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Abstract

The implication of price stabilization under a volatile exchange rate is an increasingly volatile price denominated in a foreign currency. Time series analysis is used to model the relationship between exports, prices and the AWC stocks. A second stage analysis focuses on the transmission of unanticipated volatility between the exchange rate and these variables. Significant two-way links are found between unanticipated volatility in the exchange rate and AWC stocks.

Introduction

Under a flexible exchange rate regime, the behaviour of the Australian dollar has been characterized by short periods of extreme volatility interspersed by periods of narrow trading ranges. Traditionally, the primary function of the exchange rate has been to regulate trade flows. Since the float, both the level and the volatility of the currency has been dominated by monetary policy and currency speculation.[1]

Models of exchange rate volatility have been well established theoretically (Dornbusch, 1986) and empirically (Matthews and Valentine, 1986). Volatility can be harmful in the sense that it need not represent real forces and, therefore, is potentially damaging to trade in two ways. Firstly as exchange rate movements distort price signals, and secondly, as they increase risk and uncertainty, redistributing profits and losses between different groups.

Given that all economic policy is now subject to the balance of payments constraint it is important to examine the effects of flexible exchange rates on trade. Wool is historically one of Australia's most valuable export industries and output is great enough to affect world prices.[2] Since 1974, the Australian Wool Corporation (AWC) has operated the Reserve Price Scheme (RPS) to stabilize producer prices denominated in the local currency. Since exporters face prices denominated in Australian dollars and importers the same price in foreign currency, the operation of the RPS in stabilizing prices is made more difficult and more important. The AWC must distribute currency-induced price fluctuations between the importers and exporters.

The 1983 float has had a major impact on wool prices. The effect is complex as the level of output affects prices and prices flow on to the value of the dollar. Issues are also raised in relation to the management of the Reserve Price Scheme as increased variances of exchange rates and prices require either a larger Market Support Fund or a wider price band for operations. Also, as the floor price is set in advance of the selling season, currency volatility increases forecast risk.

Data

Monthly time series data on export quantity, export value and domestic price are collected by the *Australian Bureau of Statistics*, and export price can be derived from the value and quantity series. The exchange rate denominated in $US was selected as the majority of contracts are written in $US. AWC stocks were obtained from the Australian Wool Corporation. All variables are modelled in logarithms and have been collected for the period 1973:January to 1989:June.

Notation:

Q ~ exports of greasy wool measured in tonnes.

P ~ average wool price at auction in Australia in $A/100kg.

V ~ value of greasy wool exports f.o.b. in $A millions.

Π ~ average price of exports: $\Pi = V/Q$.

E ~ Currency valued in $US per Australian dollar at the end-of-month.

S ~ AWC stocks held in operation of the Reserve Price Scheme.

Plots of the data are given in Figure 1. Although both prices are trending, they are trending together. The domestic prices are set at auction and the export price is realized on shipment. However, most export contracts are struck on a firm-offer basis in foreign currency from 2 to 9 months in advance. As a result some lag is to be expected in export prices and possibly an additional degree of volatility might arise due to unanticipated exchange rate fluctuations.

The plot of quantity shows an obvious seasonal pattern and a permanent shift in volume immediately after January 1985, the point at which the $A fell sharply due to a ministerial announcement.[3] On the other hand, stocks were relatively stable for much of the period but at both ends of the sample, sharp changes were experienced.

The Model

Econometric model specification involves a trade-off between the bias due to invalid over-identifying restrictions and inefficiency due to an insufficient number of restrictions. Sims (1980) suggested an atheoretical approach to modelling economic relationships that simplifies this decision making process by estimating a dynamic unrestricted reduced form and *implying* a structural form from a loose causal ordering of the variables in the model. This VAR (Vector Autoregressive) approach involves regressing every variable on itself and every other variable in the system lagged from one period up to some maximum lag length, p:

$$(1)\ Y_t = a + A_1Y_{t-1} + A_2Y_{t-2} + \dots + A_pY_{t-p} + u_t$$

where, in this case, Y_t is the 5×1 vector $Y' = (E\ P\ S\ \Pi\ Q)$, a and A_i are matrices of fixed coefficients and u_t is a white noise disturbance term with a covariance matrix Ω.

By backward substitution, equation (1) can be solved as an infinite moving average process providing that $A(L) = I - A_1L - A_2L^2 - A_pL^p$ has all of its roots outside the unit circle:

$$(2)\ Y_t = c + u_t + B_1u_{t-1} + B_2u_{t-2} + B_3u_{t-3} + \ldots$$

where the parameters are functions of those in equation (1).

An innovation analysis can be applied to a VAR by imposing a structural form on (2). This is achieved by a Choleski decomposition of the disturbance covariance matrix as $\Omega = HH'$, where H is lower triangular, and premultiplying (2) through by H [see Sims, 1980].

$$(3)\ HY_t = d + v_t + D_1v_{t-1} + D_2v_{t-2} + \ldots$$

Impulse response functions characterize the time profile of a response in each variable to a shock applied to each variable through one standard deviation impulses, or innovations, in v_t. In this paper, however, we choose to subject each variable to a unit shock so that the responses have the standard multiplier interpretation. Because of the triangular structure of H, the first variable in Y is contemporaneously exogenous and each subsequent variable in Y only depends contemporaneously upon those variables listed above it. That is, the system is recursive and, by definition, the disturbances in this structural form, v_t, are orthogonal. This recursive structure depends on the ordering of the variables in Y.

The exchange rate has been listed first in Y_t because its movement would be dominated by effects outside of the wool market. Export price is listed after the domestic price because of contractual delays and quantity appears last being assumed to be the combined result of the interaction of price, the exchange rate and the AWC. The proper ordering of stocks and domestic price is not clear but experimentation showed that the ensuing results were not sensitive to this order.

Because the vector Y, as defined above, does not include an index of producer costs, the supply side is not fully recognized. No such series exists on a monthly basis and whereas a monthly series could be interpolated from the available quarterly series, it is not clear that these gains offset the loss of including an additional p artificial variables in each equation. As an alternative, a linear time trend was included in equation (1) with a slope and intercept dummy centred at January 1980 to allow for a change in the rate of inflation of producer prices. The time trend also assists in the accommodation of nonstationarity in the remaining series as is standard practice in Sims methodology.

A dummy variable capturing the shift in exports from January 1985 is also included. In some sense, this dummy variable accounts for a large change in the level of the currency while E accounts for smaller changes.

Tests for Granger causality are tests for the exclusion of a particular variable at all lags from a particular equation. Owing to the trending nature of the series these F-tests can be inflated. Furthermore, the analysis reported in the next section implies that this base VAR has been inefficiently estimated. The F-tests are given in Table 1 but should be interpreted subject to these caveats.

It is not clear that impulse response functions derived from relationships that are not Granger causal have a useful interpretation. Moreover, the confidence intervals for even significant relationships diverge with lag and care should be taken interpreting these responses for long lags. Only those impulse response functions with significant F-tests are discussed below. They are presented in Figure 2.

Impulse Response Functions

A shock to domestic price has a positive effect on export price which peaks over the 4 to 9 month period. As firm offer contracts are dominant and forward sales increasingly frequent, the effect on export prices of contracts struck at a time when the domestic price rises will register when the shipment is made several months later. The response function reflects a profile of contractual lags as some contracts are for prompt delivery but most are for between two to nine months delivery.

The domestic price responds negatively to an increase in stocks. *A priori* it is not possible to determine whether price should rise or fall in response to increased stocks. AWC operations in constricting supply are aimed at preventing price falls. However, at present, stocks and prices are experiencing a negative relationship, consistent with the innovation analysis. It seems quite plausible that, in a weakening market, expectations generate further price falls as stocks build up. AWC stocks may also be used as a hedge based on anticipating the response of the AWC to a price change. As exporters make profits or losses on the differential between the auction and contract price, purchases may be delayed if prices are expected to fall further. The effect on export price is much weaker because of the relationship between the domestic and export prices. Although insignificant, export price follows a similar path to domestic price with a slightly longer delay echoing the lagged response of export to domestic price revealed by the domestic price innovation.

The exchange rate responds negatively to a shock in stocks with a peak at about one year. Interestingly there is no effect for two months. The impact effect is zero by assumption due to the ordering of the variables in the VAR but the estimated effect for the one month lag is extremely close to zero.

Unanticipated Volatility

The analysis previously outlined can be thought of as a model of the explained or anticipated responses of one variable on another. Following Rogoff (1985), who used a VAR analysis to measure the success of the European Monetary System in reducing exchange rate volatility within its member countries, the variance of the residuals from the VAR are themselves analyzed.

Rogoff split his VAR model into two sub-periods, pre- and post the introduction of the EMS, and compared the residual sum of squares for each equation. Such an analysis was also conducted here around the floating of the dollar and it was found that there was no significant difference between regimes.[4] However, such a test has little power if variance, or unanticipated volatility, alters in some more systematic fashion, or if the coefficients are constant and only the variance-covariance matrix alters.

Engle (1982) has suggested a model that has an unconditional constant variance but, at a given point of time, the variance of a disturbance term can be predicted from its recent volatility. This ARCH (autoregressive conditional heteroscedastic) model for a single equation might be expressed as

$$(4)\ \sigma_t^2 = s + \alpha_1\sigma_{t-1}^2 + \alpha_2\sigma_{t-2}^2 + \ldots + \alpha_k\sigma_{t-k}^2 + \varepsilon_t$$

where σ_t^2 is the conditional variance at a particular point in time. Under the null of homoscedasticity, $\alpha_1 = \alpha_2 = ... = \alpha_k$ but, under the alternative, such a model allows for periods of extreme volatility followed by periods of relative constancy of variance. Such a model is, therefore, far more flexible than that suggested by a two-regime Chow test.

In the case of the wool export model, it is more reasonable to allow for the unanticipated volatility from one equation to influence the volatility in another. In this sense, the transmission of volatility in this study can be expressed as a VAR in the squared residuals resulting in a VARCH process.[5]

In order to test for the existence of an ARCH process, a Lagrange multiplier test of the type suggested by Breusch and Pagan (1979) can be employed. A simpler test with the same asymptotic distribution is given by TR^2, where R^2 is the coefficient of determination in the autoregression of squared residuals.[6] Table 2 presents the R^2 for the VAR 5-equation model with 4 lags.[7] The 5% critical value of R^2 is 0.144 for a test with a null of homoscedasticity in any one equation. Hence the null was rejected in each case at the 5% level and it was, therefore, concluded that each variance followed a VARCH process.

The presence of lagged dependent variables in the base VAR does not alter the consistency of the second-stage VAR on the squared residuals. However, the finding that the base VAR's residuals are conditionally heteroscedastic and, as such, the tests for Granger causality in Table 1 are biased, apart from any effect due to the nonstationarity of Y. The base VAR was re-estimated using White's (1980) correction but there was little difference in the results.[8]

A Granger causality table is presented in Table 3 for the VARCH process. Since the price faced by wool importers is denominated in foreign currency and is directly related to the $A price through the $A, a similar table can be constructed for the causality with $US denominated prices. These results are presented in Table 4.

Impulse Response Functions.

Impulse responses were calculated to examine the effects of unanticipated volatility in the system. These are presented in Figure 3.

All impulse response functions should be positive, that is unanticipated volatility in time t is transmitted to other variables in subsequent periods in some moving average fashion.[3] Although all significant response functions are predominantly positive, some point estimates are negative as the non-negativity constraint was not imposed on the covariance matrix. As such, the resulting estimates are inefficient.

As is expected, unanticipated volatility in the exchange rate feeds back on its own series and the domestic wool price denominated in $A. The US-denominated auction-price is unaffected from currency fluctuations. These results also suggest that a more volatile period for the $A will self-generate as market nervousness amplifies speculative activity. The increased volatility of domestic price transferred from the exchange rate implies that unexpected currency swings may cause the AWC to respond with the use of flexible reserves in order to offset uncertainty in the market. The implications of the transmission of such volatility is, given the increased post-float volatility of the $A, increased difficulty in management by the AWC of the RPS.

Domestic price volatility feeds back onto the $A, stocks, and itself. The effect on the $A is a sharp shock which rapidly dies away. If wool prices jump in an unexpected fashion, exchange rate volatility increases. This is plausible as the $A is a commodity-driven currency and investment confidence and speculative activity are influenced by commodity prices. Price volatility feeds back onto itself in a similar fashion to the $A. However, the transmission of volatility in stocks peaks at a four month lag, suggesting a delay in response from the AWC.

Unanticipated volatility in the quantity series is independent of the volatility of the other series, responding only to its own past volatility. Most of the transferred effect is registered in the first month, dissipating after about 5 months.

The volatility of the exchange rate and the export price increase for a given increase in unanticipated stock volatility. The peak in volatility in the exchange rate occurs earlier than for export price, the former being 2 months and the latter 4 months.

In conclusion, it seems that there are significant feedback effects and interactions between unanticipated movements in the exchange rate, the domestic price and stocks. The responses take the form of short shocks. Given increased exchange rate volatility since the 1983 float, the implication is that a flexible exchange rate will make the operation of the Reserve Price Scheme more difficult and, in turn, that this scheme will further de-stabilize the $A.

On comparison of Granger causality tests with the same model denominated in foreign dollars shown in Table 4, it is evident that exchange rate volatility does not generate volatility in the foreign price. The distribution of unanticipated exchange rate volatility is such that the effects of price variability are experienced by producers and exporters alone.

Concluding Remarks.

Time series analysis has been used to determine the relationships between the exchange rate, the domestic and export prices, quantity and AWC stocks. Some significant short-run relationships were found and impulse response analysis showed these relationships to be consistent with economic theory.

Unanticipated volatility was examined in a second-stage analysis. Significant feedback interactions between the exchange rate, domestic price and stocks were found. This transmitted volatility generates short shock effects to the volatility of other variables.

It was seen that exchange rate volatility affects the domestic price of wool denominated in $A but not in US$. This has implications for the distribution of benefits from the RPS. Risks associated with price variations are important for investment decisions of both wool producers and importers who process the raw product. From Quiggin (1983), if price stabilization is complete and supply fluctuations dominate, the associated risk of price fluctuations is born by producers. If demand or exchange rate fluctuations dominate, risk will be born by importers.

For a given currency movement, demand will shift in terms of $A and supply will shift in terms of foreign currency. Hence, if prices moved freely, the risk associated with exchange rate fluctuations would be distributed between producers and importers dependent on the relative elasticities of supply and demand. However when price is stabilized in $A terms, the risk associated with currency fluctuations is born by importers. Given that demand and exchange rate fluctuations typically dominate the wool market and that most volatility registers in $A prices, the AWC has occupied some middle ground, with most volatility felt in local prices.

As noted by Fisher (1980), producers have a strong revealed preference for stabilization. They have been prepared to pay a levy equivalent to 5% of gross income in order to support the RPS, this levy was recently increased over the 1987/8 season. Given that the share of price variability facing producers exceeds that of importers, the benefit to producers is questionable as producer price risk is increased.

As unanticipated quantity variation is explained solely by its own past history, the price - exchange rate - stocks linkage presumably represents the interaction of AWC operations with the $A. That is, the exchange rate is de-stabilized by the operation of the Reserve Price Scheme which has in turn become increasingly difficult and costly to operate since the $A was floated. Since the float, the wool industry has experienced boom then bust, and the variations have been historically high.

Exchange rate induced responses make it difficult to interpret economic forces in the market. For example the depreciations post-float boosted the demand for wool stocks, thus pressuring prices upward. The market indicator had risen from 626 c/kg in 1986/7 to 1003 c/kg in 1987/8. The AWC had little power to stem the rise as it sold stocks rapidly, placing very definite limitations on its ability to influence the market. Currently, the market is operating at the floor price, yet this price still obscures market signals to the producer.

Successful operation of the RPS requires that management adequately forecast price, hence exchange rate interactions with price increase management fallibility.

Increased levels of price variability under flexible exchange rates raise the costs of maintaining a given level of stabilization.[10] The depreciation that fueled $A price rises eventually caused a substitution away from wool into other fibres and wool blends. So, from a policy viewpoint, the suppression of price rises perhaps delayed this event. However, in net effect the AWC was incapable of stemming the price rise. A similar result is evident with the current price falls and consequent accumulation of stocks. This illustrates the increasing costs of maintaining stabilization in the wool market when prices are more variable under flexible exchange rates. An enlarged Market Support Fund is required. It is possible this size may reach unacceptable levels. Although price variability is not a problem exclusively associated with flexible exchange rates, it is exacerbated by them. It has recently been suggested that the size of borrowings required to support the floor price will soon add to the foreign debt, a major turn around from one year ago when wool was one of the largest export income earners.

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FOOTNOTES

[1] See Adam and Bewley (1990).

[2] Australia is a price taker in all other agricultural markets with the possible exception of wheat.

[3] Prime Minister Hawke made the infamous MX missile announcement in January 1985; see Figure 1. The automatic intervention analysis in Riley (1988) was used to build an ARIMA model for Q and AUTOBOX detected a shift dummy variable from 1985:January.

[4] Effectively a Chow test was conducted that tested the equality of both the coefficients and covariance matrices.

[5] In the single equation ARCH model, squared residuals are regressed on lagged squared residuals. The implied variances are used to weight the original regression and the process repeated until convergence. In this study a two-step estimator is used and a VAR on the squared residuals is used to model the interaction effects. See Bollerserv *et al.* (1988), Engle *et al.* (1984) and Granger *et al.* (1984) for a full discussion.

[6] This test does not require the normality assumptions of Breusch-Pagan and is, therefore, more robust to the departures possibly relevant here. We would like to thank Trevor Breusch for his comments on this matter.

[7] As with the base VAR, the lag length was chosen by a sequence of adjusted LR tests.

[8] It would be preferable to iteratively re-estimate the base VAR and second-stage VAR. Given the focus of this analysis on the transmission of unanticipated volatility, the computational complexity of a full ML procedure — was judged inappropriate.

[9] Positive own-responses are required to fulfill the need for a positive definite disturbance covariance matrix globally. Negative weights do not imply that within-sample estimated covariances do not fulfill this requirement.

[10] The alternative would be to operate a wider price band for stabilization.

TABLE 1

Tests for Granger Causality

Equation	Variable				
	E	P	S	Π	Q
E	27.0	1.8	2.6	1.5	1.7
P	1.8	27.5	2.8	0.9	1.9
S	0.4	1.1	167.6	1.7	1.2
Π	1.1	5.5	1.7	21.7	0.9
Q	0.9	1.5	2.3	2.0	3.3

The critical F value is 2.08 at the 5% level.

TABLE 2

Tests for VARCH Process

Base Variable	R^2
E	0.252
P	0.378
S	0.214
Π	0.169
Q	0.189

TABLE 3

Tests For Granger Causality in Volatility - Domestic Currency

Equation	Variable				
	E	P	S	Π	Q
E	3.39	4.04	2.58	0.47	0.18
P	9.84	4.99	1.11	0.46	0.43
S	1.23	5.36	2.31	0.47	0.95
Π	0.77	0.05	6.88	0.07	0.15
Q	0.36	0.36	0.88	0.44	7.83

The critical F value is 2.43 at the 5% level.

TABLE 4

Tests for Granger Causality in Volatility - Foreign Currency

Equation	Variable				
	E	P^*	S	Π^*	Q
E	3.72	3.08	1.27	0.39	0.31
P^*	0.89	0.18	0.47	3.92	0.25
S	0.22	1.35	2.14	1.09	0.88
Π^*	1.10	0.59	0.41	6.94	0.09
Q	0.41	1.06	0.81	0.54	8.02

The critical F value is 2.43 at the 5% level. The asterisk denotes a price denominated in $US.

Figure 1 : Data

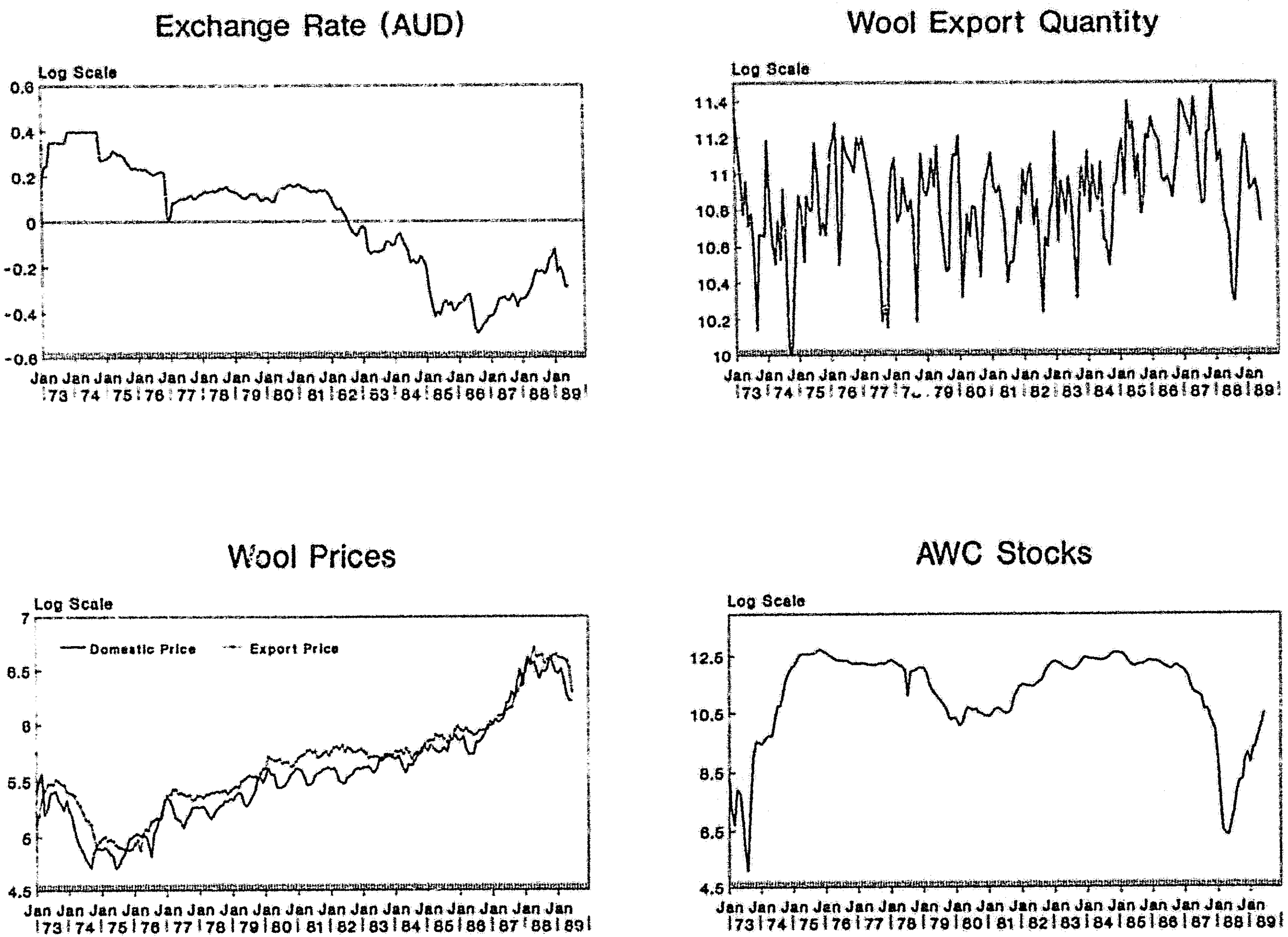

Figure 2 : Impulse Response Functions

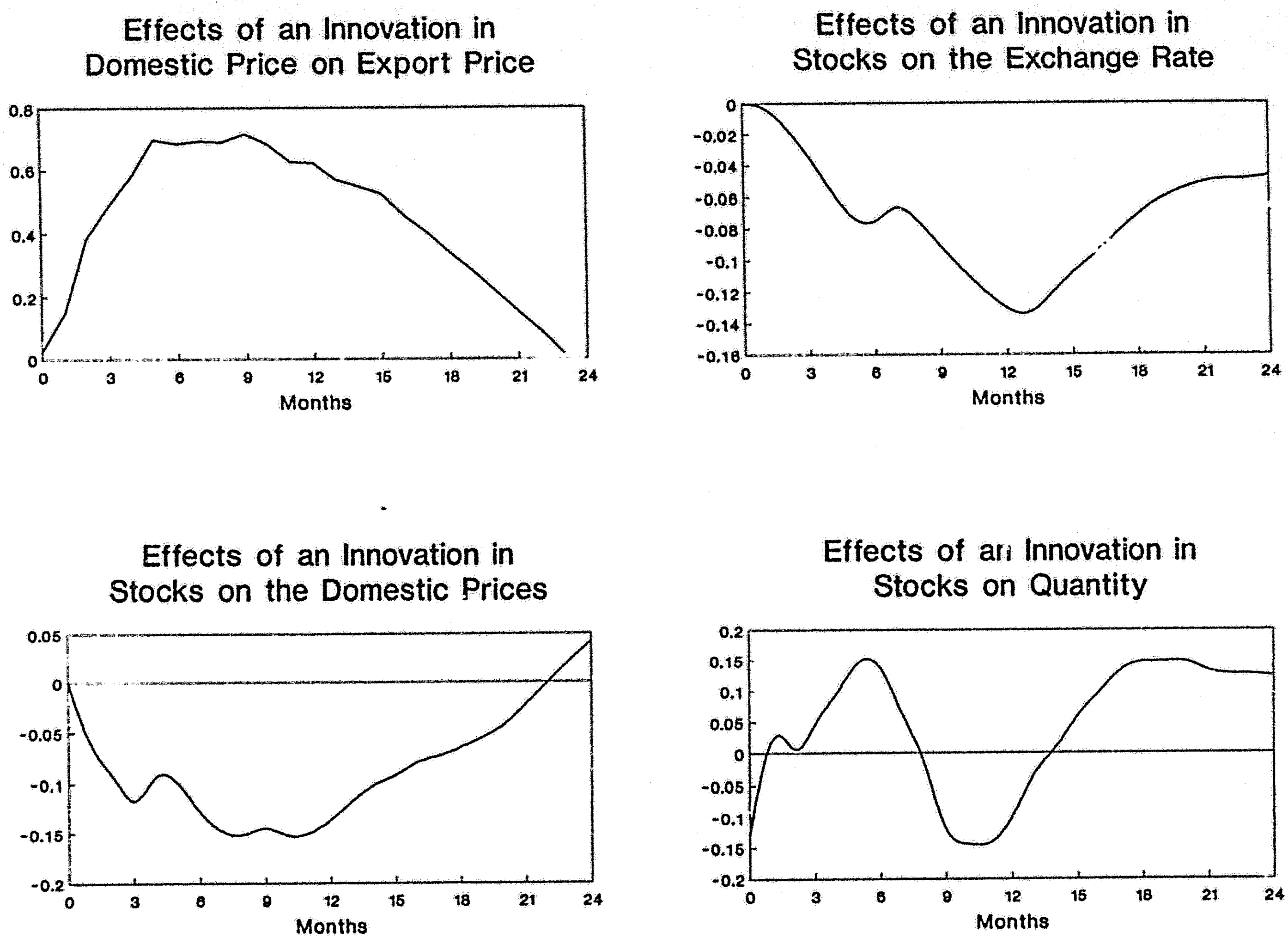

Figure 3 : Volatility Analysis