An Empirical Investigation of the Stability of the Risk Measures of Latin-American Common Stocks Through Their Underlying Return-Generating Processes

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A recent empirical study (Prakash, Moncarz, and deBoyrie, 2002) found that neither the rates of return probability distribution of the market index nor the individual stocks traded in the Latin American capital markets conform to the Gaussian (standard univariate normal) distributions. Hence, the pricing of assets in these markets may be better modeled through the Kraus and Litzenberger (1976) three-moment capital asset pricing model (CAPM) than through Sharpe's two-moment CAPM. If that is the case, the underlying return generating process will be the quadratic characteristic line model for the three-moment CAPM rather than the linear characteristic line model of the two-moment CAPM. This paper examines the stability of the parameters of these two alternative characteristic line models (which proxy for measures of market risk) over three non-overlapping regimes during the period examined. The study finds that, in general, these parameters are stable for individual stocks over our chosen sample period.

Introduction

This paper tests the stability of the parameters of the linear characteristic line (market) model of Sharpe (1964) and the quadratic characteristic line model of

0747–5535/99/1300/0049/$2.00

Kraus and Litzenberger (1976).[1] In the ex-post form the linear characteristic line (market) model is defined as:

$$\tilde{R}_{it} = \alpha_i + \beta_i \tilde{R}_{mt} + \tilde{\varepsilon}_{it}; \quad t = 1, ..., T \tag{1}$$

where $\tilde{e}_{it}$ is the random error term for the i^{th} security or the residual portion of R_{it} that is explained by the regression of the i^{th} stock during the t^{th} time period.[2] The parameters in this model represent the intercept, α_i, and the relative systematic risk of the firm, β_i. The symbols $\tilde{R}_{it}$ and $\tilde{R}_{mt}$ represent the rates of returns on security i and market m during time period t.[3,4]

In the Sharpe (1964) model, the rate of return for any security is assumed to be linearly related to exactly one stochastic factor measured by global economic activity. This factor is thought to be the most important single influence on returns of securities.[5]

The market model facilitates partitioning risk into various components. In finance, the workable measure of total risk is taken as the variance of returns on the i^{th} asset, σ_i^2. Sharpe (1964) first suggested that the total variation of a portfolio return may be segregated into two parts: (1) systematic variation, resulting from covariation of the returns of the individual securities with the market return; and (2) unsystematic variation, that portion of variation not attributable to the variation of the market return. The market model can be used to partition these components (Francis, 1980, p. 363; Ben-Horim and Levy, 1980; Fama, 1976, p. 70; Prakash *et al.*, 1999) as:

$$\mathrm{var}(\tilde{R}_{it}) = \mathrm{var}(\alpha_i + \beta_i \tilde{R}_{mt} + \tilde{\varepsilon}_{it})$$

or

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[1]The idea of this paper came from Prakash, Parhizgari, and Perritt's (1989) paper that examines similar hypotheses on the effect of listings from the over-the-counter market to the NYSE.

[2] Because one of the authors of this paper is also the lead co-author of the book *The Return Generating Models in Global Finance* (1999) published by Pergamon, an imprint of Elseiver Science, a few descriptions and explanations may be close excerpts from the book.

[3] For an excellent description of market model including its ex-ante and ex-ante/ex-post description, see Prakash *et al.* (1999) pp. 20-21. The stochastic error term follows the wide sense stationarity assumption of

$$E(\tilde{\varepsilon}_{it}) = 0 \text{ (zero mean)}, \; V(\tilde{\varepsilon}_{it}) = \sigma_\varepsilon^2 \text{ (homoskedastic)}, \; \mathrm{Cov}(\tilde{\varepsilon}_{it}, \tilde{\varepsilon}_{i,t+k}) = 0$$

for all $k \neq 0$ and error free observations on the market, i.e.,

$$\mathrm{Cov}(\tilde{\varepsilon}_{it}, \tilde{R}_{mt}) = 0 .$$

[4] The symbol '~' on top of the variable denotes that it is a random variable.

[5]Generally, in the U.S. market, *global economic activity* is proxied by the rate of return on a market index, e.g., CRSP composite market index or NYSE stock index. In the non-U.S. context, there is no unanimity as to what is the best proxy to measure global economic activity. The selection of each individual market index as reported in DataStream is our most favorable choice. Ideally, as Roll (1977) observes, the index to proxy global economic activity should encompass all assets in the world. But, of course, this is impossible.

$$\sigma_i^2 = \beta_i^2 \sigma_m^2 + \sigma_{\varepsilon i}^2$$

Thus, the systematic risk measure is $\beta_i^2 \sigma_m^2$ and the unsystematic risk is $\sigma_{\varepsilon i}^2$. Strictly speaking, β_i by itself is not a measure of systematic risk; rather, it is a measure of the relative sensitivity of an asset's rate of return to the market's rate of return (Boquist, Racette, and Schlarbaum, 1978).

The underlying return-generating process for the Kraus and Litzenberger (1976) three-moment CAPM is given by:

$$\tilde{R}_i - R_f = C_{0i} + C_{1i}(\tilde{R}_m - R_f) + C_{2i}(\tilde{R}_m - \overline{R}_m)^2 + \tilde{\varepsilon}_i \qquad (2)$$

The regression parameters C_{1i} and C_{2i} are related to β_i, the measure of relative systematic risk and γ_i, the measures of relative positive skewness risk by:

$$\beta_i = C_{1i} + C_{2i}\left[\frac{\mu_{3m}}{\sigma_m^2}\right]$$

and

$$\gamma_i = C_{1i} + C_{2i}\left[\frac{\mu_{4m} - (\sigma_m^2)^2}{\mu_{3m}}\right]$$

where μ_{jm} is the j^{th} central moment of the market rates of return probability distribution.[6]

In estimating a_i and ß$_i$ of equation (1) and C_{0i}, C_{1i}, and C_{2i} of equation (2), it is typically assumed that the underlying parameters remain constant over the estimation period.

Why the Test for Stability[7]

The measure of relative systematic risk, i.e., ß of a security, historically has been the most important tool for investment management (including portfolio revision) among both academicians and practitioners. All the important investment services (e.g., Moody's, Value Line Survey, Netscape's Thomson Investment Network, e-trade, etc.) provide the measure of beta for the underlying stock in their stock profile quotes report. Furthermore, similar to all the decision-making models in finance, the real beta should be an ex-ante measure rather than a measure limited to only ex-post data. Ex-ante measures of the beta usually are proxied with historically computed betas typically based on five years of monthly or weekly (ex-post) rates of return. The basic assumption is that the past will proxy the future. Financial

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$$\mu_{Im} = E\,[R_m - E(R_m)]^I$$

7 In this paper we test only the stability, i.e.,

$$E(\hat{\alpha}_{it}) = E(\hat{\alpha}_i)\ \forall\ t$$

rather than stationarity which implies that the probability distribution

$$f(\hat{\alpha}_{it}) = f(\hat{\alpha}_i)\ \forall\ t$$

where t is the number of non-overlapping periods.

pricing is a dynamic rather than a static process, however. A severe shock to the system may (or may not) change historical relationships. If it does, betas might change—estimates of betas without accounting for these shocks will be suspect for decision-making purposes. In the context of Latin American markets, some recent shocks, e.g., severe currency fluctuations (depreciation of currency, mainly in Brazil) and the Asian crisis may have changed the parameters of the linear as well as the quadratic characteristic line models.

Earlier Studies of Test for Stability

There have been numerous studies that have tested the stationarity of the coefficients of the market model using a variety of tests. For example, Blume (1971), uses the mean reversal technique; Brown *et al*. (1975), Bey (1983), and Lee (1985) use the cumulative sum of squares techniques, time trending regressions and moving regression, Cochran's Q and McNamara's tests; QLR (Quandt's log likelihood ratio) method tests for the stationarity of beta (see footnote 7). This study tests only the *stability* (as opposed to stationarity) of the characteristic line parameters on the lines of Furst (1970), Reints and Vandenberg (1975), Ying, Lewellen, Schlarbaum, and Lease (1977), Sanger and McConnell (1986), Dhaliwal (1983) etc. who test the effect of listings (i.e., moving from the OTC market to the New York Stock Exchange) on the parameters of the market model. To our knowledge only Prakash, Parhizgari, and Perritt (1989) test for the stability of the parameters of linear as well as the quadratic characteristic line models. Thus, the tests and methodology used in this paper are essentially the same as delineated in Prakash, Parhizgari, and Perritt.

Data and Selection of Cutoff Points

Weekly prices in local currency for Argentina, Brazil, Chile, and Mexico[8] are obtained from the DataStream database. Weekly data are collected from January 2, 1997 to December 31, 1999 for each of the stocks at the end of the Thursday trading day. Because DataStream is an online database provider, we obtain the names of the companies from the Spanish edition of the *Wall Street Journal*. Only eight companies, respectively, from Argentina and Mexico, seven companies from Chile, and five companies from Brazil have weekly data available without any break. Therefore, our sample consists of 156 observations on each of the 28 stocks from the four above-mentioned countries.[9]

[8]We tried to collect the data for stocks traded in the Venezuelan and Peruvian capital markets but due to unavailability of continuous weekly data for at least three years for any stock, we had to drop these two countries from our sample.
[9]A list of selected stocks in our study is provided in Appendix A.

To proxy for the market we use the local stock market indexes. For Argentina, Brazil, Chile and Mexico, respectively, we use Merval, Bovespa, IPSA Selective, and IPC.[10]

Unlike the U.S., it is difficult to obtain estimates of the risk-free rate for Latin American countries. Practitioners use either the 90-day U.S. Treasury bill rate to proxy for the risk-free rate based on the assumption that Latin American corporations can freely borrow/lend in the U.S. or LIBOR (London Interbank Offer Rates). In this paper we use the 90-day LIBOR rate to proxy the risk-free rate. This data also are obtained from DataStream database.

Two major events during our sample period had a significant effect on the capital markets of the Latin American countries. A news item in the *Wall Street Journal* on 8/21/98 of "Fears of Devaluation Shake up Latin America" shook the Latin American capital markets. This fear depressed the Venezuelan stock market 9.5 percent in one day. Similarly, the Brazilian market plunged 7.2 percent. Similar downward shifts also are noted on the other Latin American capital markets. Another news item in the same newspaper on10/31/97 that "Latin Markets Get Drawn into Asian Downdrift" was judged to have profound effect on the Latin American capital markets. Based on intuitive appeal of these news items, we select these dates as our breakpoints.[11]

Hypotheses to be Tested[12]

We select the two events described above as our breakpoints. Thus, there are three non-overlapping periods. Denoting the parameters of equations (1) and (2) by preceding superscripts 1, 2, and 3 pertaining to the time periods delineated by the two shock breakpoints, respectively, the following null hypotheses associated with the two models will be statistically tested.

For the linear characteristic line model:

$$H_{o1}: ({}^1\alpha_i, {}^1\beta_i)' = ({}^2\alpha_i, {}^2\beta_i)' = ({}^3\alpha_i, {}^3\beta_i)'$$

$$H_{o2}: {}^1\alpha_i = {}^2\alpha_i = {}^3\alpha_i$$

$$H_{o3}: {}^1\beta_i = {}^2\beta_i = {}^3\beta_i .$$

For the quadratic characteristic lines model:

$$H_{o4}: ({}^1C_{0j}, {}^1C_{1j}, {}^1C_{2j})' = ({}^2C_{0j}, {}^2C_{1j}, {}^2C_{2j})' = ({}^3C_{0j}, {}^3C_{1j}, {}^3C_{2j})'$$

$$H_{o5}: {}^1C_{0j} = {}^2C_{0j} = {}^3C_{0j}$$

$$H_{o6}: {}^1C_{1j} = {}^2C_{1j} = {}^3C_{1j}$$

[10]All these indexes are selected because of their inclusion in the *Wall Street Journal*.

[11] Admittedly, this is our own perception that resulted in the selection of these dates as breakpoints. Other researchers may disagree with these assertions.

[12]This section draws heavily on the Prakash, Parhizgari, and Perritt paper.

$$H_{o7}: \ {}^{1}C_{3j} = {}^{2}C_{3j} = {}^{3}C_{3j}.$$

Hypotheses H_{01} and H_{04} pertain to the equality of vectors of regression coefficients respectively in the two models. The symbol ’ denotes the transpose of this vector.

Hypothesis H_{03} tests the equality of systematic risk over the three non-overlapping regimes. H_{02} tests the equality of the alphas, the proxy for the constant return. Hypotheses H_{05}, H_{06}, and H_{07} test the equality of the coefficients of the quadratic characteristic lines model.

Hypotheses H_{02}, H_{03}, H_{05}, H_{06}, and H_{07} can be tested using a Studentized range test, provided the underlying probability distribution of the stochastic error term is Gaussian (normal). To explore this possibility, we test for the normality of the underlying probability distribution of the error terms for the two return-generating processes using the Jarque-Bera (1980) Lagrange multiplier (LM) test. This test computes the statistic

$$LM = N\left[\frac{\gamma_1^2}{6} + \frac{\gamma_2^2}{24}\right]$$

where ?$_1$ and ?$_2$ are coefficient of residual’s skewness and excess kurtosis defined as

$$\gamma_1 = \frac{\text{Third central moment}}{(\text{Second central moment})^{3/2}} = \frac{\mu_3}{\mu_2^{(3/2)}}$$

$$\gamma_2 = \frac{\text{Fourth central moment}}{(\text{Second central moment})^{2}} - 3 = \frac{\mu_4}{\mu_2^2} - 3$$

Under the null hypothesis that the stochastic error terms are normally distributed, the LM statistic will have a chi-squared distribution with two degrees of freedom. An obtained LM value greater than 5.99 (9.21) will imply that there is no evidence to support the null hypothesis of normality at the five percent (one percent) level of significance. We find the Jarque-Bera statis tics to be significant in 22 and 20 (of 28) cases, respectively, for the linear characteristic line and quadratic characteristic lines models. Therefore, instead of utilizing a Studentized range test we use the asymptotic James test (James, 1952). This is an asymptotic test and suited best for larger sample sizes (i.e., greater than 30). We use the James test to test the hypotheses, H_{02}, H_{03}, H_{05}, H_{06}, and H_{07}.

Briefly, the J-test requires the computation of the statistic:

$$J = \sum_{t=1}^{T} \frac{(b_{it} - b_i^*)^2}{S_{it}^2} \tag{3}$$

where b_{it}s are the estimated regression coefficients of concern (e.g., a_i or C_{oi} , etc.) from the separate non-overlapping regimes t = 1, 2, ... , T, and S_{it} is the standard error of b_{it} and:

$$b_i^* = \frac{\sum_{t=1}^{T} b_{it} / S_{it}^2}{\sum_{t=1}^{T} \frac{1}{S_{it}^2}} .$$

If the null hypothesis of no difference between b_{it} for t = 1, 2, … , T is true, the statistic J will be distributed as a chi-squared variate with T - 1 degrees of freedom. If the obtained J exceeds the theoretical ?² value at T - 1 degrees of freedom, it can be concluded that the regression coefficients are significantly different. For the null-hypotheses H_{01} and H_{04} we use the standard Chow test.

Empirical Findings

Table 1: An Illustrated Example

Using the ordinary least squares (OLS) procedure, the parameters of the two regression models are estimated. A typical output for a particular stock (stock number 1 from Argentina in our sample) is given in Table 1. Columns 2 and 3 give the estimates of alpha and beta of the linear-market model during the three non-overlapping periods. The figures below the estimated alphas and betas are the standard errors of the estimates. Columns 4 and 5 are the adjusted R^2 and values of the Jarque-Bera statistics, respectively. Similarly, columns 6, 7, 8, 9, and 10 provide the estimates of C_0, C_1, and C_2, of the quadratic characteristic lines model and the model's attendant adjusted R^2 and the values of Jarque-Bera statistics. The next to last row of Table 2 provides the values of James statistics as calculated using equation (3). The last row is the value of the Chow statistic pertaining to the null hypotheses H_{01} and H_{04}.

For each of the stocks we compute the values reported in Table 1. For each of the 28 stocks in our sample we estimate the parameters of each of the two return-generating processes using the OLS for each of the three non-overlapping periods and one, overall. There are a total of 224 regression equations whose parameters are estimated.

Fit of the Model

Table 2 reports the number of adjusted R^2's greater than 0.25 for the stocks of the four countries in each of three non-overlapping periods as well as overall. An adjusted R^2 of 0.25 and above and a small value of standard error of estimates provide evidence of an *absence* of substantial uncertainty (Fama, 1976) in the estimates of the parameters.

We find overwhelming evidence against the presence of substantial uncertainty. In general, the tenets of a good fit in linear regression are:

- The constant term is statistically not significant,
- The estimates of regression parameters are statistically significant, and

- The adjusted R^2 is substantially higher and statistically significant.[13]

The following table summarizes the empirical findings pertaining to a good fit (Table 2 in the appendix).

Summary of Fitness from Table 2

	Number of Significant Values of at Least 10% Level of Significance			
Estimates of	Argentina	Brazil	Chile	Mexico
a	2/32 (6.25%)	0/20 (0%)	6/28 (21.43%)	5/32 (15.62%)
ß	27/32 (84.38%)	17/20 (85%)	19/28 (67.86%)	32/32 (100%)
C_0	2/32 (6.25%)	3/20 (15%)	8/28 (28.57%)	6/32 (18.75%)
C_1	27/32 (84.38%)	18/20 (90%)	15/28 (53.57%)	32/32 (100%)
C_2	2/32 (6.25%)	7/20 (35%)	5/28 (17.86%)	14/32 (43.75%)

Table 2 shows that the estimates of ß in the linear characteristic line and the estimates of C_1 in the quadratic characteristic line models are significant for the majority of the stocks in each of the countries. The best performers, in order, are Mexico, Argentina, Brazil, and Chile. Mexico is the best performer in the sense that in all 32 cases the estimates of beta and C_1 are statistically significant at least at the ten percent level of significance. The next estimate that shows a higher statistically significant result is the estimate of C_2 in equation (2). High percentages of the estimates for alpha and C_0 (the constant terms) in models (1) and (2) are statistically not significant. Furthermore, 71 of 112 (63 percent) adjusted R^2 have values higher than 0.25. The table above shows that the most promising results are obtained from Argentina and Mexico, followed by Brazil and then Chile.

Table 2 and its summary reveal that Fama's uncertainty measure in estimates of the parameters is substantially less than what one would have thought about the stocks in the Latin American capital markets. The prevalent opinion in the U.S. about Latin American markets (or about any third world capital market) is that they are more volatile and unstable. The recent crash of the markets in the tiger countries provided further credence to this line of thinking. Our empirical results are just the opposite as far as the Latin American capital markets in our sample are concerned.

Tests of Stability

Table 3A reports the value of the Chow statistic of the null hypotheses H_{01} and H_{04}. In all cases, the Chow statistic is insignificant. This is a remarkable result. For

[13] See Fama (1976). The value of R^2 will vary from 0 to 1.00. The actual magnitude of the substantially higher R^2 will vary from task to task. In case of the market model, an adjusted R^2 of 25 percent (0.25) or higher is considered to be substantial.

significance, the degrees of freedom associated with the F-statistic in the case of the linear characteristic lines model is (4,150). Thus, an obtained F-value of greater than 2.37 will signify statistically significant evidence of structural change in the model parameters at the five percent level. Column 1 (marked with an L) for Argentina, Brazil, Chile, and Mexico shows that there has been only one structural change (Mexico's Vitro stock) as signified by the obtained Chow statistics values. Similarly, the degrees of freedom for the Chow statistic associated with the quadratic characteristic line models is (6,147). Hence, an obtained F-value greater than 2.10 is required to signal significance at the 5 percent level of significance. Again, if we look at column 2 of Table 3A (identified with a Q) we see only two values greater than 2.10 (Mexico's Maseca and Vitro stocks). Thus, in general we find no evidence against stability of the vector of parameters (hypothesis H_{04}) for the quadratic characteristic line model.

Obtained J-Statistics: A Summary

	Linear Model		Quadratic Model		
	a	ß	C_0	C_1	C_2
Argentina	0	0	1	0	0
Brazil	0	0	0	0	1
Chile	1	1	0	1	1
Mexico	1	1	2	1	0
Total	2	2	2	2	2

Stability of Individual Parameters

Table 3B presents the values of James statistics for each of the parameters for all the stocks pertaining to models 1 and 2. Referring to footnote 1 of Table 3B, we have the following numbers of significant J-statistics.

Of a total of 56 (28 each for alpha and beta) J-statistics computed for the market model, only four (seven percent) are significant beyond the five percent level. Similarly, for 84 J-statistics for the quadratic characteristic lines model only six (seven percent) are statistically significant at the five percent level. Because the evidence of statistical significance in individual parameters is small, it may be attributed to statistical anomaly. Hence, based on Chow and James tests, we conclude that for our sample of 28 stocks over our sample period, no evidence of instability is detected in the regression parameters of linear and quadratic characteristic line models for the common stock in the selected Latin American market.

Conclusion

Whether the return-generating process in the Latin American markets follows a linear or quadratic characteristic line process, this paper finds no evidence of instability in the parameters of either of these two models over our selected sample period. Admittedly, this kind of robustness was not expected, given the two shocks used to delineate the breakpoints that occurred in the Latin American markets during this time period. Indirectly, the results support the Barry and Rodriguez (1998) findings that during the December 1975 to June 1995 period the Latin American markets outperformed the S&P 500 index. This parametric stability and superior performance may be due to the fact that unlike the U.S., stocks are thinly traded in Latin American markets and heavily concentrated in a few large family-held securities. Even though the Latin American markets are considered to be among the riskiest capital markets in the world, the concentration of securities in few family holding groups may be a stabilizing factor. At this point in time we do not know. An interesting follow-up study would be to select a sample of stocks during the same time period from the developed (e.g., U.S.) market that have the same capitalization and investigate whether these (from the developed market) stocks exhibit the same characteristic as the Latin American markets.

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