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Using Vector Autoregression Models to Analyze the Behavior of the European Community Stock Markets

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Abstract

This paper examines the behavior of European Community stock markets in light of decreased barriers to internatinal investments and improved accessibility to information. The Vector Autoregression (VAR) model is able to identify the main channels of interactions and simulate the responses of a given market to innovations in other markets. The daily returns are expressed in terms of German Marks, reflecting the outlook of European investors. This paper hypothesizes that an innovation in one market is directly, rather than serially, transmitted to all other markets.

The research shows that no market is found to be completely isolated from ther others; however, these patterns of transmittal are still consistent with international market efficiency.

1. Introduction

Since 1980, as most advanced economies deregulated their capital markets, removed barriers to international investments, and improved the accessibility to information, investors in many countries have adopted a global view. These trends are especially pronounced in Europe where European Community (EC) countries have embarked on a process of unifying their economies and their financial markets. The Maastricht treaty, which was agreed to by EC leaders in December 1991, established the steps toward a currency union and closer political integration. Moreover, by 1996, the EC Investment Services Directive will allow stockbrokers to operate across national borders without the need to establish local subsidiaries.

Global trends notwithstanding, European financial intermediaries, investors and corporations are national rather than pan-European in character. There are substantial differences among EC countries in the regulation of national securities markets, taxes, corporate laws and accounting practices. Barriers to cross-border investments, e.g., pension funds, remain. The purpose of this study is to examine the dynamic linkages among the eight major EC stock markets.

The interdependence among national stock markets has been the subject of several recent papers (Schollhammer and Sands [17, 18], Eun and Shim [5], Meric and Meric [15]), Jeon and Von Furstenberg [10], Von Furstenberg and Jeon [23], Koch and Koch [11]). These studies were motivated by growing recognition of the benefits of international portfolio diversification (e.g., Grubel [7], Grubel and Fadner [8], Levy and Sarnat [11], Agmon [1] and the international propagation of the October 1987 crash, e.g., Malliaris and Urrutia [14]. None of these studies solely focused on Europe. This paper uses a Vector Auto Regressive (VAR) model to study whether EC stock markets behave like a single, integrated multi regional market. The VAR model is suitable for the analysis of dynamic linkages among the various markets since it can identify the main channels of interactions and simulates the responses of a given market to innovations in other markets. The EC stock markets operate within a single time zone and should all respond to a global news event simultaneously. Engle, Ito and Lin [4] and Ito, Engle and Lin [9] argued that shocks are transmitted as meteor showers rather than heat waves. The heat waves hypothesis assumes that volatility has only country-specific autocorrelation. An innovation in a particular market will persist only in that market and will not have a spillover effect to other markets. The meteor shower hypothesis asserts that innovations are transmitted from one market to others. A shock in one market tends to continue after that market closes, producing volatility in geographically distant markets opening several hours later. This is similar to the effect of meteor showers on earth as the globe turns. Since the hours of operations of EC securities markets overlap substantially, the meteor-showers paradigm does not apply. Instead, an alternative paradigm is postulated: we simulated shocks that resemble a hand- grenade explosion, where an innovation in one market is directly, rather than serially, transmitted to all other markets.

The rest of the paper is organized as follows: Section 2 discusses the data used in this study and their statistical properties. Section 3 details empirical results. Finally, Section 4 offers summary and conclusions.

2. Description of the Data

The data for this study comprises time series of daily stock market indices for the eight major EC stock exchanges: Belgium, Britain, Denmark, France, Germany, Italy, Netherlands, and Spain. The indices were computed by Morgan Stanley - Capital International Perspective (MSCIP) for 1/1/1988 to 12/31/1994. The MSCIP indices are reported in US dollars and in local currencies. Since this paper focuses on major EC stock markets, the indices are converted to German Marks. For each country, daily returns, rt, are computed as the first differences of the natural logarithms of, Pt, the daily close values of the indices (after they are converted to the German currency), multiplied by 100: rt=100(lnPt-lnPt-1). Table 1 shows the correlations among the daily returns for the eight major EC stock markets. Note that the EC stock markets

Insert TABLE 1 about here

are highly correlated as evidence by the correlations between the stock markets of France and Netherlands (0.66), Britain and Netherlands (0.65), France and Spain (0.59), Britain and France (0.59), Germany and Netherlands (0.57), and Germany and France (0.57). Thus, it is apparent that geographical proximity matters. It is worth noting that the Italian stock market has the lowest correlations with other EC stock markets.

Each country's series of daily returns was tested for the presence of a unit root using three alternative tests suggested by Dickey and Fuller [3], Phillips and Perron [16] and Sims [22]. All three tests, presented in Table 2, rejected the assumption of a unit root for all time series considered, implying that the relationships among the various variables analyzed below are not spurious.

Insert TABLE 2 about here

3. Empirical Results

A VAR model of the daily returns was estimated with 15 lags for each variable in each equation. Each equation has 8x15 unrestricted coefficients plus two coefficients for a constant and a trend. The number of lags was chosen based on three tests: the Likelihood Ratio tests (Sims [20]), the Information Criteria suggested by Akaike [2] and by Schwarz [19]. While the Akaike and Schwarz tests indicated that as few as 2 lagged daily returns may be sufficient, the Sims test suggested that 15 lags are needed. A lag length of 15 ensures that all the dynamics in the data are captured and are used in this analysis (Eun and Shim [5] also used 15 lags).

3.1. Granger Causality Tests

The Granger causality test (Granger [6]) is a simple way to ascertain whether a particular market is affected by innovations in other markets. The test indicates if innovations in one market help forecast a one-step ahead return in another market. An important advantage of this test is that it is unaffected by the ordering of the VAR system. The test statistics are summarized in Table 3. Each column contains the values of F-statistics testing

Insert TABLE 3 about here

the marginal effect of inclusion of lagged returns of the market in the row on the market in the column's heading. Each market, except the German and the Spanish markets, is affected by its own lagged returns. Column 1 shows that the British market is affected by the Netherlands, Spanish and the Italian markets; the French market (column 2) is influenced by the Netherlands, Belgian, Italian and Spanish markets. The German market (column 3) is influenced by Britain, France, Netherlands, and Belgium. The Dutch market (column 4) is influenced by Belgium, Italy and Spain. The Belgian market (column 5) is influenced by Britain and France; the Danish market (column 6) is influenced by France, Netherlands and Belgium; the Italian market (column 7) is not influenced by any other EC market (except its own lags); the Spanish market (column 8) is influenced only by Britain. Since many EC markets are influenced by lagged returns of other markets, the heat-wave hypothesis is refuted. Further insight is gained by looking at the rows of Table 3, rather than the columns. Each row of the table reveals the effects of a particular market on all markets. It is evident that the British, French, Netherlands, Belgian, and Italian markets are the influential in the EC. The British market affects the German, Belgian and Spanish markets. The French market affects the German, Belgian, and Danish markets. The Dutch market affects the British, French, German and Danish markets. The Belgian market affects the French, German, Dutch, Belgian and Spanish markets. The Italian market affects the British, French, and Dutch markets. It is interesting to note that the German and the Danish markets do not Granger-cause any other EC markets.

An important caveat about the above F-Tests must be noted. Although they indicate whether other markets Granger-cause a given market, it is still possible that other markets can influence that same market through other equations in the system. For example, the analysis that follows shows that the German market is as influential as the French market. For this reason we turn to the decompositions of the variances of forecast errors.

3.2. Decompostions of Variance and Resiudal Correlations

The transmission of innovations among markets may occur via many channels. When decomposition matrices are analyzed, the order of transition must be determined. Eun and Shim [5] and Von Fostenberg and Jeon [23] assume that shocks are transmitted according to the meteor shower hypothesis. In a given calendar day, a shock that originates in the USA moves to Japan and then to Europe. However, within the EC, trading hours largely overlap, and there is no a priori to specify how shocks move from one market to another.

The decomposition of the variance of the forecast errors of the returns of a given market indicates the relative importance of the various markets in causing the fluctuations in returns of that market. The decomposition allocates the variance of the forecast error into percentages that are accounted for by innovations in all markets including the market's own innovations. The decomposition of variances is sensitive to the assumed origin of the shock and to the order in which it is transmitted to other markets. This may be a problem when the contemporaneous correlations of the residuals of the VAR model are high. These residuals are that component of returns not explained by lagged returns of all eight EC markets. The correlations indicate the extent of shared responses of all markets to new information in one market. Table 4 indicates that an innovation of an unknown source affects the larger EC markets in a similar manner. The high correlations among the large markets are likely to effect inferences from the variance decompositions tables discussed below. The pairwise correlations between the Netherlands and the large markets of Britain, France and Germany are quite high (0.650, 0.646 and 0.584, respectively). This indicates that the Dutch stock market is sensitive to news from the other markets. In general, the larger EC markets appear to be integrated, i.e., the correlation between the residuals of Britain and France is 0.579 and the corresponding correlation between Germany and France is 0.566. Geographical proximity seems to be reflected in the correlation between Spain and France (0.589). The Italian market is the least correlated with other markets.

Insert TABLE 4 about here

Given the pattern of correlations of residuals, we begin by considering the effect of a shock that originates in Britain and then moves to France, Germany, the Netherlands, Belgium, Denmark, Italy, and Spain. A leading market is one which explains a large percentage of the forecast error's variance of other markets while its own forecast error is not explained by innovations in other markets. Table 5 presents the decomposition of the forecast error variance for 5-day, 10-day, and 15-day ahead horizons. Each row displays the percentage of forecast error variance explained by the market in the column heading. The table shows that none of the EC stock markets are isolated from the rest, since no variance is completely accounted for by its own innovations. At the 15-day horizon the percentage of forecast error for the British market explained by its own innovations is 91; for Italy this percentage is about 72; the corresponding percentages for Belgium, France, Germany and Denmark range from 60 to 65. The lowest percentage is for the Netherlands – about 40. This indicates that the British market is least influenced by innovations in other EC markets, whereas the Dutch is the most sensitive. In terms of influencing other markets, the British market is leading, it explains 39 percent of the Netherlands' variance, 31 percent of the French variance, 22 percent of the Spanish variance, 17 percent of German variance, about 14 percent of the variances of Belgium's and about 12 percent of the variances of Denmark and Italy. The French market influences mainly its neighbors: it accounts for 15 percent of the German variance, 14 percent of the Spanish variance and about 11 percent of the variances of Belgium and Netherlands, confirming the hypothesis that geographical proximity matters. The German market explains about 8 percent of the variance of the Belgian market, 6 percent of the Danish market, and lesser percentages of other markets. The other EC countries play a much smaller role, each explaining at most 4 percent of other countries' variances.[1]

Insert TABLE 5 about here

Since the correlation of residuals between France and Germany is high (0.566), we examine the effect of changing the order of the two countries. Table 6 presents the decomposition of variance for a shock that originates in Britain and then moves to Germany, France, the Netherlands, Belgium, Denmark, Italy and Spain. This reordering affects only results for France and Germany, without affecting explanatory power of the other markets. After the reordering, Germany explains more of its own variance (75% vs. 62%) and 13% of the French variance (vs. 1% before). The effects of Germany on the other EC markets almost doubled. On the other hand, France explains a smaller fraction of its own variance (49% vs. 61%). France now explains 2% of the German variance, compared to 15% before. The effect of France on the other EC markets is approximately halved. These two experiments show that France and Germany are influential, but their effects cannot be separated.

Insert TABLE 6 about here

The above discussion demonstrates the difficulty resulting from the inability to determine a correct order. One way to overcome this indeterminacy is by conducting different simulations. One interesting simulation is to examine what is, for example, the immediate effect on the German market of a news event, or an innovation, that occurs in Spain. In contrast to the heat-waves and meteor-showers paradigms discussed in the introduction, an innovation in this experiment is viewed as similar to a hand-grenade that explodes in one market and ricochets to other markets. This is done by tracing the effects of a shock that bursts in one market, j, and ricochets directly to another market, i, ignoring effects on other markets. Table 7 summarizes the results: each entry aij shows the effect of a one standard deviation shock originated in market j and directly transmitted to market i. The larger markets of Britain, France, Germany and the Netherlands are affecting one another substantially, with Britain and the Netherlands being the most interrelated. In addition, France exhibits considerable dominance on its neighbors, Belgium and Spain. The smaller EC markets, Belgium, Denmark and Italy are less influential than the larger markets. Note that a shock that begins in Spain, though a small market, directly explains about 32 percent of the French variance, and about 23 percent of the variance of Britain, German and the Netherlands. Compared to the other small markets Spain seems to be more influential. Italy, on the other hand, is the least influential.

Insert TABLE 7 about here

3.3. Moving Average Representations

Further insight into the dynamic interrelations among the EC stock markets is obtained by simulating the VAR system of equations and observing its dynamic response to shocks through Moving Average Representations (MAR), see Sims [21] and Litterman [13]. A shock of one standard deviation is introduced in a given market and its dynamic effects are traced throughout the system for the next 15 trading days. These impulse responses are highly non-linear functions of the estimated parameters with numerous coefficients. The confidence bands presented below were computed using Monte Carlo integration. Figures 1 to 8 depict the dynamic behavior of the system of eight countries ordered as follows: Britain, France, Germany, the Netherlands, Belgium, Denmark, Italy and Spain. In each graph, the center line represents the impulse responses and the two outer lines represent the two-standard-deviations band. All innovations taper off in at most three trading days, often within one or two days. Furthermore, only a few markets influence other markets considerably. Figure 1 shows the influence of a shock in Britain on other EC markets. No significant response is evident, since the confidence bands of all markets other than Britain include zero. Figure 2 shows that a shock in the French market affects only Britain, causing a jump of about 64 percent standard deviation. Figure 3 shows that the German market affects only the British and the French markets, causing 50 percent standard deviation jumps. Figure 4 shows that the Dutch market affects Britain – inducing a half standard deviation jump. France and Germany are also affected, but to a smaller extent. Figures 5, 6, and 7 show that shocks in Belgium, Denmark, and Italy hardly influence the other markets. Innovations in these markets have only small effects on other markets (less than 20 percent of the corresponding standard deviations). Figure 8 shows that the Spanish market affects the French and British markets, reaffirming the finding that Spain is more influential than other small EC markets. Evidently, innovations in the larger markets are transmitted to other markets, especially if they are neighboring markets.[2]

4. Conclusion

This paper formulates and estimates a Vector Autoregression (VAR) model of the daily stock market returns for eight major EC countries. The daily returns are expressed in terms of German Marks, reflecting the outlook of European investors. The model is used to investigate the dynamic linkages among the various markets. Additionally, the model is used to simulate the responses of a given market to innovations in other markets. The large stock markets of the EC (Britain, France, Germany and the Netherlands) are found to be highly related, but the smaller EC markets are more independent.

The results of the Granger causality tests may lead to a conclusion that EC markets are inefficient, since current returns are predicted by their own and by other markets' lagged values. However, the impulse response analyses indicate that although innovations are transmitted from some markets to others, most of the responses vanish within one or two days. These patterns are consistent with international market efficiency.

The decomposition of forecast variance indicates varying degree of interdependence among EC markets. Regardless of the order of the decomposition, no market is found to be completely isolated from the others, since no forecast variance is fully explained by its own innovations. Britain is a leading market within the EC because it explains most of its own innovations (91 percent) and significant parts of the innovations in other markets. In general, larger markets such as France and Germany, influence their neighbors. In contrast, smaller markets, such as Belgium, Denmark and Italy have no impact on other markets. Simulations of shocks resembling a hand-grenade explosion, where an innovation in one market is directly transmitted to all other markets, rather than serially, show that the larger markets are substantially affecting one another.

The impulse-response analysis which dynamically simulates the model provides additional insights. The responses, as depicted by the graphs, confirm that Britain is a leading market that affects France, the Netherlands, and Germany. In addition, the graphs show that Britain, France, Germany, and the Netherlands form a cluster of highly interdependent markets. The graphs reinforce the finding that smaller markets do not influence larger markets.

One implication of these findings is that investors will achieve larger benefits from international portfolio diversification by including the smaller markets in their opportunity set.

APPENDIX A.
THE VAR MODEL

The VAR model assumes that each variable depends on its own past values and on the past values of all other variables in the system of equations. The model can be expressed as:

$$Y_t = X_t \cdot \beta + \sum A_s \cdot Y_{t-s} \ + \ U_t \tag{A.1}$$

$$E\,[U_t \cdot U_t'] = \Psi \tag{A.2}$$

where Y_t is an nx1 vector of daily returns, $X_t \cdot \beta$ is the deterministic component of Y_t, U_t is an nx1 vector of serially uncorrelated errors, A_s is an nxn matrix of coefficients and L is the number of lags. The moving average representation (MAR) of the VAR model can be written as:

$$Y_t = X_t \cdot \beta + \sum B_s \cdot E_{t-s} \tag{A.3}$$

where, E_{t-s} for s=0,...,∞ is an n-variate white noise process, and E_t and E_s are uncorrelated for $t \neq s$, (Sims [21]).

There are many equivalent representations for this model. For any non-singular matrix G, the matrix of coefficients B_s can be replaced by $B_s \cdot G$ and E by $G^{-1} \cdot E$. A particular version is obtained by choosing some normalization.

If B_0 is normalized to be the identity matrix, each component of E_t is the error that results from the one step ahead forecast of the corresponding components of Y_t. These are the non-orthogonal innovations in the components of Y because, in general, the covariance matrix $\Phi = E[E_t \cdot E_t']$ is not diagonal.

It is more useful to look at the moving average representation of the system with orthogonalized innovations. If any matrix G is constructed to satisfy

$$G^{-1} \cdot \Phi \cdot G^{-1} = I \tag{A.4}$$

then the new innovations $v_t = E_t \cdot G^{-1}$ satisfy:

$$E\left[v(t) \cdot v(t)'\right] = I \tag{A.5}$$

These orthogonalized innovations have the important property that they are uncorrelated across time and across equations. Such a matrix G can be any solution which satisfies the condition that GG' = Φ. The problem is that there are many such factorizations of a positive definite matrix Φ.

The literature on time-series suggests a number of ways to accomplish the factorization of Φ. Some techniques are based on the Choleski factorization, where G is restricted to be a lower triangular matrix. Other techniques are based on orthogonalization using the eigenvalues. Sims [21] suggested imposing restrictions on the matrix by constraining it to be a lower triangular matrix. In general, the moving average model (A.4) is diagonalized as follows:

$$BU(t) = V(t) \tag{A.6}$$

and

$$E\left[V(t) \cdot V(t)'\right] = D \tag{A.7}$$

where D is a diagonal matrix. The model can be estimated by minimizing the log likelihood function with respect to the free parameters in the matrices, A and D, i.e., minimize:

$$-2log \mid A \mid +log \mid D \mid +trace(D^{-1} \cdot A \cdot S \cdot A') \tag{A.8}$$

where S is the sample covariance matrix of residuals, and A is the coefficients matrix of (A.1).

Notes

1. The orthogonalization as reported in Table 5 is ordered as the order of the columns in the table suggests, namely, Britain, France, Germany, the Netherlands, Belgium, Denmark, Italy, Spain. However, since the decomposition of variance is sensitive to the ordering of the markets' returns when the innovations in different markets are correlated, we experimented with changing the order among markets with high correlations.

2. Different orderings produce somewhat different figures and they are available from the authors upon request.

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