*African Review of Economics and Finance | ISSN 2042-1478 | Volume 9 | Issue 1 | June 2017*

# On the stability of the CAPM before and after the financial crisis: Panel evidence from the Johannesburg Securities Exchange

[#] Paul Alagidede, [**]Nikolaos Koutounidis and [***]Theodore Panagiotidis

[#]University of the Witwatersrand, South Africa, paul.alagidede@wits.ac.za
[**]Erasmus School of Economics, Rotterdam, Netherlands, koutounidisn@gmail.com
[***]Department of Economics, University of Macedonia, Greece, tpanag@uom.gr

**Abstract**

This study examines the stability of the CAPM before and after the recent global financial crisis in the Johannesburg Securities Exchange (JSE). Firms' betas are derived from OLS and M-estimation regressions. Fixed and random effects are employed to estimate the linear and the nonlinear version of the CAPM. Evidence against a stable beta emerges after the crisis but not before. The latter holds for the non-linear paradigm as well.

**Keywords**: Panel data; CAPM; South Africa; Global financial crisis.

## 1. Introduction

Africa has been at the spotlight of investors given its potential for growth. The South African market is the most developed one in the continent (see Alagidede and Panagiotidis 2009). The literature on the Capital Asset Pricing Model (CAPM) for the South African Stock Market (JSE) is mixed and previous studies include van Rensburg and Slanley (1997), van Rensburg and Robertson (2003), Strugnell, Gilbert and Kruger (2011), Ward and Muller (2012) and Samouilhan (2007). Most of these approaches employ time series methods.

Barnes and Hughes (2001) used panel data to test the validity of the CAPM for the U.S. They argue in favour of CAPM within a panel framework and found that homogeneity restrictions on the time-variation component of multifactor betas and on the slope parameters for the conditioning variables cannot be rejected. Pandey (2001) incorporated a fixed effects panel data analysis to examine the effects of beta, among other company specific variables on expected stock returns in the Malaysian stock exchange. Beta played a significant role in the explanation of the expected stock returns. More recently Korkmaz, Yıldız and Gökbulut (2010) showed that CAPM is valid for the Turkish stock market.

In the light of emerging evidence of the reality of panel relative to time series tests of the CAPM, this letter examines the issue for a cross section of JSE stocks. To the best of our knowledge we are unaware of studies of this nature in the JSE. Additionally, properly estimating beta would have important implications for risk management. Lastly, the effect of the global financial crisis (2007) on the evolution of beta is paramount to understand whether or not the CAPM has been stable during our sample period.

## 2. Data description

Monthly index and stock price data of the top 40 JSE (Johannesburg Securities Exchange) companies (according to market cap) were obtained from DataStream for the period between January 2000 and December 2014 (180 months). Stock prices expressed in US Dollars were converted to monthly stock returns. Monthly returns of the market index are captured by the JSE – All Market Share Index, while the risk free rate is proxied by the 3 Month T-bill rate of South Africa.

The Top 40 index includes the 40 biggest companies of the JSE, ranked by market capitalization. This index is a fair reflection of the South African stock market as a whole. Even though it contains only 40 out of the roughly 400 stock listed, it represents over 80% of the total market cap of all JSE listed companies. Most of the companies that constitute the Top 40 index are associated with the financial products and services sector. The full list of the companies is available upon request.

## 3. Methodology

We consider Fama and MacBeth's two-step estimation procedure where in the first step a CAPM time series regression produces the $\beta$'s and in the second step:

$$R_{it} - R_{ft} = \lambda_0 + \lambda_m \beta_{Pi} + u_i \tag{1}$$

where $R_{it}$ - $R_{ft}$ denotes excess return of the stock *i* at time *t* (dependent variable), $\lambda_m$ the amount of the excess return change if beta (i.e. risk) increases by 1% and $\beta_{Pi}$ estimated beta of the stock (*P*).

If the CAPM is valid, then $\lambda_0$ is not expected to be significantly different from zero and $\lambda_m$ approximates the (time average) equity market risk premium $R_m$- $R_f$.

Fama and MacBeth (1973) estimated this second stage (cross-sectional) regression separately for each time period and then calculated the average of the parameter estimates in order to conduct hypotheses testing.

The present analysis utilizes a two-step procedure. Firstly, annual betas for each firm are estimated through the *Single Index Model* (*or Market Model*), which relates the return on each stock to the return on the market, assuming a linear relationship:

$$R_{it} = a_{it} + \beta_{it} R_{mt} + e_{it} \tag{2}$$

where $R_{it}$ denotes return of asset *i* at time *t* and $R_{mt}$ return of market at time *t*. The Single Index Model is estimated both with OLS and M-estimation (maximum likelihood type introduced in Huber 1973) methods. The latter has advantages in cases where outliers are present. Monthly returns are averaged for each year to acquire annual stock returns.

The second stage of the methodology is the estimation of the CAPM through panel data analysis. Unlike Fama and MacBeth (1973), we do not include portfolio formation and thus the model incorporates a regression of *average annual excess stock returns on annual stock betas*:

$$R_{it} - R_{ft} = \lambda_0 + \lambda_m \beta_{it} + u_{it} \tag{3}$$

On top of the estimation of beta within a linear CAPM, we also consider a non-linear CAPM (Harvey and Siddique, 2000), to examine if the systematic risk – as measured by the covariance with the market – explains more satisfactorily the cross-sectional variation in expected returns. To achieve this we add the conditional covariance of the return of asset *i* with the square of the market return. This stands for the conditional co-skewness in the model.

$$R_{it} = a_{it} + \beta_{it} R_{mt} + \gamma_{it} R_{mt}^2 + e_{it} \tag{4}$$

Therefore, the second step estimation for the non-linear CAPM is the following:

$$R_{it} - R_{ft} = \lambda_0 + \lambda_{m1} \beta_{it} + \lambda_{m2} \beta^2 + u_{it} \tag{5}$$

We need to augment the above equations to account for the panel structure. Equations (6) and (7) represent the fixed effects and the random effects of CAPM respectively.

$$R_{it} - R_{ft} = \lambda_0 + \lambda_m \beta_{it} + \mu_i + u_{it} \tag{6}$$

$$R_{it} - R_{ft} = \lambda_0 + \lambda_m \beta_{it} + \varepsilon_i + v_{it} \tag{7}$$

Additionally, equations (8) and (9) stand for the fixed and random effects of the non-linear CAPM:

$$R_{it} - R_{ft} = \lambda_0 + \lambda_{m1}\beta_{it} + \lambda_{m2}\beta^2 + \mu_i + u_{it} \tag{8}$$

$$R_{it} - R_{ft} = \lambda_0 + \lambda_{m1}\beta_{it} + \lambda_{m2}\beta^2 + \varepsilon_i + v_{it} \tag{9}$$

where $\varepsilon_i$ measures the random deviation of each entity's intercept term from the "global" intercept term $\lambda_0$. The Hausman (1978) test is employed to choose between the fixed and the random effects.

## 4. Empirical analysis

### *4.1. Descriptive statistics*

The descriptive statistics of the average stock returns as well as the beta series are presented in Table 1. Beta OLS (M) refer to the OLS (M) estimate of beta in equation 2.

TABLE 1: DESCRIPTIVE STATISTICS OF TIME SERIES

| **Descriptive Statistics** | **Average Returns** | **Beta OLS** | **Beta M** |
|---|---|---|---|
| Observations | 521 | 521 | 521 |
| Mean | 0.017 | 0.828 | 0.818 |
| Median | 0.011 | 0.821 | 0.810 |
| Maximum | 0.136 | 2.454 | 2.560 |
| Minimum | -0.108 | -0.677 | -0.910 |
| Std. Dev. | 0.041 | 0.402 | 0.431 |
| Skewness | 0.428 | 0.339 | 0.333 |
| Kurtosis | 3.258 | 3.940 | 4.442 |
| Jarque-Bera (JB) | 17.349 | 29.165 | 54.838 |
| JB *p*-value | 0.000171 | 0.000 | 0.000 |

The value of the average stock return is positive and equal to 1.7% and the estimated standard deviation 0.041. Skewness within JSE takes positive values and the kurtosis is greater than 3 (leptokurtic distribution). The mean beta values are close 0.82 (defensive on average). This fact reveals that the behavior of the investors within the JSE is – on average – defensive. Max beta is 2.4 and the min is negative.

## *4.2. Comparison of OLS betas with M-estimation betas*

Given the presence of outliers in our series, we estimate the betas of the stocks (1st step) using both OLS and robust M-estimation[1]. Figures 1 and 2 present the annual mean and standard deviations of betas from OLS and M. Estimated betas are lower under robust M-estimation but OLS provides lower standard deviations.

Figure 1: Annual mean and Standard Deviation of OLS Betas

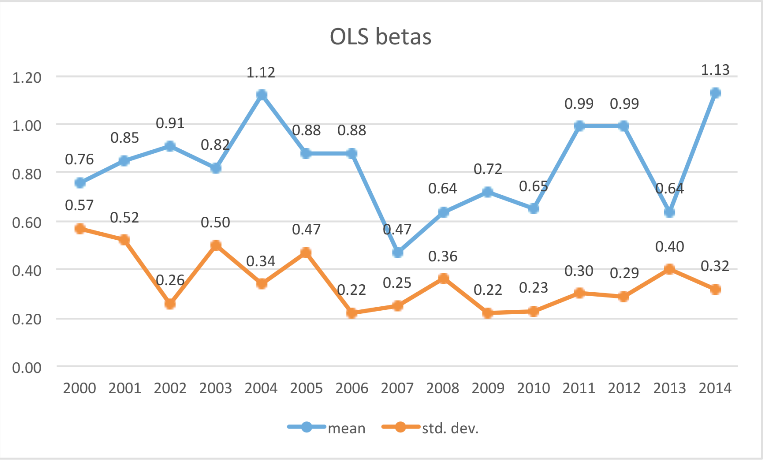
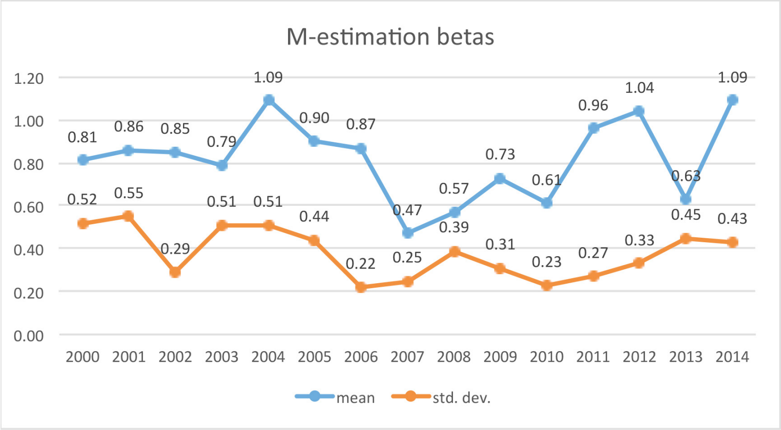



Figure 2: Annual mean and Standard Deviation of M-Estimation Betas




[1] We use the Bi-square function with a default tuning parameter value of 4.685 was used, that the scale was estimated using the median centered, median absolute deviation method, and that the z-statistics in the output are based on Huber Type I covariance estimates. This is a maximum likelihood estimator.

## *4.3. Panel data analysis*

Next we estimate equations 6 and 7 for (i) the whole sample, (ii) before the crisis and (iii) after (during) the crisis with pooled OLS, (time)-fixed effects (with and without year dummies)[2] and random effects. Table 2 (3) present the panel results from the OLS (M) betas. CAPM seems to hold before the global financial crisis (2007) but not afterwards. The constant term ($\lambda_0$) is insingificant for the period 2000-06 under both fixed and random effects but becomes singificant after. For the entire period it is significant. The estimate of $\lambda_m$ decreases and loses its significance after the crisis.

TABLE 2: SUMMARY STATISTICS OF CAPM - INDEPENDENT VARIABLE IS BETA (OLS)

| **Model** | $\lambda_0$ | $\lambda_m$ | **Akaike Info criterion** | **Schwarz criterion** | **Hannan-Quinn criterion** |
|---|---|---|---|---|---|
| Pooled OLS | 0.99%** | 0.82%* | -3.54 | -3.52 | -3.53 |
| Pooled OLS 2000-06 | 0.91%* | 1.29%** | -3.75 | -3.72 | -3.74 |
| Pooled OLS 2007-14 | 1.30%** | 0.03% | -3.39 | -3.37 | -3.38 |
| Fixed Effects | 0.96%** | 0.84%* | -3.43 | -3.14 | -3.32 |
| Fixed Effects 2000-06 | 0.89% | 1.32%** | -3.51 | -2.99 | -3.30 |
| Fixed Effects 2007-14 | 1.39%** | -0.08% | -3.19 | -2.72 | -3.00 |
| Time-Fixed Effects | 1.12%*** | 0.66%** | -4.94 | -4.53 | -4.78 |
| Time-Fixed Effects 2000-06 | 1.37%*** | 0.77%** | -4.83 | -4.22 | -4.58 |
| Time-Fixed Effects 2007-14 | 1.09%*** | 0.30% | -4.92 | -4.37 | -4.70 |
| Random Effects | 0.99%** | 0.82%* | - | - | - |
| Random Effects 2000-06 | 0.91% | 1.29%** | - | - | - |
| Random Effects 2007-14 | 1.30%** | 0.03% | - | - | - |

Note: The *p*-value of $\lambda_m$ for the 200-06 random effects is 10.23% (marginally not significant).

[2] A redundant fixed effects test is conducted in order to infer whether the fixed effects are necessary or not. Two different fixed effects tests are conducted, each in both x^2 and F-test versions: (i) restricting the cross-section-fixed effects to zero and (ii) restricting the period-fixed effects to zero. The test indicates that the null hypothesis can be rejected only for the time-fixed model, therefore cross section effects are redundant for the entity-fixed effects model.

Table 3: Summary Statistics of CAPM - Independent Variable is Beta (*M*-estimation)

| Model | $\lambda_0$ | $\lambda_m$ | Akaike Info criterion | Schwarz criterion | Hannan-Quinn criterion |
|---|---|---|---|---|---|
| Pooled OLS | 1.09%*** | 0.71%* | -3.54 | -3.52 | -3.53 |
| Pooled OLS 2000-06 | 1.24%** | 0.93%* | -3.74 | -3.71 | -3.73 |
| Pooled OLS 2007-14 | 1.13%** | 0.26% | -3.39 | -3.37 | -3.38 |
| Fixed Effects | 1.00%** | 0.81%* | -3.43 | -3.14 | -3.32 |
| Fixed Effects 2000-06 | 1.15%* | 1.03% | -3.50 | -2.98 | -3.29 |
| Fixed Effects 2007-14 | 1.07%* | 0.33% | -3.19 | -2.72 | -3.00 |
| Time-Fixed Effects | 1.26%*** | 0.50%** | -4.93 | -4.53 | -4.77 |
| Time-Fixed Effects 2000-06 | 1.38%*** | 0.77%** | -4.83 | -4.22 | -4.59 |
| Time-Fixed Effects 2007-14 | 1.31%*** | 0.01% | -4.92 | -4.36 | -4.70 |
| Random Effects | 1.09%*** | 0.71% | - | - | - |
| Random Effects 2000-06 | 1.24%** | 0.93% | - | - | - |
| Random Effects 2007-14 | 1.13%* | 0.26% | - | - | - |

Note: The *p*-value of $\lambda_m$ for the 200-06 random effects is 10.23% (marginally not significant).

Table 4: Summary Statistics of Non-linear CAPM – Independent Variable is Beta (OLS)

| Model | $\lambda_0$ | $\lambda_{m1}$ | $\lambda_{m2}$ | Akaike Info criterion | Schwarz criterion | Hannan-Quinn criterion |
|---|---|---|---|---|---|---|
| Pooled OLS | 1.16%*** | 3.20%*** | -2.43%*** | -3.57 | -3.54 | -3.56 |
| Pooled OLS 2000-06 | 1.21%** | 4.36%*** | -3.12%*** | -3.85 | -3.81 | -3.84 |
| Pooled OLS 2007-14 | 1.31%** | 0.23% | -0.21% | -3.39 | -3.35 | -3.37 |
| Fixed Effects | 1.13%** | 3.50%*** | -2.67%*** | -3.46 | -3.16 | -3.35 |
| Fixed Effects 2000-06 | 1.21%** | 4.75%*** | -3.48%*** | -3.63 | -3.10 | -3.42 |
| Fixed Effects 2007-14 | 1.46%** | 1.12% | -1.24% | -3.18 | -2.70 | -2.99 |
| Time-Fixed Effects | 1.11%*** | 0.61% | 0.05% | -4.93 | -4.52 | -4.77 |
| Time-Fixed Effects 2000-06 | 1.39%*** | 0.96%* | -0.19% | -4.82 | -4.20 | -4.57 |
| Time-Fixed Effects 2007-14 | 1.09%*** | 0.23% | 0.07% | -4.92 | -4.34 | -4.69 |
| Random Effects | 1.16%*** | 3.20%*** | -2.43%*** | - | - | - |
| Random Effects 2000-06 | 1.21%** | 4.36%*** | -3.12%*** | - | - | - |
| Random Effects 2007-14 | 1.31%** | 0.23% | -0.21% | - | - | - |

TABLE 5: SUMMARY STATISTICS OF NON-LINEAR CAPM – INDEPENDENT VARIABLE IS BETA M

| **Model** | $\lambda_0$ | $\lambda_{m1}$ | $\lambda_{m2}$ | **Akaike Info criterion** | **Schwarz criterion** | **Hannan-Quinn criterion** |
|---|---|---|---|---|---|---|
| Pooled OLS | 1.34%*** | 2.10%*** | -1.59%*** | -3.55 | -3.53 | -3.54 |
| Pooled OLS 2000-06 | 1.59%*** | 2.85%*** | -2.12%*** | -3.79 | -3.75 | -3.77 |
| Pooled OLS 2007-14 | 1.28%** | 1.00% | -0.89% | -3.39 | -3.35 | -3.37 |
| Fixed Effects | 1.26%*** | 2.44%*** | -1.81%*** | -3.45 | -3.15 | -3.33 |
| Fixed Effects 2000-06 | 1.59%*** | 3.17%*** | -2.40%*** | -3.56 | -3.03 | -3.35 |
| Fixed Effects 2007-14 | 1.28%* | 1.64% | 1.51% | -3.19 | -2.71 | -3.00 |
| Time-Fixed Effects | 1.20%*** | 0.19% | 0.35% | -4.93 | -4.52 | -4.77 |
| Time-Fixed Effects 2000-06 | 1.31%*** | 0.46% | 0.36% | -4.83 | -4.21 | -4.58 |
| Time-Fixed Effects 2007-14 | 1.32%*** | 0.03% | -0.02% | -4.92 | 4.34 | -4.69 |
| Random Effects | 1.34%*** | 2.10%*** | -1.59%*** | - | - | - |
| Random Effects 2000-06 | 1.59%*** | 2.85%*** | -2.12%*** | - | - | - |
| Random Effects 2007-14 | 1.28%** | 1.00% | -0.89% | - | - | - |

Tables 4 and 5 present the estimates of equations 8 and 9 that reflect the non-linear version of CAPM. The nonlinear version of CAPM is supported for the entire period and for the period before the crisis (under both fixed and random effects).

It is of interest to check whether the random effects model above passes the Hausman test for the omitted variables being uncorrelated with the explanatory ones. The *p-value* for the test is superior to 10%, which implies that the null hypothesis cannot be rejected or that the random effects are uncorrelated with the explanatory variables. Therefore, the Hausman test indicates that the random effects model is appropriate and should be preferred over the fixed effects specification. This conclusion holds for both versions of our analysis.

Despite the fact that both the information criteria and the adjusted coefficient of determination indicate that the time-fixed effects model is the most suitable for the JSE CAPM, the Hausman test points towards random effects. Both models provide qualitatively similar results though.

## 5. Conclusions

This paper examined the validity of the CAPM for JSE before and after the great financial crisis. The latter is done within a panel framework for both the linear and a nonlinear version of the CAPM. Betas are coming from OLS and robust M-estimation. Evidence emerges in favor of the CAPM before the crisis and against it thereafter. The latter holds for the nonlinear version of the CAPM as well.

## Biographical Notes

**Paul Alagidede** is a Professor of Finance at the University of the Witwatersrand, South Africa.

**Nikolaos Koutounidis** is a postgraduate student at the Erasmus School of Economics, Rotterdam, Netherlands.

**Theodore Panagiotidis** is an Associate Professor at the Department of Economics, University of Macedonia, Greece.

## References

Alagidede, P., & Panagiotidis, T. (2009). Modelling stock returns in Africa's emerging equity markets, *International Review of Financial Analysis*, 18, 1-11.

Barnes, M. L., & Hughes, A. T. W. (2001). Conditional beta estimation and forecasting with panel data methods. *SSRN Electronic Journal*.

Fama, E. F., & MacBeth, J. D. (1973). Risk, return, and equilibrium: Empirical tests. *The Journal of Political Economy*, vol 81, no. 3, pp. 607-636.

Harvey, C. and Siddique, A. (2000). Conditional Skewness in Asset Pricing Tests. *The Journal of Finance*, 55(3), pp. 1263-1295.

Hausman, J. A. (1978). Specification tests in econometrics. Econometrica: *Journal of the Econometric Society*, vol. 46, issue 6, pp. 1251-71.

Huber, P.J. (1973). Robust regression: Asymptotics, conjestures and Monte Carlo, *Annals of Statistics*, 1(5), 799-821.

Korkmaz, T., Yıldız, B., & Gökbulut, R. İ. (2010). Testing the validity of CAPM in ISE national 100 index with panel data analysis. *Istanbul University Journal of the School of Business*, 39(1), 95-105.

Pandey, I. M. (2001). The Expected Stock Returns of Malaysian Firms: A Panel Data Analysis. *SSRN Electronic Journal*.

Samouilhan, N. L. (2007). The price of risk in the South African equity market. *South African Journal of Economics*, 75(3), 442-458.

Strugnell, D., Gilbert, E., & Kruger, R. (2011). Beta, size and value effects on the JSE, 1994–2007. *Investment Analysts Journal*, 40(74), 1-17.

van Rensburg, P., & Robertson, M. (2003). Size, price-to-earnings and beta on the JSE Securities Exchange. *Investment Analysts Journal*, 32(58), 7-16.

van Rensburg, P., & Slaney, K. (1997). Market segmentation on the Johannesburg Stock Exchange. *Journal for Studies in Economic and Econometrics*, 21, 1-23.

Ward, M., & Muller, C. (2012). Empirical testing of the CAPM on the JSE. *Investment Analysts Journal* (76), vol 41, issue 76, pp 1-12.