International Evidence on Mean Reversion in Stock Prices

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This paper uses a regression-based test to examine whether international stock price indexes contain slowly mean-reverting components. The results indicate that most of the 18 country indexes studied exhibit variations during the past two decades inconsistent with mean reversion in long-horizon returns. Where mean-reversion is evident, it appears to arise from both common and country-specific factors.

INTRODUCTION

This paper examines whether international stock price indexes contain slowly mean-reverting components. This issue has generated substantial debate in recent years and has significant implications for stock market efficiency. The study employs the regression-based tests of Fama and French (1988) that focus on the autocorrelations of stock returns for increasing holding periods. The results show that a majority of the 18 country indexes studied exhibit variations during the past two decades inconsistent with mean-reversion in long-horizon returns. Evidence also is provided that suggests that any apparent mean-reversion is due largely to country-specific factors.

Previous studies have found predictability in return data, but most have relied on short-horizon data and found only a small degree of systematic change in prices (Lo and MacKinlay, 1988; French and Roll, 1986; O'Brien, 1987; Poterba and Summers, 1988; and Cochrane and Sbordone, 1988). But stock prices may mean revert very slowly as Summers (1986) argues; hence, predictability may be evident only at longer return horizons. The tests of Fama and French (1988) explicitly capture Summers' (1986) insight. Their evidence, based on U.S. data for industry and decile price indexes, implies considerable predictability for the 1926 to 1985 period, especially for smaller firms. They find much less predictability, however, in the 1940 to 1985 subperiod. Because the present study covers the 1970 to 1989 period, the results are broadly consistent with those of Fama and French (1988).

The present study's application of the Fama/French test to international data is important both for practical and scientific reasons. On a practical level, interest in worldwide investing is growing rapidly. Worldwide investors are interested in whether patterns observed in the United States apply to foreign markets with their differing institutional arrangements. On a scientific level, results from a wide range of countries provide new evidence on time-series properties of returns and allow more general inferences than do results based on a single country. In addition, any apparent cross-country differences may provide insights into the sources of predictability, which are still the subject of debate.

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A TEST OF MEAN-REVERSION IN STOCK PRICES

Fama and French (1988) develop their test from a simple model of stock price behavior.[1] The log of a stock's price, p(t), is the sum of a random walk component, q(t), and a slowly decaying stationary component, z(t) = az(t-1) + e(t), where e(t) is white noise and a is close to, but less than, unity. The continuously compounded return from t to t+T is:

$$(1)\ r(t, t+t) = [q(t+T) - q(t-1)] + [z(t+T) - z(t)].$$

The random walk component produces white noise in returns while the stationary component induces negative autocorrelation. Two results based on equation (1) are of particular interest. First, the first order autocorrelation of T-period changes in z(t), that is,

$$(2)\ \rho(T) = \frac{\mathrm{cov}[z(t+T) - z(t), z(t) - z(t-T)]}{\sigma^2[z(t+T) - z(t)}$$

approaches -0.5 for large T. Second, the slope in the regression of r(t, t+T) on r(t-T, t), β(T), equals

$$(3)\ \beta(T) = \frac{\rho(T)\sigma^2[z(t+T) - z(t)]}{\sigma^2[z(t+T) - z(t)] + \sigma^2[q(t+T) - q(t)]}$$

The test centers on predictions about changes in the magnitude of β(T) as the return horizon, T, increases. Three cases can be considered, each reflecting the relative importance of q(t) and z(t) in the variance of p(t). Assume first that q(t) is nonexistent. In this case p(t) is stationary, and mean reversion pushes the slope, β(T), toward -0.5 as T increases. Recall from equation (3) that if no random walk component exists, β(T) = ρ(T) which approaches -0.5 as T becomes large. If p(t) is a pure random walk, β(T) will equal zero regardless of T because r(t+T, t) is white noise. Finally, assume that p(t) has both random walk and stationary components. The combined effect of both components might produce a U-shaped pattern in the estimated β(T) as T increases. When T is small, β(T) will be close to 0.0 because the stationary component is slowly decaying and resembles a random walk for short horizons. But as T grows, β(T) will become increasingly negative (approaching -0.5) as the mean-reverting component becomes increasingly dominant. β(T) ultimately will fall to 0.0 as the random walk component eventually dominates, the result of a growing variance that makes r(t+T, t) increasingly unpredictable.

A test for the presence of stationary components in p(t) can be based on the estimated pattern of the β(T)s for increasingly large T. If a stationary component exists, one expects to see negative values for β(T) that become significantly different from zero at some horizon. The estimates of β(T) also provide insight into the economic (as opposed to just statistical) importance of the stationary component. From equation (2) and equation (3), the ratio of the variance of [z(t+T) - z(t)] to the variance of r(t, t+T) equals 2β(T) when T

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[1] The text provides only an abbreviated description of the Fama/French model. Readers are directed to the original paper for a full explanation.

is large. That is, the estimated $\beta(T)$s can be used to measure the percent of total return variance due to the stationary component, $z(t)$.

THE DATA

The empirical analysis relies on the Morgan Stanley Capital International (MSCI) stock price indexes for 18 countries. Included stocks comprise a representative sample of large, medium, and small capitalization companies from each local market and are meant to replicate the industry composition of each market. The MSCI indexes attempt to include 60 percent of the total capitalization of each market. Stocks of nondomiciled companies and investment funds are excluded from the indexes, and companies with restricted float due to dominant shareholders or cross-ownership also are avoided. The MSCI indexes are calculated using Laspeyeres' concept of a weighted arithmetic average together with the concept of chain linking. The weights equal the number of shares outstanding. The data are monthly and cover the period 1969:12 to 1989:12. All of the indexes share an identical base, December 1969 = 100. The country indexes are compatible with one another because they are constructed using the same procedures.

Returns are computed as the log difference of a country's price index for the appropriate return horizon.[2] The returns are valued in local currencies and are annualized. Both nominal and real returns are studied. Consumer price data needed for the calculation of real returns are from the International Monetary Fund's *International Financial Statistics* (1985=100). Price data for Australia, Belgium, Hong Kong, and Singapore/Malaysia are unavailable.

THE EMPIRICAL RESULTS

$\beta(T)$ is estimated for each of the 18 markets using ordinary least squares for return horizons ranging from one month to four years.[3] For horizons greater than one month, returns are constructed using overlapping price data. Thus, the standard errors of the estimated $\beta(T)$s are adjusted for the sample autocorrelation of overlapping residuals using the method of Hansen and Hodrick (1980). The $\beta(T)$s are estimated using data for the period 1969:12 to 1989:12.

THE ESTIMATED β (T)S

The estimates for nominal and real returns are shown in Tables 1 and 2, respectively, and display similar patterns. Most of the price indexes studied have exhibited behavior during the past two decades inconsistent with mean reversion. With regard to nominal returns, only eight of 18 indexes have predominantly negative $\beta(T)$s across return horizons. Recall that mean reversion in prices implies a negative $\beta(T)$, as temporarily

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[2] Because interest lies in examining the time-series properties of prices, the dividend yield is excluded from the return calculation.

[3] Prior to estimation, Phillips-Perron unit root tests are performed on the log level and first difference of the log level of each index. The results show that log prices are integrated of order one, while first differences, which here constitute returns, are stationary.

Table 1—Estimated First Order Nominal Autocorrelations*

$$r(t, t+T) = \alpha(T) + \beta(T)r(t-T, t) + \varepsilon(t, t+T)$$

Country	3 month	6 month	1 year	2 year	3 year	4 year
U.S.	0.0308	-0.0757	-0.1626	-0.2007	0.2592	0.5739
	1.943	-2.238	-2.562	-1.725	1.136	1.639
Australia	0.2394	0.3507	0.0442	-0.1710	-0.1872	-0.4125
	7.896	5.802	0.714	-1.937	-1.545	-1.606
Austria	-0.0269	0.0075	-0.0461	-0.1457	-0.0153	-0.1136
	-2.437	0.341	-0.832	-1.206	-0.0583	-0.300
Belgium	-0.074	0.1911	0.1541	0.2905	0.4266	0.6549
	-3.807	0.524	1.944	1.943	1.581	1.427
Canada	0.0452	0.0611	-0.1542	-0.4010	-0.4844	-0.4787
	2.586	1.657	-2.188	-2.606	-1.843	-1.450
Denmark	0.3561	0.3643	-0.1937	-0.2021	-0.4298	-0.5837
	8.179	4.701	-2.090	-1.506	-1.748	-1.463
France	0.1198	0.0153	-0.1058	0.0214	0.0506	0.3024
	5.867	0.461	-1.455	0.169	0.203	0.744
Germany	0.0531	0.1007	-0.0591	-0.1624	-0.2604	-0.4046
	4.086	3.513	-1.143	-1.551	-1.120	-1.104
Hong Kong	-0.0468	-0.0087	-0.0696	-0.5107	-0.5311	-0.6382
	-2.929	-0.3032	-1.214	-3.494	-2.247	-1.676
Italy	0.1722	0.2965	0.0864	-0.0248	0.0088	0.1974
	7.963	5.677	1.328	-0.198	0.004	0.584
Japan	0.0407	0.0358	-0.0412	-0.1247	0.0453	0.3986
	1.070	0.483	-0.271	-0.502	0.096	0.445
Netherlands	-0.0128	-0.0833	0.0015	0.0514	0.0492	0.1019
	-0.903	-2.847	0.023	0.407	0.190	0.259
Norway	0.0682	0.1060	-0.1406	-0.3363	-0.3716	-0.1663
	3.977	3.344	-2.385	-2.819	-2.150	-0.738
Singapore/Malaysia	-0.0168	-0.0273	-0.1451	-0.3388	-0.4365	-0.6860
	-1.202	-0.979	-2.409	-3.515	-2.556	-2.488
Spain	0.0140	0.2723	0.3731	0.3786	0.2456	0.0715
	1.591	6.491	4.328	2.863	2.220	0.526
Sweden	0.1945	0.1378	-0.0027	0.1171	0.0867	-0.0741
	5.495	2.220	-0.024	0.557	0.236	-0.155
Switzerland	-0.0408	0.0677	-0.0387	-0.1993	-0.1364	0.0929
	-3.785	2.825	-0.946	-2.586	-0.854	0.274
UK	0.0500	-0.086	-0.2009	-0.2145	-0.1731	-0.0594
	2.535	-2.258	-2.552	-1.350	-0.687	-0.147

* The first row for each country contains the estimated β coefficients for selected return horizons. The associated t-statistic is located directly below each estimate

low returns. Only eight of 18 indexes reveal the U-shaped pattern of $\beta(T)$ consistent with prices that have both random walk and stationary components. The countries are Australia, Canada, Denmark, Germany, Hong Kong, Norway, Singapore/Malaysia, and the United States. U.S. prices show mean reversion tendencies in the six month to two year return horizons. Fama and French (1988), by contrast, find no significant stationary component for either the equal-weighted or value-weighted NYSE market portfolio from 1941 to 1985. (Their findings for market portfolios, as opposed to their results for industry and decile portfolios, are most comparable to the present results.) The estimated $\beta(T)$s are sometimes positive in both short-horizon and long-horizon returns, although they are often close to zero. Significant positive $\beta(T)$s generally occur at short horizons.

Table 2—Estimated First Order Real Autocorrelation*

$$\text{Real } r(t, t+T) = \alpha(T) + \beta(T) \text{ real } r(t-T, t) + \varepsilon(t, t+T)$$

Country	3 month	6 month	1 year	2 year	3 year	4 year
U.S.	0.0716	-0.0028	-0.0532	-0.0746	0.3273	0.7111
	10.278	-1.732	-2.737	-1.565	3.418	3.138
Australia	0.2657	0.3978	0.0894	-0.0682	-0.0976	-0.2343
	9.913	6.921	4.331	-2.268	-2.078	-3.614
Canada	0.0773	0.0877	-0.1103	-0.3905	-0.4856	-0.4730
	10.544	7.117	-4.835	-3.528	-3.246	-3.143
Denmark	0.3508	0.3682	-0.1997	-0.1882	-0.3076	-0.3777
	9.874	6.109	-4.389	-3.626	-2.866	-2.415
France	0.1511	0.0707	-0.0404	0.0926	0.1032	0.3851
	10.188	7.000	-4.445	3.313	1.904	1.954
Germany	0.0637	0.1380	-0.0071	-0.0553	-0.1481	-0.2537
	9.720	7.068	-0.6308	-2.434	-1.454	-1.298
Italy	0.1786	0.3149	0.1007	0.0458	0.0383	0.2774
	9.395	6.663	3.938	1.553	2.887	2.054
Japan	0.0979	0.1727	0.0820	0.0298	0.2587	0.7370
	4.121	3.544	0.951	0.254	0.974	1.416
Netherlands	0.0043	-0.0114	0.1011	0.2246	0.2390	0.3126
	2.300	-2.971	4.167	3.243	1.752	1.370
Norway	0.0984	0.1344	-0.1188	-0.3430	-0.3885	-0.1556
	9.643	7.093	-4.923	-3.630	-3.002	-2.888
Spain	0.0953	0.3660	0.4658	0.4611	0.3088	0.0930
	5.006	6.164	4.034	2.210	1.271	0.390
Sweden	0.2104	0.1679	0.0143	0.1349	0.1620	0.0086
	8.800	4.799	0.299	1.514	0.944	0.036
Switzerland	-0.0152	0.1196	0.0408	-0.1158	-0.1165	0.0444
	-7.935	7.632	3.934	-2.430	-2.367	0.340
UK	0.0431	-0.0072	-0.0670	-0.0318	0.0325	0.2130
	10.186	-6.058	-4.998	-1.679	0.517	1.320

* The first row for each country contains the estimated β coefficients for selected return horizons. The associated t-statistic is located directly below each estimate

The results based on inflation-adjusted returns provide similar evidence on mean reversion. The U-shaped pattern arises in five (Australia, Canada, Denmark, Germany, and Norway) of the 14 country indexes studied (consumer price data are unavailable for four of the original 18). U.S. prices again exhibit mean reversion over the six month to two year horizons, but the estimated $\beta(T)$s become positive and significant at longer horizons. Overall, both nominal and real data indicate that mean reversion in stock prices occurs, but not universally.

The average nominal slope coefficients for the eight countries exhibiting the U-shaped pattern are -0.25 for two year returns, -0.39 for three year returns, and -0.48 for four year returns. This implies that between 50 percent and 96 percent of the variance of long-horizon returns in these eight countries is due to the stationary price component of $z(t)$. The average real slope coefficients (in the five relevant countries) for the two year, three year, and four year returns are -0.21, -0.29, and -0.30, respectively. This indicates that between 40 percent and 60 percent of the variance of long-horizon returns is due to the stationary component of $z(t)$. Thus, in country indexes where a stationary component is statistically significant, this component also is economically significant.

NEGATIVE AUTOCORRELATION: COMMON OR COUNTRY-SPECIFIC FACTORS?

Does the negative autocorrelation for the eight country indexes that exhibit mean reversion come from common or country-specific factors? As Fama and French (1988) point out, evidence of common factors would support the use of parsimonious equilibrium pricing models, while country-specific autocorrelation suggests possible idiosyncratic components in returns. Evidence that a single country index explains the negative autocorrelation of other countries' indexes would indicate that apparent mean reversion arises from a common source. To provide such evidence, the returns for countries revealing mean reversion are regressed on the returns for Norway. The residual autocorrelations are observed. If a common factor is at work, then negative autocorrelation should be largely absent from the residuals. Norway is chosen as the explanatory index because it behaves most consistently with the U-shaped pattern predicted by the Fama/French model.[4]

For each country, residual autocorrelations of up to 36 months are estimated for five nominal return horizons (one month, one year, two years, three years, and four years). The results are mixed. Negative autocorrelation at longer horizons where mean reversion is most apparent is virtually nonexistent in the residuals for three countries—the United States, Canada, and Australia. That is, the number of estimated negative and statistically significant autocorrelations is close to zero (0/36 to 3/36).[5] A common factor thus appears to underlie mean reversion in these countries. This implies that the stationary, mean-reverting components of the three indexes arise from the same fundamental shocks. For the remaining four countries—Singapore/Malaysia, Hong Kong, Germany, and Denmark—a significant amount of negative autocorrelation remains in the regression residuals, indicating an absence of a common factor (between 7/36 and 17/36 autocorrelations are significantly negative). Analysis of real returns leads to the same conclusions. (Recall that real returns for Hong Kong and Singapore/Malaysia are not available.)

CONCLUSIONS

A growing literature has revealed that stock prices are predictable to some extent. This paper examines whether 18 country stock price indexes mean revert using regression-based tests developed by Fama and French (1988). The results indicate that indexes in a majority of the countries are not stationary. For the indexes that do mean revert, stationary components account for an economically significant part of the total return variance. The mean reversion that does occur arises both from common and country-specific factors.

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[4] Alternative countries, including the United States, were used as the base. These results are similar to those obtained when Norway is used as the base country.

[5] A normal approximation was used to test formally whether the observed proportion of the 36 autocorrelations that are significantly negative is significantly different from zero. The 95 percent confidence region for the observed proportion, p, is:

$$p \pm 1.96*(p*(1-p)/36)^{.5}.$$

The standard error of the autocorrelations is $N^{-.5}$, where N is the number of observations (Pindyck and Rubinfeld, 1991).

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