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The Stability of the Estimated Risk-Structure of Asset Returns

1. Introduction

This paper examines the stability of stock and bond market correlations. The estimated correlation structure of investment returns is a major determinant of the expected gains from international diversification and the weight of different asset categories in mean-variance efficient portfolios. Unlike the expected returns and volatilities of different national asset markets where analysts' forecasts are commonly used by investment professionals for asset allocation, the investment community relies heavily on past sample estimates for the correlation structure of asset returns in an international setting. Thus the question arises whether the stock market crash and high currency volatility during the last quarter of 1987 had a lasting impact on the estimated risk structure of internationally diversified stock and bond portfolios. The study continues thus the examination of the stability of the co-movement of asset returns from a Swiss investor's perspective which was already the focus of SCHULTZ/ZIMMERMANN (1989).

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The paper has the following structure:
Section 2 summarizes the effect of the stock market turmoil on the correlations of international asset returns. Section 3 uses a regression analysis to examine whether there is a priori evidence for a profound change of the 5-year correlations during the period 1977-82 and 1983-87. Section 4 employs a formal statistical test to verify the degree of intertemporal stability of international bond and equity returns in a portfolio context. Section 5 draws some implications for portfolio management which follow from these results.

2. Equity Market Correlations in the Aftermath of the October 1987 Stock Market Crash

The assumed risk-structure between assets across markets and currencies is a major determinant of the expected gains from diversification. The correlation structure is extremely sensitive to "events" such as the stock market crash in 1987 and the length of the sample period. The correlations between stock markets during and after the crash were uncanny and unpredecented. They are leading investors to reasses their reasons for investing outside their domestic markets. Is this justified? In a world of increasing global economic interdependence, it would be odd if stock markets moved entierly independently of one another. Clearly, some economic factors - world trade flows and interest

rates, for instance - will affect share prices in several markets. Yet the impact of such global factors on national economies varies.
Until the crash, stock markets seemed to recognize this: between January 1981 and September 1987, the monthly average correlation between the 23 biggest national stock markets was just 0.222 in local currency terms. In October 1987 most of the 23 stock markets fell by more than 20%. The average monthly correlation, at 0.755, was extremely high. With the last three month of 1987 included, the correlation since 1981 nearly doubled, to 0.415 [1]. Thus those investors which held foreign assets as a way to spread risk across several markets found themselves pretty much undiversified and may wonder whether the perceived gains from international diversification persist at all. However, the long-term investment horizon of most institutional investors implies that short-term changes in the degree of parallelism of stock-market price behaviour will not trigger a reassessment of the portfolio weights of international asset holdings as long as there is no evidence that correlations become more unstable over estimation periods of several years. This follows from the use of rather long-term historical estimates of markets' risk/return trade-offs and correlations for the determination of the currency and asset mix of internationally diversified portfolios.

3. Examining the Direction of Change of Correlation Coefficients

The data used in our analysis is the Salomon Brothers World Bond Index (Government bonds only, monthly total rates of return in Sfr-terms) and the Morgan Stanley Capital International Index (equities, monthly total rates of return). The absolute change in correlation coefficient has been calculated for each of the country sub-indices of the two international benchmarks. In order to examine the direction and the magnitude of change in the degree of co-movement of asset returns over time we use a simple linear regression model of the from:

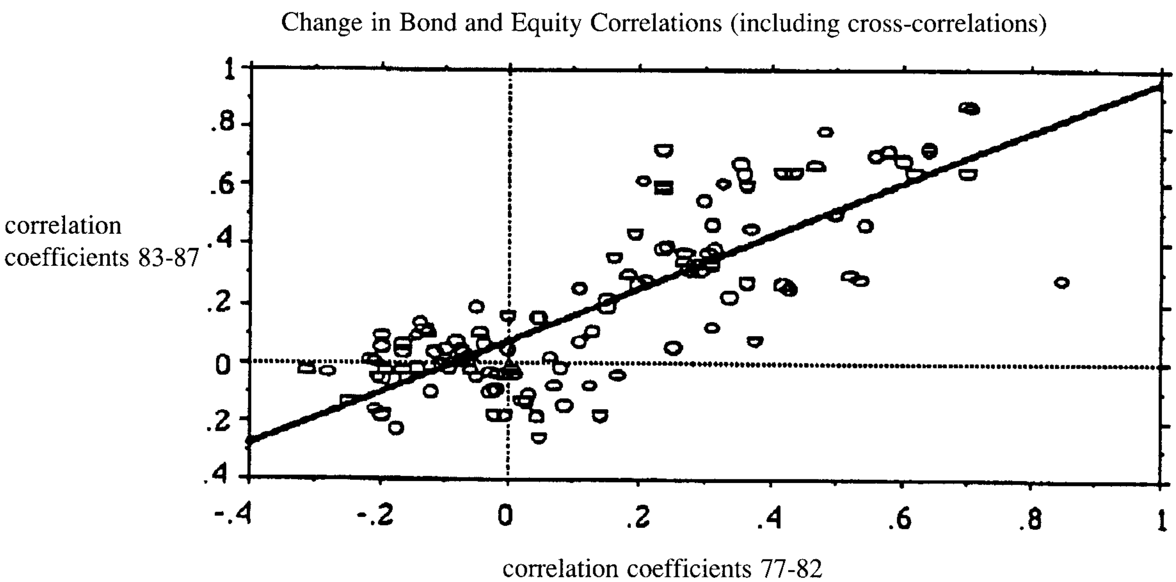
$$\text{Corr}_{78\text{-}82} = \alpha + \beta \, \text{Corr}_{83\text{-}87} + u$$

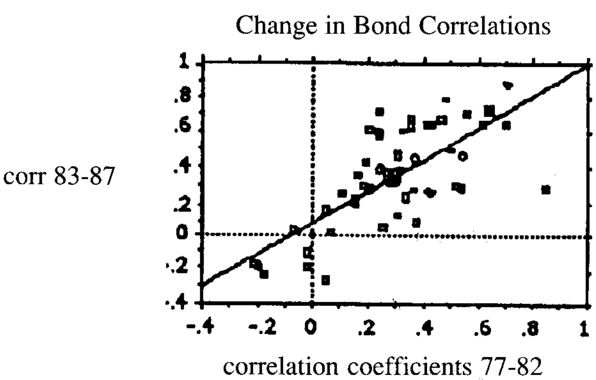
where

- α is the intercept; a positive intercept indicates that the correlations increased by a fixed amount across the board, visually this means an upward shift of the regression line.
- β is the slope coefficient; if correlations did not change significantly the slope coefficient should not be significantly different from 1. A steeper slope indicates rising correlation coefficients in the later sub-period.

By way of illustration, Figure 1 shows the correlation coefficients of bond and equity returns in SFr-terms estimated over the periods of 1978-82 and 1983-1987. The figure illustrates that the correlation coefficients of a 8-country bond and equity portfolio [2] did not uniformly increase between the two reference periods.
Although our estimated model has a positive intercept and a slope coefficient which is smaller than one, both parameters fail the hypothesis test that they are significantly different from 0 and 1 respectively (see Table 1). If they remain unchanged, all the data points would plot on a straight 45° line through the origin. This is equally true for the correlation coefficients of equity markets. Initially we would expect a positive intercept and a slope greater than one in order to reflect the strong increase in short term correlations during the last quarter of 1987. This is, indeed, the result of our regression analysis of the change of correlation coefficients over the sub-periods 12/1977 - 12/1982 and 1/1983 - 12/1987. However, as it was the case with the analysis of bond an equity correlations together, the coefficients do not deviate significantly from their hypothezised values. Nevertheless, a simple linear regression might not be good enough to spot inter-temporal changes in the risk structure of asset returns. If we look at the individual pairwise correlations in Table 2 we find that some of the correlations between equity returns were generally higher during the 1983-87 period when compared

Figure 1: Absolute Change in Correlation Coefficients Between 1977-82 and 1983-1987. (Total rate of return in SFr-terms; end-of-month data).





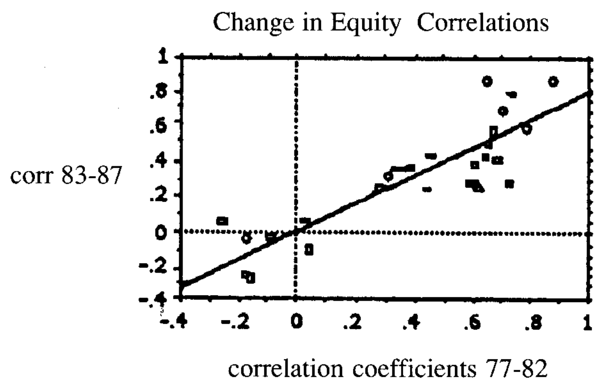


Table 1: Regression Analysis: Correlation Coefficients 1977-82 vs. 1983-87.

	Intercept	Slope	95%Lower	95% Upper	R^2
Bonds&Equities	0.078	0.882	0.736	1.000	0.35
Bonds	0.066	0.697	0.381	1.014	0.42
Equities	0.108	1.140	0.896	1.385	0.26

Note:
The intercepts (α) were in no case different from zero at the 5% level of significance.

Table 2: Absolute Change in Correlation Coefficients Between 1978-82 and 1983-1987 (Total Rate of Return in SFr.-Terms; end of month data).

	CH-S.	CH-B.	CH-F.B.	CH-C.	USA-S.	CAN-S.	FRG-S.	FRA-S.	NETH-S.	UK-S.	JAP-S.	USA-B.	USA-C.	CAN-B.	CAN-C.	FRG-B.	FRG-C.	FRA-B.	FRA-C.	NETH-B.	NETH-C.	UK-B.	UK-C.	JAP-B.	JAP-C.	GOLD
CH-Stocks	0.000																									
CH-Bonds	0.237	0.000																								
CH-For.Bonds	0.338	-0.046	0.000																							
CH-Cash	0.002	-0.279	-0.666	0.000																						
USA-Stocks	-0.356	0.103	-0.101	0.023	0.000																					
CAN-Stocks	-0.246	0.144	-0.132	-0.122	-0.195	0.000																				
FRG-Stocks	-0.299	0.050	-0.037	-0.110	-0.295	-0.087	0.000																			
FRA-Stocks	-0.426	-0.183	-0.230	-0.282	-0.391	-0.271	-0.354	0.000																		
NL-Stocks	-0.115	0.386	0.130	0.003	-0.126	-0.146	-0.206	-0.259	0.000																	
UK-Stocks	-0.294	0.127	-0.243	-0.118	-0.159	-0.097	-0.100	-0.288	0.033	0.000																
JAP-Stocks	-0.095	-0.098	-0.097	0.049	-0.065	-0.018	-0.089	-0.280	-0.142	0.013	0.000															
USA-Bonds	-0.253	-0.152	-0.139	-0.206	0.029	-0.104	-0.380	-0.458	-0.028	0.015	-0.001	0.000														
USA-Cash	-0.423	-0.088	-0.324	0.196	0.014	-0.228	-0.210	-0.262	-0.147	0.108	0.132	-0.060	0.000													
CAN-Bonds	0.011	0.148	0.097	0.003	0.068	-0.053	-0.046	-0.169	0.139	0.147	0.105	-0.074	-0.178	0.000												
CAN-Cash	-0.360	-0.020	-0.269	0.217	0.008	-0.166	-0.133	-0.210	-0.076	0.178	0.144	-0.047	-0.008	-0.169	0.000											
FRG-Bonds	0.285	-0.110	-0.116	-0.260	0.270	0.305	0.243	0.061	0.390	0.184	0.027	-0.065	0.137	0.194	0.253	0.000										
FRG-Cash	0.078	-0.441	-0.660	-0.339	0.384	0.333	0.152	0.011	0.372	0.309	0.286	0.022	0.542	0.140	0.597	-0.230	0.000									
FRA-Bonds	0.106	-0.241	-0.308	-0.343	0.214	0.138	0.059	0.110	0.231	0.167	0.320	-0.157	0.256	0.112	0.309	-0.059	-0.011	0.000								
FRA-Cash	-0.203	-0.227	-0.471	-0.282	0.120	0.108	-0.042	0.204	0.183	0.103	0.496	-0.139	0.180	-0.021	0.242	-0.137	0.095	0.158	0.000							
NETH-Bonds	0.282	-0.163	-0.162	-0.349	0.347	0.226	0.186	0.020	0.427	0.282	0.193	0.095	0.289	0.256	0.345	-0.045	-0.107	0.034	-0.021	0.000						
NL-Cash	-0.157	-0.366	-0.600	-0.363	0.182	0.142	0.003	-0.003	0.212	0.190	0.336	-0.072	0.300	0.034	0.356	-0.193	0.033	0.012	-0.091	-0.067	0.000					
UK-Bonds	0.071	-0.182	-0.292	-0.335	0.403	0.280	0.043	-0.021	0.402	0.346	0.022	0.271	0.358	0.230	0.395	-0.061	0.048	0.003	0.098	0.154	0.110	0.000				
UK-Cash	-0.192	-0.387	-0.509	-0.315	0.350	0.155	-0.008	-0.034	0.292	0.251	0.234	0.233	0.453	0.072	0.426	0.005	0.295	0.107	0.273	0.210	0.330	-0.072	0.000			
JAP-Bonds	0.264	-0.039	-0.248	-0.201	0.169	0.176	0.099	-0.018	0.196	0.248	0.319	-0.087	0.142	0.070	0.225	-0.123	0.047	0.124	0.333	0.037	0.165	0.024	0.199	0.000		
JAP-Cash	0.085	-0.115	-0.382	-0.207	0.200	0.143	-0.045	-0.082	0.114	0.308	0.359	-0.029	0.236	0.045	0.284	-0.138	0.131	0.186	0.426	0.079	0.219	0.122	0.284	0.017	0.000	
GOLD	0.072	-0.117	-0.377	-0.206	0.192	0.130	-0.059	-0.091	0.102	0.298	0.347	-0.036	0.227	0.038	0.275	-0.142	0.128	0.189	0.421	0.077	0.218	0.124	0.285	0.016	0.000	0.000

Note:
Negative signs indicate a higher correlation coefficient for the period 1983-1987.

to the period 1977-82. For example, the correlation coefficients between Swiss and foreign equity returns increased on average by about 30% of their initial value during the 1983-87 sub-period. US-European equity correlations increased by more than 20% if the two sub-periods are compared. The positive intercept of the regression line suggests also that mostly those correlations changed significantly which were previously "small", i.e. smaller than 0.5, while those markets which have traditionally shown a strong parallelism of price movements reinforced this link only slightly. This gives us a regression line with a positive intercept which is significant at the 5% level and a slope which is slightly below 1.

4. A Formal Test of Stability

The behaviour of world equity markets in October 1987 is often cited as an example of the interlinking of world markets. During times of crisis or excess, this may indeed be the case. However, does this mean a vanishing of the risk reduction potential of international investments and thus their declining attractiveness?

In order to answer this question we have to test for the inter-temporal stability of correlation coefficients. Again, we use the 10-year monthly rate of return series of bonds and stocks in 8 national markets covering the period from 12/1977 until 12/1987. Two, three and five-year sub-periods where formed and the pairwise correlation coefficients for each sub-period calculated. Thus the number of observations within each sub-period is given by the total number of observations (i.e 120) divided by the number of sub-periods, i.e. 5, 3 and 2. Following the approach of SHAKED (1985), we test the hypothesis that the correlation coefficients estimated for the different sample periods are equal [3]. Because the distribution of the sample estimates becomes skewed, when the population correlation coefficient between the rates of return on various assets is different from zero, it follows that the conventional t-test is unsuited for testing null hypotheses other than those that $\rho = 0$. We thus use a technique that transforms the sample estimate correlation coefficient to a quantity z_t in order to develop a statistic that is distributed Chi-squared. The null hypothesis is that the z_t for a given pair of countries are all estimates of the same "true" population correlation coefficient with variances $\sigma^2 = 1/(n_t - 3)$ and where the observed z_t's are distributed approximately normal around the "true" population correlation coefficient with a standard error of $\sigma_z = 1/\sqrt{n-3}$. The relation of z to ρ the "true" correlation coefficient is given by

$$z_{i,j,t} = (0.5)[\ln(1 + \rho_{i,j,t}) - \ln(1 - \rho_{i,j,t})]$$

Now we want to test for stability over time. The null hypothesis is that the z_t's for a given pair of countries and assets are all estimates of the same mean μ with variances $\sigma_z^2 = 1/(n-3)$ the test of the significance is based on the result, that, if k normal deviates have those characteristics, the quantity

$$\Sigma W_t(z_t - (\bar{z}_w))^2 = \Sigma W_t z^2 - (\Sigma W_t z_t)^2 / \Sigma W_t$$

is distributed Chi-squared with (k-1) degrees of freedom, where W_t is the reciprocal of the standard deviation of z_t and where

$$\bar{z}_w = \Sigma W_t z_t / \Sigma W_t.$$

For the case of a two-year holding period, the 120-month period was divided into 5 sub-periods ($k = 5$, $n_t = 24$). The Chi-squared statistics were derived for each of the pairwise correlation coefficients; acceptance of the null hypothesis was recorded for any Chi-squared with value lower than the critical value at the 5% level. The hypothesis that all correlation coefficients are estimates of the same r was accepted for 11 out of 28 coefficients in the case of an equity portfolio. For the combined bond/equity portfolio 39 coefficients passed the hypothesis test out of a total of 120. On the other hand, the results obtained by assuming investment horizons of 3 and 5 years reveal a substantially increased degree of stability of the sample correlations.

Table 3: Test of Stability of Correlation Coefficients: 12/1977-12/1987. (8 countries, monthly total rates of return in SFr.-terms).

Assets	2 years	in%	3 years	in%	5 years	in %
Bonds (28 pairs)	11	39%	14	50%	22	78%
Equity (28 pairs)	3	10%	7	25%	11	39%
Bonds&Equity (120 pairs)	39	33%	58	48%	89	74%

Note:
The Chi-squared statistics were recorded for each of the possible pairs; acceptance was recorded for any Chi-squared with value lower than the critical value of the Chi-squared with k-1 degrees of freedom.

We can see this in the summary provided in Table 3. The number of equity correlations which meet the test criterion increases to 7 and 16 and those of bonds to 14 and 22 coefficients if the sample period is extended to 3 and 5 years. However, the most dramatic improvement takes place if we look at the correlation coefficients of combined bond and equity holdings. Here the acceptance rate of the null hypothesis is 74% (89 pairs out of 120). Our findings confirm the analysis of SHAKED (1985) who examined the stability of correlation coefficients over the period 1960-1979 and KAPLANIS (1988) [4] who investigated the stability of the correlation structure of equity returns in 10 countries over the period 1967-1982. These results combined with those shown here therefore establish a powerful evidence over the last 30 years that the analysis of correlation structures yields indeed relevant insights for the investor if the investment horizon exceeds two years. Thus the use of estimates of the risk structure of asset returns for portfolio decision making seems only appropriate if it serves the purpose of determining long term rather than short term asset allocation strategies. The findings presented in Table 3 extend the earlier study as they include bonds as an asset category.

5. Implications for Portfolio Management

There are a number of implications for portfolio management which follow from this result:

- As our time horizon increases the estimates of the correlation structure become more reliable and thus more relevant for investment decisions. The long term investor should therefore take this information into account.
- Due to the instability of correlation coefficients over investment horizons up to two years a passive strategy can be expected to outperform an optimized portfolio which is frequently rebalanced to reflect changes in the short term risk structure between assets. This follows from the above evidence that changing correlations yield misleading signals for portfolio adjustments.
- The experience of the stock market crash does not justify a withdrawal from diversification. Not only was the aggregate change of the correlation coefficients not substantial for a mixed bond/equity portfolio but also are higher equity correlations expected to approach their long term means over time rather than staying at their present level.
- The result obtained provide a powerful argument for the case of diversification across asset categories (i.e. holding a sizeable fraction of the portfolio in bonds) because this reduces estimation risk.

In principle, correlation coefficients should convey information about the degree of interdependence between economies, monetary policies, trade linkages, similarities of the economic bases etc. which may be regarded as fundamental factors for the determination of the co-movement between asset markets. On this account, it is unlikely that correlation coefficients will ever approach unity, (perfect correlation). Equally, the correlation coefficients between asset markets of a distinct economic region, where physical and tariff barriers are low, such as the USA and Canada, within the European Community and around the Pacific Basin, can always be expected to be higher than market correlation between these regions. Any development which is likely to bring about further economic and monetary integration contributes to rising correlation coefficients. A typical example for such a development is the project EC 1992 which, if successfully implemented will probably lead to an incrasing parallelism of European stock market behaviour.

Footnotes

[1] Figures obtained from THE ECONOMIST (1989) p. 77, see also BERTERO/MAYER (1989) and KING/ WADHAWINI (1988), for a recent discussion of the rise in co-movement of equity returns. See also SCHULTZ/ZIMMERMANN (1989) who recorded exceptional instability of Swiss stock betas during the last quarter 1987.

[2] See DUBACHER/HEPP (1989) for a description of the data used.

[3] This test goes back to SHAKED (1985) who tested for the inter-temporal stability of correlation coefficients of equity returns over the period 1960-1979 and found them to approach their past sample means as the investment horizon lengthens. For a detailed analysis of the test see also SNEDELOR/COCHRAN (1980).

[4] See KAPLANIS (1988) pp. 63-75 for a detailed description of the results.

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