E C O N O M I C S   B U L L E T I N

Mean Reversion in Stock Prices: New Evidence from Panel Unit Root Tests for Seventeen European Countries

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Abstract

There is a large and growing literature that investigates evidence for mean reversion in stock prices. Empirically, there is no consensus as to whether stock prices are mean reverting or random walk processes; at best, the results are mixed. In this paper, we provide further evidence on the mean reversion hypothesis for seventeen European countries using the Levin and Lin (1992), seemingly unrelated regression and the multivariate augmented Dickey-Fuller panel unit root tests. Our main finding is that stock prices of all seventeen European countries are characterised by a unit root, consistent with the efficient market hypothesis.

I would like to thank David Rapach for making available the GAUSS codes for the panel unit root tests used in this paper. The codes were modified to conduct the empirical analysis in this paper.
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1. Introduction

Stock market efficiency implies that prices respond quickly and accurately to relevant information. An efficient stock exchange is characterized by a random walk process, which is a clue that returns of a stock market are unpredictable from previous price changes (see Osborne, 1959). Hence, testing for mean reversion is one avenue for examining market efficiency. Test for mean reversion also allows one to gauge whether shocks to stock prices have a permanent or a transitory effect. For instance, if it is established that stock prices are mean reverting, i.e. they are stationary processes, then this implies that shocks to stock prices will have a transitory effect, in that prices will return to their trend path over time. From an investment point of view, this ensures that one can forecast future movements in stock prices based on past behavior and trading strategies can be developed so as to earn abnormal returns. However, if it is found that stock prices are nonstationary then shocks will have a permanent effect, implying that stock prices will attain a new equilibrium and future returns cannot be predicted based on historical movements in stock prices.

There is no consensus view on whether or not stock prices are mean reverting. For instance, Chaudhuri and Wu (2003) examine stock prices for seventeen emerging countries and find mean reversion for eleven countries, and unit root in the remaining six countries. Kawakatsu and Morey (1999) examine stock prices for thirty-one emerging stock markets and find no evidence of mean reversion. Urrutia (1995) examines stock prices for Argentina, Brazil, Chile and Mexico and find evidence of mean reversion, while Choudhry (1997) finds that stock prices for Argentina, Bolivia, Chile, Colombia, Mexico, Venezuela and US were characterized by a unit root. In a recent study, Grieb and Reyes (1999) find strong evidence of mean reversion in stock prices for Brazil and Mexico. Moreover, Huber (1997) and Liu *et al*. (1997) find no evidence of mean reversion in Vienna's stock prices and China's stock prices, respectively.

It is clear from the above-mentioned studies that the results on mean reversion are mixed. Contrary to a large group of studies using univariate unit root tests to examine mean reversion in stock prices there are only a few studies that use panel unit root test approaches. For instance, Zhu (1998) applied the Levin and Lin (1992) panel unit root test to a panel of G7 countries and finds no evidence of mean reversion in stock prices. Balvers *et al*. (2000) investigated mean reversion in stock prices for eighteen industrialized countries using the SUR panel unit root approach. They find stock prices to be mean reverting. Recently, Chaudhuri and Wu (2004) use the SUR test and find mean reversion for seventeen emerging markets' stock prices, a result consistent with Balvers *et al*. (2000) but contrary to Zhu (1998).

This paper contributes to the literature by examining mean reversion in stock prices for seventeen European countries by employing panel unit root testing approaches on monthly data over the period 1988:1 to 2003:03. The objectives of this paper are achieved in three steps. In the first step, we explain the panel unit root tests. Here, we use three different panel unit root tests, namely the Levin and Lin (LL, 1992) test, the seemingly unrelated regression (SUR) test and the multivariate augmented Dickey Fuller (MADF) test advocated by Taylor and Sarno (1998). Given that the literature has not achieved a consensus on whether or not stock prices are characterized by a unit root, our use of more than one panel unit root test statistic is crucial, for it will allow one to gauge the robustness of the results. As a contribution to the literature, it should be noted that such a comprehensive treatment of mean reversion in stock prices, within a panel setting, has not been undertaken previously. In the third step, we discuss the empirical results. In the final step we provide some concluding comments.

2. Methodology

2.1. Levin and Lin test

For a sample of N groups observed over T time periods, the LL panel unit root regression of the conventional ADF test is of the following form:

$$\Delta SP_{i,t} = \alpha_i + \pi_i t + \beta_i SP_{i,t-1} + \sum_{j=1}^{k} \psi_{i,j} \Delta SP_{i,t-j} + \varepsilon_{i,t} \tag{1}$$

Here, SP denotes stock prices, Δ is the first difference operator, $\varepsilon_{i,t}$ is a white noise disturbance term with variance σ^2, $i = 1,2,...,N$ indexes countries and $t = 1,2,...,T$ indexes times. The $\Delta SP_{i,t-j}$ terms on the right hand side of Equation (1) allow for serial correlation, with the aim of achieving white noise disturbance term. The LL panel unit root test increases the power of the conventional ADF test by restricting β_i to be identical across-sectional units.

We estimate Equation (1) using ordinary least squares (OLS) under the null hypothesis by restricting β and π_i $(i = 1,...,N)$ to be equal to zero. Following Rapach (2002), we simulate a panel series of $T + 100$ observations for $\Delta SP_{it}(i = 1,...,N)$ by using the restricted OLS estimates of α_i and ψ_{ij} $(i = 1,...,N, \quad j = 1,...,k)$, random draws from a $N(0, \hat{\sigma}^2)$, where $\hat{\sigma}^2$ is the restricted OLS estimate of σ^2, and setting the initial $SP_{i,t-1}$ and $\Delta SP_{i,t-j}$ values equal to zero. An additional 100 observations are generated but discarded to avoid initial value bias. This process is generated 2000 times so as to achieve 2000 simulated panel series. We calculate and store the t_B statistics of the OLS panel test for each simulated panel and then order the simulated t_B statistics such that the 20th, 100th, and 200th, values are the 1 per cent, 5 per cent and 10 per cent critical values, respectively.

2.2. Seemingly unrelated regressions (SUR) estimator

A common problem with both the LL and IPS panel tests involves cross-sectional dependence. LL and IPS control for cross-sectional dependence by subtracting the cross-sectional means from both sides of Equation (1) prior to estimation, which removes the effect of a common time component (Rapach, 2002). However, O’Connell (1998) shows that this procedure will do little to reduce cross-sectional dependence and size distortions when the time component varies across countries. One way of handling cross-sectional dependence that may vary across countries is by estimating Equation (1) using the SUR estimator (Zellner, 1962), following the work of Abauf and Jorian (1990) and Jorian and Sweeney (1996). This is essential given that O’Connell (1998) finds that size distortions can be avoided with minimal loss of power by using the SUR estimator instead of the

OLS estimator. The SUR estimator is basically a multivariate generalized least squares, using an estimate of the contemporaneous variance-covariance matrix of the disturbances obtained using the OLS residuals from Equation (1). Following Rapach (2002), we estimate Equation (1) for the panel data using SUR and restricting β and π_i $(i=1,...,N)$ to be equal to zero. We generate 2000 simulated panel series of $T+100$ observations using the restricted SUR parameter estimates of α_i and ψ_{ij} $(i=1,...,N, \quad j=1,...,k)$, random draws from a $N\left(0,\hat{\Sigma}_{\varepsilon}\right)$, where $\hat{\Sigma}_{\varepsilon}$ is the restricted SUR estimate of the contemporaneous covariance matrix for the disturbances and initial $SP_{i,t-1}$ and $\Delta SP_{i,t-j}$ values set equal to zero. We drop the first 100 observations to yield simulated panel series of T observations. We calculate and store the t_B statistics of the SUR panel test for each simulated panel and then order the simulated t_B statistics such that the 20th, 100th, and 200th, values are the 1 per cent, 5 per cent and 10 per cent critical values, respectively.

2.3. A multivariate augmented Dickey-Fuller test

A limitation of the SUR panel test is that β is restricted to be identical across countries under the alternative hypothesis. Taylor and Sarno (1998) suggest a modified version of the SUR panel test, naming it multivariate augmented Dickey-Fuller (MADF) test, that allows for β to vary under the alternative hypothesis and controls for cross-sectional dependence. Equation (1) is estimated as a systems of N equations, taking account of contemporaneous correlations among the disturbances. The null hypothesis that each series has a unit root, $\beta_i = 0$ for all $i=1,...,N$ is tested against the alternative hypothesis that at least one series is stationary, $\beta_i < 0$ for some i, taking the Wald statistics as the MADF statistics. The Wald statistic does not have a chi-squared distribution with N degrees of freedom as a limiting distribution under the null hypothesis. Taylor and Sarno (1998) recommend using Monte Carlo simulations to calculate critical values. We calculate critical values, with appropriate modifications, following the methodology for the SUR case outlined above.

3. Empirical results

3.1. Data

The stock price indexes included in the study are USE WBI Index (Austria), BSE Belgium All Shares (Belgium), CSE All Shares Index (Denmark), HEX All Shares Index (Finland), Paris Stock Exchange SBF 250 (France) CDAX Share Price Index (Germany), ASE Composite (Greece), ISEQ Index (Ireland) ISB MIB Storico (Italy), CBS All Shares Index (Netherlands), OSE All Share Index (Norway) BVL General Share Price Index (Portugal), MSE General Index (Spain), AF GX Index (Sweden), SBC 100 Index (Switzerland) ISE National-100 (Turkey) and FT-SE-A non-financials (UK). We use monthly data for the period 1988:01 to 2003:03, culminating into 183 observations. The timeframe is dictated by data availability. All data were obtained from *OECD Main Economics Indicators*.

In Table 1, we report the three panel unit root test (LL, SUR and MADF) results. The results are presented for lag lengths ranging from 0 to 8 in order to gauge the robustness of the results. According to the LL test, for $k =$ 0, 1, 4, 8, we find the test statistics to be -3.787, -5.570, -5.749 and -6.4398, respectively, which are greater than the corresponding critical values at the 10 per cent level or better. According to the SUR test, for $k =$ 0, 1, 4, 8, we find the test statistics to be -6.877, -7.268, -6.822, -8.161, respectively, which are again greater than the corresponding critical values at the 10 per cent level or better. In panel C of Table 1 we present the test results from the MADF. We find that for $k =$ 0, 1, 4, 8, the statistics are 88.14, 78.87, 77.54 and 91.70, respectively. These test statistics are all smaller than the corresponding critical values at the 10 per cent level or better. Taken together, these results fail to reject the unit root null hypothesis for the stock price series for the seventeen European countries in our sample, consistent with the efficient market hypothesis.

INSERT TABLE 1

4. Conclusions

An important area of research in the financial economics literature has centered on the issue of mean reversion in stock prices. Despite the plethora of studies dating back to the 1960s, the extant literature has not reached a consensus on whether or not stock prices follow a unit root process. This information is crucial for investors, for if stock prices can be characterized as a unit root process then it implies that shocks to prices have a permanent effect, in that stock prices will attain a new equilibrium and future returns cannot be predicted based on historical movements in stock prices. This also opens up the possibility that volatility in stock markets will increase in the long run without bound. On the other hand, if stock prices are mean reverting then shocks to prices will have a temporary effect, ensuring that one can forecast future movements in stock prices based on past behavior and trading strategies can be developed so as to earn abnormal returns.

This paper considers mean reversion in seventeen European countries' stock price indices by employing panel unit root testing approaches on monthly data over the period 1988:1 to 2003:03. We use three different panel unit root tests, namely the LL test, the SUR test and the MADF test. All tests indicate that stock prices for the seventeen European countries are characterized by a unit root, consistent with the efficient market hypothesis.

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Table 1: Panel unit root test results

Panel A: LL test						
				t_B Critical values		
	k	T	t_B	1 per cent	5 per cent	10 per cent
$N=17$	0	182	-3.787	-9.959	-9.367	-9.067
	1	181	-5.570	-9.786	-9.271	-8.979
	4	178	-5.749	-9.776	-9.208	-8.918
	8	174	-6.440	-9.602	-9.142	-8.821
Panel B: SUR test						
				t_B Critical values		
	k	T	t_B	1 per cent	5 per cent	10 per cent
$N=17$	0	182	-6.877	-10.400	-9.780	-9.481
	1	181	-7.268	-10.340	-9.772	-9.486
	4	178	-6.822	-10.390	-9.681	-9.352
	8	174	-8.161	-10.050	-9.509	-9.212
Panel C: MADF test						
				t_B Critical values		
	k	T	t_B	1 per cent	5 per cent	10 per cent
$N=17$	0	182	88.14	140.2	128.4	122.6
	1	181	78.87	139.8	128.5	122.3
	4	178	77.54	139.6	127.6	121.3
	8	174	91.70	137.6	126.1	119.6