ matrices of order $m \times m$, I the $m \times m$ identity matrix, θ_0 a $m \times 1$ vector of constants, $x_t = (x_{1t}, x_{2t}, \ldots, x_{mt})'$ a $m \times 1$ vector of observations at time t on a set of m univariate jointly stationary time series, $a_t = (a_{1t}, a_{2t}, \ldots, a_{mt})'$, a $m \times 1$ vector of stochastically independent and normally distributed random shocks with zero mean and covariance matrix Σ_a, *i.e.* $Ea_t = 0$ and $E(a_t, a_t') = \Sigma_a$, where Σ_a is a positive definite matrix of order $m \times m$. Equation $\langle 1\text{a} \rangle$ is called a vector ARMA model. It is well known that the parameters of the vector ARMA model must meet certain conditions to ensure stationarity and invertibility, *i.e.* the roots of the equation of both $|\phi(B)|=0$ and $|\theta(B)|=0$ should all lie outside the unit circle.

An alternative but equivalent representation of ⟨1a⟩ is:

$$\langle 1b\rangle \quad \begin{pmatrix} \phi_{11}(B) & \cdots & \phi_{1m}(B) \\ \vdots & & \vdots \\ \phi_{m1}(B) & \cdots & \phi_{mm}(B) \end{pmatrix} \begin{pmatrix} x_{1t} \\ \vdots \\ x_{mt} \end{pmatrix} = \begin{pmatrix} \theta_1 \\ \vdots \\ \theta_m \end{pmatrix} + \begin{pmatrix} \theta_{11}(B) & \cdots & \theta_{1m}(B) \\ \vdots & & \vdots \\ \theta_{m1}(B) & \cdots & \theta_{mm}(B) \end{pmatrix} \begin{pmatrix} a_{1t} \\ \vdots \\ a_{mt} \end{pmatrix},$$

with $\phi_{ij}(B)$ and $\theta_{ij}(\mathrm{B})$ scalar polynomials in B of degree p_{ij} and q_{ij} respectively. The polynomials in the diagonal position start with unity, while the polynomials in the off-diagonal position start with terms which are some power of B.

To illustrate the above notation and for future reference I consider the bivariate ARMA (1, 1) model:

$$\langle 1c\rangle \quad \begin{pmatrix} 1-\phi_{11}B & -\phi_{12}B \\ -\phi_{21}B & 1-\phi_{22}B \end{pmatrix} \begin{pmatrix} x_{1t} \\ x_{2t} \end{pmatrix} = \begin{pmatrix} 1-\theta_{11}B & -\theta_{12}B \\ -\theta_{21}B & 1-\theta_{22}B \end{pmatrix} \begin{pmatrix} a_1 \\ a_2 \end{pmatrix}$$

I.B. Conditions for causality

Since Sims' (1972) seminal article on the causality between money and income the time series framework has become an important statistical tool for empirical causality analysis in economics along the lines suggested by Granger (1969).

Of course, this does not mean that there is full agreement among economists about the appropriateness of Granger's definition of causality (see Zellner, 1979). The multivariate time series model offers a natural generalization for this purpose. Following Kang (1981), Hsiao (1982) and Osborn (1984), necessary and sufficient conditions for causality in the multivariate ARMA process can be formulated. These formal conditions are formalizations of the intuitive notion that in a multivariate framework causality means something like an upper-block-triangular structure of the matrices $\phi(B)$ and $\theta(B)$ in equation ⟨1b⟩. Suppose that in this general multivariate ARMA model the vectors x and a can be partitioned so that x_1 and a_1 are $g\times 1$ vectors and x_2 and a_2 are $h\times 1$ vectors, $g+h=m$, with submatrices $\phi(B)_{ij}$ and $\theta(B)_{ij}$ conformably partitioned. Then, according to Osborn, the variables in the vector x_1 do not cause the variables in the vector x_2 if and only if there is a representation of the multivariate ARMA system ⟨1b⟩ in which the submatrices $\phi(B)_{21}=\theta(B)_{21}=0$. In other words, x_1 does not cause x_2 if and only if in $x=\phi(B)^{-1}\theta(B)a$ either the polynomial matrix $\phi(B)^{-1}\phi(B)$ is upper-block-triangular, when partitioned conformably to x and a, or equivalently, in $a=\theta(B)^{-1}\phi(B)x$ the polynomial matrix $\theta(B)^{-1}\phi(B)$ is upper-block-triangular, when partitioned conformably.

Using the bivariate ARMA model ⟨1c⟩ to illustrate the above, the necessary and sufficient condition for x_1 not to cause x_2 is:

$$\langle 2\rangle \qquad -\theta_{21}+\phi_{11}\theta_{21}-\phi_{21}\theta_{11}+\phi_{21}=0,$$

with ϕ_{ij} and θ_{ji} elements of the coefficient matrices in ⟨1c⟩. Note that this condition is weaker than the condition $\phi_{21} = \theta_{21} = 0$ which is of course sufficient, but, in spite of its strong intuitive appeal, not necessary. A similar reasoning holds to determine the necessary and sufficient conditions for x_2 not to cause x_1.

I.C. Specification and estimation

The class of vector ARMA models contains a large number of possible models. Therefore, my aim is to specify a parsimonious model representing the data as adequately as possible. The main instrument of model selection, *i.e.* choosing numerical values of the integers p and q of the polynomials in the backshift operator B, includes the sample cross-correlation and partial-autocorrelation matrices, which are estimated from the data. A useful device for determining the order of the model is the pattern of the indicator symbols of the sample cross-correlations and of the partial-autoregressive matrices and related statistics suggested by Tiao and Box (1981) and technically simplified for practical use in Tiao and Tsay (1983).

As soon as a suitable tentative specification has been chosen, efficient estimates of the parameter matrices ϕ, θ and Σ_a are obtained by maximizing the exact likelihood function L with

$$L(\phi, \theta, \Sigma_a | x) \propto L_c(\phi, \theta, \Sigma | x) L_1(\phi, \theta, \Sigma | x),$$

where

$$L_c(\phi, \theta, \Sigma_a | x) \propto |\Sigma_a|^{(-n-p)/2} \exp\{-\tfrac{1}{2} \operatorname{tr} \Sigma_a^{-1} S(\phi, \theta)\}$$

is the conditional likelihood function with $S(\phi, \theta) = \sum_{t=p+1}^{n} a_t a_t'$, the a_t following from the vector ARMA(p, q) model to be estimated and L_1 depending only on the data vectors $x_1, \ldots, x_p$ if all $q = 0$ or on all data vectors $x_1, \ldots, x_n$ if $q \neq 0$ with n the number of vector observations. Because estimation using the exact likelihood function is rather slow, the conditional likelihood function is used in the preliminary stage of model building and the exact method is used mainly towards the end (see also Tiao and Box, 1981, p. 809).

The test statistic given by ⟨2⟩ is easily computed while its variance follows immediately using Cramèr's approximation formula (see Cramèr, 1946, pp. 353–354; Klein, 1953, p. 258). It reads as:

$$\langle 3 \rangle \quad \begin{aligned} \operatorname{var} f(\phi, \theta) = {} & (1-\phi_{11})^2 \operatorname{var} \theta_{21} + \theta_{21}^2 \operatorname{var} \phi_{11} + (1-\theta_{11})^2 \operatorname{var} \phi_{21} \\ & + \phi_{21}^2 \operatorname{var} \theta_{11} - 2\theta_{21}(1-\phi_{11}) \operatorname{cov}(\theta_{21}, \phi_{11}) \\ & - 2(1-\phi_{11})(1-\theta_{11}) \operatorname{cov}(\theta_{21}, \phi_{21}) \\ & + 2(1-\phi_{11})\phi_{21} \operatorname{cov}(\theta_{21}, \theta_{11}) \\ & + 2\theta_{21}(1-\theta_{11}) \operatorname{cov}(\phi_{11}, \phi_{21}) - 2\theta_{21}\phi_{21} \operatorname{cov}(\phi_{11}, \theta_{11}) \\ & - 2\phi_{21}(1-\theta_{11}) \operatorname{cov}(\phi_{21}, \theta_{11}). \end{aligned}$$

Equations ⟨2⟩ and ⟨3⟩ are the main statistical ingredients for this statistical testing on feedback in the next section.

TABLE 1. Summary statistics sample for 1989.

Firm	Stock volume ($\times 10^{-6}$ traded number of shares)	Option volume ($\times 10^{-6}$ traded number of underlying shares)	Share of options traded (%)	Share price volatility (%)
Heineken	23.0	11.0	48	17.5
Hoogovens	94.4	135.4	143	32.9
Nedlloyd	37.2	36.3	98	28.2
Philips	283.1	175.9	62	21.4
Royal Dutch	153.3	132.3	86	15.1

II. Statistical analysis of option series

II.A. The data

The starting point for the statistical analysis is a sample of five firms listed at the Amsterdam Stock Exchange and additionally listed for call and put option trading at the European Options Exchange. The data are daily trading volumes for the period from January 2, 1985 through December 30, 1989. A listing of the sampled firms, together with a few statistics, is provided in Table 1.

The collected data include the daily volume of trade on common shares and the corresponding number of underlying shares for options. For options the data concern the volume of all call and put options series respectively, and also the subseries: short at-the-money series, short out-of-the-money series, as well as the remaining series. The latter include both the short in-the-money series and all long series. An option series is defined as short if the remaining term to maturity is less than three months. At-the-money options are options with an exercise price differing less than 5 per cent from the final quote of the day considered; out-of-the-money call options are options with an exercise price at least 5 per cent above the final quote; out-of-the-money put options are options with an exercise price at least 5 per cent lower than the final quote.

Apart from the five firms I have considered all stocks for which options exist at the European Options Exchange (EOE) in Amsterdam. The reason I confined the analysis of individual stocks to a sample of only five was a matter of convenience and resources: collecting the daily data for the five stocks over a period of five years was an enormous task. Moreover, with this sample of five out of 23 EOE stock options at the end of 1989, the research covers almost 50 per cent of trade in options and 40 per cent of trade at the Amsterdam stock market. Looking at the spectrum of the sample, I believe that it offers a rather representative picture having two firms (Hoogovens and Nedlloyd) with a very high share of options traded and the others much more in line with the conventional picture. Also with respect to share price volatility the sample seems to be fairly representative with Royal Dutch having a low volatility and Hoogovens the highest. Another way to look at the sample is offered in Table 2

TABLE 2. Number of outstanding shares, shares traded and options traded (in thousands).

	Outstanding shares (1)	Shares traded (2)	(2) as a percentage of (1) (3)	Options traded[a] (4)	(4) as a percentage of (1) (5)
1985					
Heineken	19,267	16,985	88	16,572	86
Hoogovens[b]	10,852	34,133	315	42,821	395
Nedlloyd	3,466	9,822	283	15,423	445
Philips	219,900	169,441	77	108,238	49
Royal Dutch	268,040	109,054	41	91,450	34
1986					
Heineken	23,816	16,680	70	14,539	61
Hoogovens[b]	15,242	62,124	408	98,312	645
Nedlloyd	3,466	7,042	203	16,692	482
Philips	229,500	183,295	80	130,885	57
Royal Dutch	268,040	147,050	55	156,852	59
1987					
Heineken	25,689	17,927	70	16,501	64
Hoogovens[b]	16,013	29,522	184	38,317	239
Nedlloyd	3,466	7,727	223	16,509	476
Philips	243,900	216,531	89	140,152	57
Royal Dutch	268,040	155,367	58	152,573	57
1988					
Heineken	25,689	16,320	64	8,249	32
Hoogovens[b]	15,871	49,853	314	43,915	277
Nedlloyd	3,469	14,252	411	19,139	552
Philips	257,600	180,278	70	71,695	28
Royal Dutch	268,040	99,346	37	91,709	34
1989					
Heineken	30,232	23,019	76	11,035	37
Hoogovens[b]	16,805	94,373	562	135,431	806
Nedlloyd	9,761	37,223	381	36,330	372
Philips	268,200	283,146	106	175,943	66
Royal Dutch	523,596	153,252	29	132,275	25

[a]Total of call and put turnovers expressed as numbers of underlying shares.
[b]Adjusted for the interests of the Government and the Municipality of Amsterdam: 35% in 1985, 19% in 1986/87, 20% in 1988/89.

showing the number of outstanding shares, the number of shares traded and the number of underlying shares traded for options as well as some turnover statistics. Again it is seen how vulnerable the firms Hoogovens and Nedlloyd are when annual trade is compared with the outstanding stock of shares.

II.B. The estimated models

A preliminary analysis of the pattern of the sample cross correlations as well as of the likelihood-ratio statistic—for the sake of brevity not reported here—for the daily data within each of the years 1985–89 for each of the series considered suggest bivariate ARIMA models of low order. The number of models to be estimated amounts to 240 ($= 6 \times 5 \times 4 \times 2$) resulting from six cases, five years and four different series both for calls and puts. This large number of estimated models prohibits full reporting of the estimated results. Table 3, therefore, shows a summary of the main characteristics of the estimated ARIMA models and illustrates this with the estimated model of Royal Dutch in the sample year 1988.

As Table 3 shows, the majority of the estimated models are of the ARIMA (1, 1, 1) type and a few are of higher order with a maximum of 4. This means that on the whole the implied lag structure is simple and that in most cases there is only a one day lag. This holds for the models for all option series as well as for the short at-the-money, short out-of-the-money and the remaining series. An example of a model estimated for the put option series of Royal Dutch in 1988 is:

$$\begin{pmatrix} \underset{(0.06)}{1-0.187B} & 0 \\ 0 & \underset{(0.05)}{1+0.704B} \end{pmatrix} \begin{pmatrix} \Delta x_1 \\ \Delta x_2 \end{pmatrix} = \begin{pmatrix} \underset{(0.04)}{1-0.777B} & 0 \\ 0 & \underset{(0.05)}{1-0.601B^2} \end{pmatrix} \begin{pmatrix} a_1 \\ a_2 \end{pmatrix}$$

with standard errors in parentheses.

II.C. The causality analysis

As pointed out before, the number of 240 estimated ARIMA models prohibits a full reporting and discussion of estimation results (see Fase and Mourik, 1990). However, the main purpose of the analysis is to establish the type of feedback between trade on the Amsterdam stock exchange and the EOE option market. Causality testing provides the appropriate framework to establish the feedback relations statistically.

The test results are shown in Table 4; the statistics behind this qualitative summary are set out in Table 6. The general picture that emerges from Table 4 is that very often the causality runs from trade on the option market to trade on the stock market. This holds in particular for the remaining series and for the short at-the-money series. More surprising, however, is that in about 50 per cent of the cases studied the hypothesis of feedback—*i.e.* two-way causality—or any other form of causality should be rejected. This implies that very often the stock and options market in Amsterdam operate independently and cannot have aggravated a possible unstable situation. However, this general conclusion does not hold for 1987 as Table 4 shows, indicating that in this particular episode trade on the EOE was the driving force for trade at the Amsterdam stock market.

TABLE 3. Frequency of different ARIMA model specification, 1985–1989.

	Call								Put							
	Model type								Model type							
	(4, 0)	(3, 1)	(2, 1)	(1, 1)	(1, 2)	(1, 3)	(1, 4)	other	(4, 0)	(3, 1)	(2, 1)	(1, 1)	(1, 2)	(1, 3)	(1, 4)	other
All series:																
Heineken	—	—	—	4	—	—	—	1	—	1	1	1	—	—	—	2
Hoogovens	—	—	—	2	1	—	—	2	—	—	—	1	1	1	—	2
Nedlloyd	—	—	—	2	1	—	—	2	—	—	—	2	—	—	—	3
Philips	—	—	—	3	2	—	—	—	—	—	—	1	2	1	—	1
Royal Dutch	—	—	1	—	2	1	—	1	—	1	—	—	2	—	—	2
Total	—	—	—	—	2	—	—	1	—	—	—	—	1	—	—	2
At-the-money:																
Heineken	—	1	—	2	—	—	—	2	—	—	1	1	—	—	1	2
Hoogovens	—	—	—	2	1	1	—	1	—	—	1	2	—	—	—	2
Nedlloyd	2	—	—	2	—	—	—	1	1	—	—	2	—	—	2	—
Philips	—	—	—	3	—	—	—	2	—	—	—	3	—	2	—	—
Royal Dutch	—	—	2	2	—	1	—	—	—	—	—	3	—	1	—	1
Out-of-the-money:																
Heineken	1	2	—	2	—	—	—	—	1	—	—	2	—	—	—	2
Hoogovens	—	—	1	3	—	1	—	—	—	—	—	1	—	—	1	3
Nedlloyd		—	1	3	—	—	—	1	1	1	1	1	—	—	1	—
Philips	—	—	—	2	1	1	—	1	—	1	—	3	—	—	—	1
Royal Dutch	1	—	—	1	—	1	—	2	—	1	2	1	—	1	—	—
Remaining series:																
Heineken	1	1	—	—	—	—	—	3	1	2	—	1	—	—	—	1
Hoogovens	—	—	3	2	—	—	—	—	—	—	3	1	—	—	—	1
Nedlloyd	1	1	—	2	—	—	—	1	—	—	1	1	—	—	1	2
Philips	—	1	1	1	1	—	—	1	—	1	—	1	1	1	—	1
Royal Dutch	—	1	2	1	—	—	1	—	—	1	—	3	—	—	—	1
Total	6	7	11	39	11	6	1	22	4	9	10	31	7	7	6	29

Note: Model type (p, q) indicates an AR part of order p and an MA part of order q, with first order differences in the variables; 'other' covers 25% of all models.

TABLE 4. Summary of test results.

	1985		1986		1987		1988		1989		1985–89		1987–89	
	call	put	call	put	call	put	call	put	call	put	call	put	call	put
All series:														
Heineken	A	A	no	no	O	O	W	O	no	no	A	O	no	O
Hoogovens	W	no	O	O	O	W	no	O	no	no	W	O	O	O
Nedlloyd	no	O	O	W	O	A	O	no	no	W	O	W	O	W
Philips	no	A	A	no	no	no	O	no	no	O	W	W	O	W
Royal Dutch	O	O	A	O	O	O	O	no	O	no	W	O	O	O
Short at-the-money series:														
Heineken	O	A	A	no	no	O	A	O	A	no	A	no	W	g
Hoogovens	A	A	no	W	O	O	no	no	A	no	W	W	W	g
Nedlloyd	A	A	O	no	O	no	no	no	W	no	W	O	W	O
Philips	O	no	A	no	no	O	O	no	no	no	A	A	A	W
Royal Dutch	O	no	no	no	no	O	no	no	W	no	W	O	no	g
Short out-of-the-money series:														
Heineken	no	W	O	O	A	no	no	O	O	no	O	A	O	A
Hoogovens	A	A	no	no	O	O	no	A	no	W	O	O	no	O
Nedlloyd	O	no	A	A	no	no	no	no	A	W	O	A	O	W
Philips	no	no	A	no	no	O	no	no	no	no	W	W	A	W
Royal Dutch	no	no	no	no	no	no	W	W	W	no	W	A	O	g
Remaining series:														
Heineken	no	A	no	no	no	O	A	no	no	no	A	O	O	O
Hoogovens	no	no	A	O	O	O	no	A	O	no	O	W	W	O
Nedlloyd	O	A	O	W	no	W	no	no	A	O	W	W	O	W
Philips	O	no	no	no	no	O	no	no	O	no	O	A	O	O
Royal Dutch	no	no	O	no	O	O	O	no	O	no	O	W	O	O

Note: 'A' means that the causality runs from stocks to options; 'O' indicates that the causality runs from options to stocks and 'W' that there exists feedback; 'no' means that statistically no interrelationship was found.

TABLE 5. Frequency of different ARIMA model specification, 1985–1989.

	Call Model type					Put Model type				
	(2...4, 1)	(1, 1)	(1, 2...4)	(0, 1...4)	other	(2...4, 1)	(1, 1)	(1, 2...4)	(0, 1...4)	other
All series:										
Heineken	—	4	0	1	—	2	1	—	2	—
Hoogovens	—	2	1	—	2	—	1	2	1	1
Nedlloyd	—	2	1	2	—	—	2	—	2	1
Philips	—	3	2	—	—	—	1	3	—	1
Royal Dutch	1	—	3	1	—	1	—	2	2	—
Total	—	—	2	1	—	—	—	1	—	2
At-the-money:										
Heineken	1	2	—	1	1	1	1	1	1	1
Hoogovens	—	2	2	1	—	1	2	—	1	1
Nedlloyd	2	2	—	1	—	1	2	2	—	—
Philips	—	3	—	2	—	—	3	2	—	—
Royal Dutch	2	2	1	—	—	—	3	1	—	1
Out-of-the-money										
Heineken	3	2	—	—	—	1	2	—	2	—
Hoogovens	1	3	1	—	—	—	1	1	3	—
Nedlloyd	1	3	—	—	1	3	1	1	—	—
Philips	—	2	2	1	—	1	3	—	—	1
Royal Dutch	1	1	1	1	1	3	1	1	—	—
Remaining series:										
Heineken	2	—	—	3	—	3	1	—	1	—
Hoogovens	3	2	—	—	—	3	1	—	—	1
Nedlloyd	2	2	—	—	1	1	1	1	1	1
Philips	2	1	1	1	—	1	1	2	1	—
Royal Dutch	3	1	1	—	—	1	3	—	1	—
Total	24	39	18	16	6	23	31	20	18	11

Note: Model type (p, q) indicates an AR part of order p and an MA part of order q, with first order differences in the variables; 'other' covers 25% of all models.

TABLE 6. Summary of test results.

		1985		1986		1987	
		call	put	call	put	call	put
All series:							
Heineken	S→O	0.51E-3	0.58E-3	0.0	0.0	18.01	0.0
		(0.24E-3)	(0.19E-3)	(0.0)	(0.0)	(0.0)	(0.0)
	O→S	0.0	0.0	0.0	0.0	0.41E-3	38.2
		(0.0)	(0.0)	(0.0)	(0.0)	(8.43)	(8.69)
Hoogovens	S→O	−0.13E-3	0.0	0.0	0.0	0.0	−0.33E-2
		(0.66E-4)	(0.0)	(0.0)	(0.0)	(0.0)	(0.57E-3)
	O→S	48.96	1.42	5.11	25.27	31.63	66.51
		(7.41)	(0.87)	(2.47)	(9.59)	(9.53)	(6.07)
Nedlloyd	S→O	0.0	0.0	0.0	−0.19E-3	0.0	0.24E-4
		(0.0)	(0.0)	(0.0)	(0.64E-4)	(0.0)	(0.10E-4)
	O→S	0.0	102.1	125.52	21.21	41.67	0.0
		(0.0)	(40.69)	(27.68)	(9.60)	(18.46)	(0.0)
Philips	S→O	0.0	0.69E-4	0.13E-3	0.0	0.0	0.0
		(0.0)	(0.33E-4)	(0.53E-4)	(0.0)	(0.0)	(0.0)
	O→S	2.52	0.0	0.0	0.0	0.0	14.40
		(1.27)	(0.0)	(0.0)	(0.0)	(0.0)	(8.83)
Royal Dutch	S→O	0.0	0.0	0.54E-3	0.0	0.0	0.0
		(0.0)	(0.0)	(0.22E-3)	(0.0)	(0.0)	(0.0)
	O→S	46.01	37.64	0.0	35.86	59.70	156.95
		(13.25)	(17.83)	(0.0)	(12.99)	(20.99)	(29.85)
Short at-the-money series:							
Heineken	S→O	0.52E-4	0.35E-4	0.77E-4	0.0	0.0	0.0
		(0.31E-4)	(0.15E-4)	(0.34E-4)	(0.0)	(0.0)	(0.0)
	O→S	41.22	0.0	0.0	0.0	0.0	12.76
		(14.94)	(0.0)	(0.0)	(0.0)	(0.0)	(6.30)
Hoogovens	S→O	0.52E-4	0.97E-4	0.0	0.96E-4	0.0	0.0
		(0.21E-4)	(0.45E-4)	(0.0)	(0.35E-4)	(0.0)	(0.0)
	O→S	3.10	0.0	0.0	86.95	56.89	100.21
		(1.80)	(0.0)	(0.0)	(36.58)	(24.84)	(18.93)
Nedlloyd	S→O	0.29E-4	0.16E-4	0.0	0.0	0.0	0.27E-5
		(0.12E-4)	(0.52E-4)	(0.0)	(0.0)	(0.0)	(0.15E-5)
	O→S	42.79	0.0	283.58	7.94	23.10	0.0
		(22.90)	(8.68)	(88.65)	(5.12)	(10.63)	(0.0)
Philips	S→O	0.0	0.0	0.44E-4	0.0	0.0	0.39E-4
		(0.0)	(0.0)	(0.16E-4)	(0.0)	(0.0)	(0.20E-4)
	O→S	84.64	0.0	0.0	0.0	0.0	193.08
		(33.34)	(0.0)	(0.0)	(0.0)	(0.0)	(67.52)
Royal Dutch	S→O	0.0	0.0	0.17E-4	0.74E-5	0.0	0.0
		(0.0)	(0.0)	(0.11E-4)	(0.43E-5)	(0.0)	(0.0)
	O→S	−6.33	3.61	0.0	0.0	0.0	448.99
		(2.64)	(2.40)	(0.0)	(0.0)	(0.0)	(162.17)

TABLE 6. Summary of test results (cont.).

1988		1989		1985–89		1987–89	
call	put	call	put	call	put	call	put
8.36	0.0	0.0	0.17E-4	0.39E-4	0.0	0.0	0.0
(0.13E-3)	(0.0)	(0.0)	(0.97E-5)	(0.11E-4)	(0.0)	(0.0)	(0.0)
6.51	−45.81	0.0	0.0	0.0	0.50	−0.27	0.44
(2.24)	(13.52)	(0.0)	(0.0)	(0.0)	(0.24)	(0.37)	(0.17)
0.0	0.26E-5	0.0	0.0	0.22E-4	0.0	0.0	0.0
(0.0)	(0.26E-5)	(0.0)	(0.0)	(0.10E-4)	(0.0)	(0.0)	(0.0)
0.0	27.41	0.0	0.0	7.96	0.80	8.35	38.79
(0.0)	(12.05)	(0.0)	(0.0)	(1.47)	(0.28)	(1.92)	(4.41)
0.0	0.0	0.0	0.20E-3	0.0	0.41E-5	0.0	0.94E-4
(0.0)	(0.0)	(0.0)	(0.51E-4)	(0.0)	(0.16E-5)	(0.0)	(0.24E-4)
144.33	0.0	0.0	50.65	7.68	1.96	5.42	11.21
(36.94)	(0.0)	(0.0)	(23.80)	(1.89)	(0.92)	(1.67)	(4.02)
0.0	0.0	0.0	0.0	−0.93E-4	0.25E-4	0.0	0.32E-7
(0.0)	(0.0)	(0.0)	(0.0)	(0.34E-4)	(0.86E-5)	(0.0)	(0.15E-7)
7.04	0.0	1.79	−249.38	0.95	32.38	5.30	27.48
(2.91)	(0.0)	(0.93)	(39.25)	(0.40)	(8.39)	(1.46)	(6.44)
0.0	0.0	0.0	0.0	0.44E-4	0.0	0.0	0.0
(0.0)	(0.0)	(0.0)	(0.0)	(0.13E-4)	(0.0)	(0.0)	(0.0)
4.05	0.0	21.29	0.0	0.30	1.32	3.36	13.36
(1.93)	(0.0)	(4.79)	(0.0)	(0.11)	(0.37)	(1.32)	(3.23)
0.18E-3	0.0	0.18E-4	0.0	−0.21E-4	0.0	0.20E-4	0.0
(0.56E-4)	(0.0)	(0.88E-5)	(0.0)	(0.67E-5)	(0.0)	(0.73E-5)	(0.0)
3.78	−146.48	0.01	0.0	0.0	0.0	4.56	2.44
(1.96)	(49.47)	(0.20)	(0.0)	(0.0)	(0.0)	(1.58)	(2.21)
0.43E-4	0.0	0.24E-4	0.49E-5	0.85E-5	0.77E-5	0.15E-5	0.0
(0.53E-4)	(0.0)	(0.12E-4)	(0.28E-5)	(0.27E-5)	(0.24E-5)	(0.52E-5)	(0.0)
4.10	15.83	0.0	0.0	2.76	2.33	3.23	−6.65
(2.83)	(9.78)	(0.0)	(0.0)	(0.79)	(0.78)	(1.06)	(8.31)
0.0	0.0	0.33E-5	0.0	0.13E-5	0.0	0.20E-5	0.0
(0.0)	(0.0)	(0.15E-5)	(0.0)	(0.35E-6)	(0.0)	(0.62E-6)	(0.0)
0.0	0.0	125.24	0.0	19.64	8.77	6.78	4.37
(0.0)	(0.0)	(58.15)	(0.0)	(5.15)	(2.97)	(2.69)	(1.64)
−0.50E-5	0.0	0.0	0.20E-5	−0.17E-4	0.28E-5	−0.10E-4	0.15E-4
(0.35E-5)	(0.0)	(0.0)	(0.11E-5)	(0.52E-5)	(0.97E-6)	(0.38E-5)	(0.64E-6)
3.89	0.0	0.59	0.0	0.78	16.90	1.00	3.91
(2.44)	(0.0)	(0.52)	(0.0)	(0.63)	(9.04)	(0.88)	(1.50)
0.0	0.0	−0.31E-3	0.0	−0.81E-4	0.0	0.33E-6	0.0
(0.0)	(0.0)	(0.86E-4)	(0.0)	(0.95E-5)	(0.0)	(0.33E-5)	(0.0)
0.0	0.0	78.59	0.0	38.01	2.11	0.0	0.0
(0.0)	(0.0)	(27.13)	(0.0)	(8.63)	(0.82)	(0.0)	(0.0)

TABLE 6. Summary of test results (cont.).

		1985		1986		1987	
		call	put	call	put	call	put
Short out-of-the-money series:							
Heineken	S→O	−0.19E-4	0.66E-4	0.0	0.0	0.22E-4	0.0
		(0.28E-4)	(0.14E-4)	(0.0)	(0.0)	(0.11E-4)	(0.0)
	O→S	0.0	−26.44	602.85	−74.92	0.0	0.0
		(0.0)	(13.09)	(146.38)	(34.19)	(0.0)	(0.0)
Hoogovens	S→O	0.65E-4	0.54E-4	0.0	0.0	0.0	0.0
		(0.25E-4)	(0.16E-4)	(0.0)	(0.0)	(0.0)	(0.0)
	O→S	11.68	0.0	0.0	0.0	−128.47	−157.73
		(5.92)	(0.0)	(0.0)	(0.0)	(63.07)	(78.08)
Nedlloyd	S→O	0.0	0.0	0.32E-4	0.24E-4	0.0	0.23E-5
		(0.0)	(0.0)	(0.63E-5)	(0.76E-5)	(0.0)	(0.12E-5)
	O→S	1027.54	0.0	552.10	0.0	0.0	0.0
		(313.47)	(0.0)	(317.03)	(0.0)	(0.0)	(0.0)
Philips	S→O	0.0	0.0	0.84E-5	0.15E-4	0.0	0.0
		(0.0)	(0.0)	(0.31E-5)	(0.86E-5)	(0.0)	(0.0)
	O→S	86.31	0.0	0.0	0.0	0.0	117.01
		(43.57)	(0.0)	(0.0)	(0.0)	(0.0)	(44.79)
Royal Dutch	S→O	0.0	0.0	0.86E-5	0.71E-5	0.0	0.0
		(0.0)	(0.0)	(0.48E-5)	(0.0)	(0.0)	(0.0)
	O→S	0.0	−9.65	11.87	0.0	0.0	0.0
		(0.0)	(6.02)	(7.15)	(0.0)	(0.0)	(0.0)
Remaining series:							
Heineken	S→O	0.36E-3	0.23E-3	0.0	0.0	0.0	0.0
		(0.18E-3)	(0.23E-3)	(0.0)	(0.0)	(0.0)	(0.0)
	O→S	0.0	0.0	0.0	0.0	8.02	0.0
		(0.0)	(0.0)	(0.0)	(0.0)	(3.02)	(0.0)
Hoogovens	S→O	0.38E-4	0.84E-4	0.0	0.11E-3	0.0	0.0
		(0.65E-4)	(0.11E-3)	(0.0)	(0.52E-4)	(0.0)	(0.0)
	O→S	0.0	0.0	4.82	0.0	18.48	3.06
		(0.0)	(0.0)	(1.71)	(0.0)	(3.37)	(1.07)
Nedlloyd	S→O	0.36E-4	0.0	−0.15E-3	0.0	0.31E-4	0.11E-5
		(0.17E-4)	(0.0)	(0.77E-4)	(0.0)	(0.12E-4)	(0.49E-5)
	O→S	3.65	9.64	50.78	38.59	−3.28	15.63
		(2.35)	(4.37)	(24.88)	(13.35)	(1.47)	(8.33)
Philips	S→O	0.12E-5	0.0	0.0	−0.18E-4	0.0	0.0
		(0.24E-5)	(0.0)	(0.0)	(0.45E-4)	(0.0)	(0.0)
	O→S	0.0	4.50	0.0	0.0	198.66	0.0
		(0.0)	(2.17)	(0.0)	(0.0)	(27.79)	(8.0)
Royal Dutch	S→O	0.0	0.0	0.0	0.0	0.0	0.0
		(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
	O→S	0.0	0.92	0.0	2.70	95.54	10.79
		(0.0)	(0.87)	(0.0)	(1.19)	(13.60)	(4.00)

TABLE 6. Summary of test results (cont.).

1988		1989		1985–89		1987–89	
call	put	call	put	call	put	call	put
0.0	0.0	0.0	0.0	0.0	0.38E-6	0.0	0.79E-6
(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.17E-6)	(0.0)	(0.37E-6)
0.0	−622.39	63.73	0.0	8.83	0.0	0.13	0.0
(0.0)	(238.52)	(25.17)	(0.0)	(3.14)	(0.0)	(0.05)	(0.0)
0.0	0.76E-5	0.0	−0.10E-4	0.0	0.0	0.0	0.0
(0.0)	(0.23E-5)	(0.0)	(0.49E-5)	(0.0)	(0.0)	(0.0)	(0.0)
0.0	36.35	0.0	576.03	16.58	1.84	0.0	68.76
(0.0)	(27.24)	(0.0)	(184.75)	(5.23)	(0.77)	(0.0)	(25.58)
0.0	0.0	0.34E-5	0.60E-6	0.0	0.37E-6	0.0	0.62E-6
(0.0)	(0.0)	(0.11E-5)	(0.29E-6)	(0.0)	(0.13E-6)	(0.0)	(0.21E-6)
0.0	0.0	0.0	324.81	89.63	0.0	39.51	67.63
(0.0)	(0.0)	(0.0)	(136.27)	(24.52)	(0.0)	(16.20)	(31.17)
0.0	0.23E-5	0.0	0.0	0.79E-7	0.86E-6	−0.11E-7	0.13E-5
(0.0)	(0.12E-5)	(0.0)	(0.0)	(0.39E-6)	(0.38E-6)	(0.52E-6)	(0.57E-6)
0.0	0.0	21.26	0.0	7.90	9.67	3.52	16.60
(0.0)	(0.0)	(11.44)	(0.0)	(2.97)	(3.65)	(3.08)	(5.92)
0.45E-4	0.42E-4	−0.66E-5	0.83E-7	0.15E-5	0.27E-6	0.0	0.21E-5
(0.17E-4)	(0.99E-5)	(0.22E-5)	(0.24E-6)	(0.75E-6)	(0.80E-7)	(0.0)	(0.12E-5)
450.20	304.36	36.47	0.0	10.19	0.0	25.39	0.0
(217.67)	(56.97)	(15.87)	(0.0)	(3.21)	(0.0)	(8.25)	(0.0)
0.0	0.99E-4	0.15E-4	0.0	0.25E-5	0.28E-4	0.75E-5	−0.62E-4
(0.0)	(0.48E-4)	(0.79E-5)	(0.0)	(0.17E-5)	(0.87E-5)	(0.40E-5)	(0.49E-4)
0.0	4.66	0.0	0.0	0.50	0.0	0.24	−4.83
(0.0)	(2.90)	(0.0)	(0.0)	(0.24)	(0.0)	(0.06)	(2.18)
0.29E-4	0.0	0.0	0.0	0.20E-4	0.19E-4	0.0	−0.57E-3
(0.10E-4)	(0.0)	(0.0)	(0.0)	(0.97E-5)	(0.29E-4)	(0.0)	(0.12E-3)
0.0	1.48	2.55	7.90	1.90	1.75	46.08	6.34
(0.0)	(0.75)	(1.33)	(3.04)	(0.47)	(0.48)	(5.37)	(1.43)
0.0	0.0	0.29E-4	0.23E-4	0.51E-5	0.31E-5	0.43E-5	0.0
(0.0)	(0.0)	(0.25E-4)	(0.10E-4)	(0.14E-5)	(0.99E-6)	(0.15E-5)	(0.0)
0.0	0.0	13.77	0.0	6.15	2.80	6.80	3.48
(0.0)	(0.0)	(6.40)	(0.0)	(1.54)	(0.74)	(2.26)	(1.33)
−0.15E-4	−0.25E	0.53E-5	0.0	0.72E-5	0.10E-5	0.17E-5	−0.15E-5
(0.99E-5)	(0.14E-4)	(0.28E-5)	(0.0)	(0.24E-5)	(0.88E-5)	(0.42E-5)	(0.56E-5)
0.0	5.55	0.0	2.07	0.0	1.84	32.11	1.02
(0.0)	(3.87)	(0.0)	(0.87)	(0.0)	(0.55)	(9.83)	(0.36)
0.0	0.0	0.0	0.0	0.23E-4	0.0	0.0	0.0
(0.0)	(0.0)	(0.0)	(0.0)	(0.76E-5)	(0.0)	(0.0)	(0.0)
0.0	2.33	0.0	0.58	0.57E-2	0.67	6.80	0.89
(0.0)	(1.11)	(0.0)	(0.29)	(0.25E-2)	(0.17)	(2.34)	(0.31)

III. Summary and conclusions

Perhaps the most important finding of this paper is that the bivariate ARIMA model offers an appropriate statistical framework to examine the feedback among trade on the stock and option market. This is the main novelty of this paper. More interesting from an economic and finance point of view, however, is the fact that very often causality runs from options trade to the stock market, seeming to support the feeling of the business profession and the main hypothesis of this paper. Nevertheless, in a large number of cases no interaction was established at all. As to the length of lags, most models indicate a one day lag for options. This seems to be in accordance with the leading function of option trade with respect to trade in stocks. Statistically it is interesting that the results obtained indicate very convincingly that the relation reveals no stability over time.

References

ANTHONY, J. H., 'The interrelation of stock and options market trading-volume data,' *Journal of Finance, September 1988*, **43**: 949–964.

BLACK, F., 'Fact and fantasy in the use of options,' *Financial Analysts Journal*, July/August 1975, **31**: 36–41, 61–72.

COPELAND, T. E., 'A model of asset trading under the assumption of sequential information arrival,' *Journal of Finance*, September 1976, **31**: 1149–1168.

CRAMÈR, H., *Mathematical methods of statistics*, Princeton NJ: Princeton University Press, 1946.

FASE, M. M. G., C. E. BECKERS, A. G. Z. KEMNA AND S. DE WILDE, *Tussen Rokin en Damrak: de wisselwerking tussen de Effecten- en Optiebeurs*, Schoonhoven: Academic Service, 1990.

FASE, M. M. G. AND T. J. MOURIK, 'Samenhang omzet op aandelenmarkt en optiemarkt: een statistische causaliteitsanalyse,' Amsterdam: De Nederlandsche Bank NV Research Memorandum No. 9020, 1990.

GRANGER, C. W. J., 'Investigating causal relations by econometric models and cross-spectral methods,' *Econometrica*, July 1969, **37**: 424–438.

HSIAO, CH., 'Autoregressive modelling and causal ordering of economic variables,' *Journal of Economic Dynamics and Control*, 1982, **4**: 243–259.

JENNINGS, R. AND L. STARKS, 'Earnings announcements, stock price adjustment, and the existence of option markets,' *Journal of Finance*, March 1986, **41**: 107–125.

KANG, H., 'Necessary and sufficient conditions for causality testing in multivariate ARMA models,' *Journal of Time Series Analysis*, 1981, **2**: 95–101.

KLEIN, L. R., *A textbook of econometrics*, Evanston: Row, Peterson, 1953.

MANASTER, S. AND R. RENDLEMAN, 'Option prices as predictors of equilibrium stock prices,' *Journal of Finance*, September 1982, **37**: 1043–1058.

OSBORN, D. R., 'Causality testing and its implications for dynamic econometric models,' *Economic Journal*, 1984, **94**: Supplement, 82–96.

SIMS, C. A., 'Money, income and causality,' *American Economic Review*, 1972, **62**: 540–552.

TIAO, G. C., AND G. E. P. BOX, 'Modelling multiple time series with applications,' *Journal of the American Statistical Association*, December 1981, **76**: 802–816.

TIAO, G. C. AND R. S. TSAY, 'Multiple time series modelling and extended sample cross-correlations,' *Journal of Business and Economic Statistics*, January 1983, **1**: 43–56.

ZELLNER, A., 'Causality and econometrics,' in K. Brunner and A. H. Meltzer, eds, *The aspects of policy and policymaking*, Amsterdam/New York/Oxford: North-Holland, 1979: 9–54.