The risk-return relationship in the South Africa stock market

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Abstract

This paper analyses the intertemporal risk-return relationship in the South African stock market based on Merton's (1973) single factor ICAPM framework. The GARCH-in-mean model is used to analyse the daily excess returns of market and industry stock price indexes of the Johannesburg stock exchange listed companies. The estimated results generally lend support to the robust positive risk-return relationship between expected returns and the market risk premium. This suggests that the market and industry excess returns in the South African stock market behave according to the standard asset pricing theory.

JEL classification: C22, G12

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1 Introduction

Standard asset pricing theory postulates a direct relationship between expected excess stock returns and risk. This risk-return trade-off is a long standing phenomenon in investments analysis and is the foundation of financial economics (Leon, Nave and Rubio, 2005). Authors such as Ghysels, Santa-Clara and Valkanov (2004) describe this relation as the “first fundamental law of finance.” The risk-return trade-off is explained by the Capital Asset Pricing Model (CAPM), which relates the required return on investment to the risk of undertaking such an investment. Specifically, Merton’s (1973) Intertemporal Capital Asset Pricing Model (ICAPM) hypothesises a positive correlation between expected return on an investment and the associated risk.

The rate of return on an investment is weighted by the perceived risk of undertaking such an investment. This implies a direct relationship between market risk and return for the reason that risk-averse investors require additional compensation for assuming extra risk. Markets which are perceived by investors to be high risk are associated with higher returns in order to compensate the risk involved in investing in such markets. Conversely, lower risk markets are characterised by relatively lower returns. Thus it is unambiguous that the risk-return relationship is a fundamental concept in investment decision making and that it is accepted as the cornerstone of rational expectations asset pricing models.

This paper examines the intertemporal risk-return relationship in the South African stock market based on Merton’s (1973) single factor ICAPM framework. Although it is a long standing phenomenon in investments analysis, the empirical evidence on the risk-return trade-off is ambiguous with some empirical studies documenting a weak or negative relationship at best. Thus there is an ongoing uncertainty in the literature concerning this phenomenon and the extent to which the expected return on investment is commensurate with the associated risk premium.

The next section is the literature review which discusses the theoretical basis and the empirical findings on the risk-return relationship. The discussion on the empirical model and data is presented in section 3. Section 4 discusses the empirical results, while section 5 concludes.

2 Literature review

Assuming rational, risk-averse investors, the Sharpe (1964) and Lintner (1965) Capital Asset Pricing Model (CAPM) implies a positive, linear relationship between the expected market risk and returns. Merton (1973) estimated a variant of the traditional CAPM called the Intertemporal Capital Asset Pricing Model (ICAPM). Similar to the CAPM, the ICAPM implies a positive, linear relationship between the aggregate market return and the market risk premium of the market. This asset pricing model can be summarised by the following equation:

$$E_t r_{m,t+1} - r_{f.t+1} = \left[\frac{-J_{ww}W}{J_w}\right] E_t \sigma^2_{m,t+1} + \left[\frac{-J_{wf}}{J_w}\right] E_t \sigma_{mf,t+1} \quad [1]$$

where $E_t r_{m,t+1} - r_{f,t+1}$ is the conditional market return between period t and $t+1$. $E_t r_{m,t+1}$ is the rate of return on the stock market index and $r_{f,t+1}$ is the rate of return on risk-free asset. $E_t \sigma^2_{m,t+1}$ is the conditional variance of the market return or the risk component. $E_t \sigma_{mf,t+1}$ is the covariance of the market return with investment opportunities or the hedge component. $W(t+1)$ is wealth and $F(t+1)$ is the vector of state variables that describe wealth such that $J(W(t+1), F(t+1), t+1)$ is the indirect utility function of wealth. $\frac{-J_{ww}W}{J_w}$ is the measure of risk aversion or price of risk and is positive if investors are risk averse.

Assuming that investors have a recursive (power) utility function and the rates of return are independent and identically distributed, Merton (1980) agues that relative risk aversion is constant such that that the hedge component is negligible. In particular, Guo and Neely (2006) argue that investment opportunities are sluggish, such that their impact on stock returns is almost constant in the short term. This makes the case for the exclusion of the hedge component and the use of high frequency data to precisely uncover the risk-return relationship. Therefore, it follows that:

$$E_t r_{m,t+1} - r_{f.t+1} = \left[\frac{-J_{ww}W}{J_w}\right] E_t \sigma^2_{m,t+1} \qquad [2]$$

so that the ICAPM is a single factor model where the conditional excess market return is directly related to the conditional variance of the market. Equation [2] can be written as:

$$E_t r_{m,t+1} - r_{f.t+1} = \theta_0 + \lambda_m \sigma^2_{m,t+1} \qquad [3]$$

where, as discussed above, λ_m is positive given investor risk aversion and θ_0 is equal to zero.

Since Merton's (1973) work, the single factor risk-return relationship has been subject to voluminous empirical investigation, with empirical studies founding conflicting results on the sign and statistical significance of the coefficient of risk aversion (Guo and Whitelaw, 2001). The relationship between market risk-return is found to be positive and statistically significant by Bollerslev, Engle and Wooldridge (1988), Chou (1988) as well as Harvey (1989). Campbell (1987), Turner, Startz and Nelson (1989) as well as Glosten, Jaganathan and Runkle (1993) document a negative and statistically significant relationship, while French, Schwert and Stambaugh (1987) as well as Baillie and DeGenmaro (1990) find no statistically significant risk-return trade-off. Nonetheless, a positive, statistically significant risk-return relationship has been reinstated by Scruggs (1998) and more recent studies such as Guo and Whitelaw (2001), Ghysels, Santa-Clara and Valkanov (2004) as well as Leon, Nave and Rubio, (2005).

It is apparent form the foregoing discussion that the empirical applications of the Merton's single factor risk-return have achieved mixed successes. The majority of the studies use several variants of the General Autoregressive Conditional Heteroscedasticity (GARCH) model to estimate the risk-return relationship. There are also instances where Generalised Method of Moments (GMM) is used such as in Guo and Whitelaw (2001). Ghysels, Santa-Clara and Valkanov (2004) introduce the Mixed Data Sampling (MIDAS) approach, which forecasts monthly variance with past daily squared returns. Although most studies use monthly data, the use of daily denominated data is also prevalent. Intraday and quarterly data features in some studies such as Balios (2008) and Guo (2002), respectively. Data span varies considerably with Ghysels, Santa-Clara and Valkanov (2004) as well as Lundblad (2004) employing the longest, which cover 76 and 68 years, respectively.

3 Methodology and data

3.1 Model

Following Merton's (1973) single factor risk-return framework, the following estimable version of equation [3] is estimated to establish the relationship between market risk premium and stock returns:

$$r_{m,t} - r_{f,t} = \theta_0 + \lambda_m \sigma^2_{m,t} + \varepsilon_{m,t} \qquad [4]$$

where r_m is the market return and r_f is the risk-free rate of return so that $r_m - r_f$ is the excess market return. σ^2_m is the variance of excess market return. ε_m is the white noise error term, θ_0 is the intercept term and λ_m approximates the coefficient of market risk aversion. As implied by the theoretical model, the intercept is restricted to zero and the coefficient of market risk aversion is positive. According to Merton (1980), the single factor risk-return model can reasonably approximate the trade-off between time-varying risk premium and stock returns and has become the standard model in empirical finance literature.

Equation [4] is estimated directly using the General Autoregressive Conditional Heteroscedasticity in mean (GARCH-M) model by Engle, Lilien and Robins (1987). This model has received considerable popularity in the risk-return trade-off empirical literature because the GARCH type conditional variance is handy as a representation of the time-varying risk premium in excess returns. It is also desirable in that it specifies the heteroskedastic conditional variance term directly into the mean equation so that it characterises the evolution of the excess returns and conditional variance simultaneously.

The GARCH(p,q)-M model is specified as follows:

$$r_{m,t} - r_{f,t} = \theta_0 + \lambda_m \sigma^2_{m,t} + \varepsilon_{m,t} \qquad [4]$$

$$\sigma^2_{m,t} = \omega + \sum_{j=1}^{q} \beta_j \sigma^2_{m,t-j} + \sum_{i=1}^{p} \alpha_i \varepsilon^2_{m,t=1} \qquad [5]$$

$$\varepsilon_{m,t} \Big| \Phi_{m,t-1} \sim N(0, \sigma^2_{m,t}) \qquad [6]$$

where equation [4] and [5] are the mean and variance equations, respectively. ω is the constant, α_i and β_j are the coefficients of the ARCH and GARCH terms, respectively. The market conditional variance σ^2_m is a one step ahead forecast variance based on past information Φ_m.

The assumption about the distribution of the error term is required because GARCH models are computed using the method of maximum likelihood. Gaussian (normal), student's t and the general error distributions are the three commonly employed assumptions about the distribution of the error term. In this study, the residuals are assumed to be normally distributed as shown in equation [6] above. To ensure that the normality condition holds, the Bollerslev and Wooldridge (1992) quasi-maximum likelihood standard errors are used. The vector of population parameters to be estimated is:

$$\phi = (\theta, \lambda, \omega, \beta, \alpha, \sigma^2) \qquad [7]$$

In estimating the population parameters ϕ, the following conditional log likelihood function is maximised under the assumption of normally distributed errors:

$$L(\phi) = \sum_{t=1}^{T} L_t(\phi) = \sum_{t=1}^{T} -\frac{1}{2}\left(\log(\sigma^2) + \log(2\pi) + \frac{\varepsilon^2}{\sigma^2}\right) \qquad [8]$$

where the first two conditional moments should be correctly specified to ensure that the parameters estimation is consistent.

3.2 Data

Anderson and Bollerslev (1997) argue that the use of high frequency data is desirable to uncover the risk-return relationship. This is because it allows for a better measurement of risk and enables precise identification of the risk-return trade-off. This is because high frequency data produces better estimates of conditional volatility process. The risk-return trade-off is estimated using daily returns on 50 market and industry stock price indexes of the Johannesburg stock exchange listed companies. These market and industry stock price indexes are weighted by market capitalisation, where industry stock price indexes assume the Industry Classification Benchmark (ICB) system.

The bond exchange yields on R153 (short term government bond) and R186 (long term government bond) are used to approximate the risk-free rate of interest. Most studies use the three month treasury bill rate for this purpose. However, the risk free rate of return is only available in monthly frequency. All data are sourced from the South African Reserve Bank database and spans the period January 04, 1995 to February 06, 2009. This yields 2635 data points.

The data for the industry stock price indexes of aerospace and defence, personal care and household products, tobacco, utilities, electricity, gas distribution, gas, water, and multiutilities as well as alternative exchange were not available and as such, their risk-return relationships could not be estimated. The market and industrial groups' stock indexes descriptions are detailed in table A1 in the appendix and their descriptive statistics are shown on in table 1 below. According to the descriptive statistics, consumer goods, food producers, equity investments as well as development and venture capital stock price indexes show high volatility during the sample period based on standard deviations.

Table 1 Variables' descriptive statistics

Variable	Std. Dev.	Skewness	Kurtosis	Variable	Std. Dev.	Skewness	Kurtosis
S01	1.578	-0.010	7.813	**S30**	2.209	1.197	17.897
S02	2.095	0.308	8.466	**S32**	1.507	-0.357	7.156
S03	2.168	0.323	8.269	**S33**	1.661	-0.417	6.970
S04	2.758	0.611	7.921	**S34**	1.665	0.106	8.410
S06	3.072	-13.76	444.1	**S35**	2.300	-0.116	6.368
S07	2.543	-0.150	6.062	**S36**	1.798	-0.104	6.735
S08	2.805	0.697	8.188	**S37**	2.538	-22.68	885.7
S09	2.688	-0.231	10.20	**S38**	2.483	0.407	7.804
S10	2.470	0.259	6.219	**S39**	1.821	-0.237	6.726
S11	1.477	-0.168	7.420	**S40**	2.575	0.406	8.301
S12	2.046	0.291	9.355	**S45**	1.636	0.019	7.240
S13	1.403	0.148	6.314	**S46**	2.071	0.201	6.141
S14	2.608	-21.81	843.7	**S47**	1.695	0.032	7.437
S15	2.493	0.231	6.584	**S48**	1.907	-0.083	7.149
S16	2.758	0.199	9.808	**S49**	17.81	49.67	2525.2
S17	1.567	-0.248	7.343	**S50**	1.288	-0.130	7.892
S19	1.707	-0.028	7.182	**S51**	1.872	-0.050	6.784
S20	1.555	-0.188	6.933	**S52**	2.348	-0.280	9.304
S21	1.684	-0.695	48.82	**S53**	1.836	0.082	5.335
S22	17.84	49.54	2517.1	**S54**	2.439	-0.233	8.807
S23	2.346	4.193	176.7	**S55**	22.34	40.08	1686.9
S25	1.606	-0.145	6.384	**S56**	20.06	39.39	1647.9
S26	1.935	0.026	6.410	**S58**	1.284	-0.466	9.781
S27	17.70	49.95	2544.8	**S59**	1.104	-0.662	10.35
S28	1.956	0.237	6.154	**S62**	1.677	0.050	7.579

4 Empirical Results

The maximum likelihood estimates of the ICAPM are estimated using the GARCH(1,1)-M model for the whole sample period. The data series for some of the industry stock price indexes do not span the sample period and as such, their risk-return relationships were estimated using data from January 04, 1999 up to December 30, 2005, April 03, 2007 and December 21, 2007 for mining finance, technology and hardware as well as diamonds and gemstones industries, respectively, while the sample period for development capital and venture capital spans January 02, 2002 to February 06, 2009.

In accordance with ICAPM theory, the intercept term was restricted to zero in all the estimated GARCH-M models. Lanne and Saikkonen (2006) have also shown that the inclusion of an intercept term when it is statistically insignificant results in lack of power in the standard Wald test on the mean effect parameter in the GARCH-M model. Furthermore, the Bollerslev and Wooldridge (1992) quasi-maximum likelihood standard errors and the heteroscedastic consistent covariances are used to ensure that the normality condition holds in all the estimated models.

The maximum likelihood estimates of the GARCH-M model for the coefficient of risk aversion λ_m are reported in table 2. According to the empirical results, out of the 50 stock price indexes, 45 (95 percent) show a positive and a highly statistically significant coefficient of risk aversion. This includes the stock price indexes for the overall market index and the indexes of the major industries such as resources, Industrials, consumer goods, health care, telecommunications and financials. This is also the case with the major group indexes such as the top 40, mid cap and small cap stock indexes.

The stock price indexes for technology sub-sectors; software and computer services as well as technology and hardware are borderline statistically significant. Only 5 (5 percent) of the 50 stock price indexes show no statistically significant coefficient of risk aversion. These are the indexes for diamonds and germstones, construction and materials as well as technology, while the indexes for automobiles and parts as well as industrial transportation are not only statistically insignificant but also show negative coefficient of risk aversion.

In summary, the empirical evidence on risk-return relationship as conjectured by the ICAPM is ambiguous with some empirical studies documenting a weak or negative relationship at best. In spite of this, the estimated results generally lend support to the robust positive risk-return relationship between expected returns and the market risk premium in the South African stock market, notwithstanding the few exceptions. Consequently, the South African stock market indexes conform to the Merton's (1973) ICAPM theoretical hypothesis so that the expected return on an investment in the South African stock market is commensurate with the market risk premium.

Table 2 GARCH(1,1)-M model results

Variable	λ_m	Std. Error	z-Stat.	Variable	λ_m	Std. Error	z-Stat.
S01	0.062	0.013	4.905	**S30**	0.031	0.008	3.732
S02	0.042	0.010	4.289	**S32**	0.054	0.012	4.630
S03	0.039	0.009	4.129	**S33**	0.040	0.011	3.686
S04	0.014	0.007	2.061	**S34**	0.042	0.012	3.623
S06**	0.004	0.007	0.628	**S35**	0.025	0.008	3.079
S07	0.026	0.008	3.405	**S36**	0.036	0.011	3.414
S08	0.026	0.007	3.833	**S37****	-0.002	0.004	-0.404
S09	0.016	0.007	2.294	**S38**	0.030	0.008	3.847
S10	0.029	0.008	3.558	**S39**	0.040	0.010	3.851
S11	0.064	0.013	5.077	**S40**	0.023	0.008	3.070
S12	0.040	0.010	4.092	**S45**	0.042	0.011	3.797
S13	0.062	0.013	4.604	**S46**	0.031	0.009	3.563
S14**	0.004	0.003	1.285	**S47**	0.044	0.011	4.097
S15	0.021	0.008	2.724	**S48**	0.025	0.010	2.489
S16	0.021	0.007	3.062	**S49**	0.006	0.000	20.022
S17	0.062	0.013	4.909	**S50**	0.059	0.015	3.970
S19	0.056	0.011	5.189	**S51**	0.029	0.010	3.004
S20	0.044	0.012	3.578	**S52****	0.009	0.007	1.210
S21	0.055	0.015	3.711	**S53**	0.021	0.011	1.970
S22	0.006	0.000	18.335	**S53**	0.021	0.011	1.970
S23**	0.000	0.010	-0.012	**S55**	0.005	0.000	16.591
S25	0.046	0.012	3.945	**S56**	0.001	0.000	2.796
S26	0.032	0.010	3.100	**S58**	0.076	0.013	5.770
S27	0.006	0.000	93.128	**S59**	0.100	0.016	6.236
S28	0.041	0.009	4.334	**S62**	0.057	0.012	4.765

** Statistical insignificance at 5 percent level

5 Conclusion

This study examined the intertemporal risk-return relationship in the South African stock market based on Merton’s (1973) single factor ICAPM framework. The GARCM-M model by Engle, Lilien and Robins (1987) is used to estimate the risk-return trade-off of 50 daily excess returns of market and industry stock price indexes of the Johannesburg stock exchange listed companies. According to the empirical results, 95 percent of stock price indexes show a positive and a highly statistically significant coefficient of risk aversion, while 5 percent are not only statistically insignificant but also show negative coefficient of risk aversion. This suggests that, generally, the market and industry stock prices in the South African stock market conform to the Merton’s (1973) ICAPM theoretical hypothesis of a positive relationship between excess market returns and the market risk premium.

Several challenges to successfully estimating the risk-return trade-off remain and need further examination. These are the issues of the methodological approach, volatility characteristics of the risk premium as well as data span and frequency. Guo and Neely (2006) suggest that the leverage effects should be accounted for to address the asymmetry in the response to the conditional volatility. They further argue that the long run conditional variance is more important in the determination of equity risk premium, which calls for the component GARCH model to uncover these short and long run conditional variance dynamics. There is also a need to explore the MIDAS approach by Ghysels, Santa-Clara and Valkanov (2004), which has recently become popular in uncovering the market risk-return trade-off to see if it can replicate the results in this paper.

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Appendix

Table A2 Variables' descriptions

Share/Bond	**Description**	**Share/Bond**	**Description**
b40	R 153 Government bond	**s28**	Healthcare equipment and services
b42	R 186 Government bond	**s30**	Pharmaceutical and Biotechnology
s01	All Share	**s32**	Consumer services
s02	Resources	**s33**	General retailers
s03	Mining	**s34**	Travel and leisure
s04	Gold mining	**s35**	Media
s06	Diamonds & gemstones	**s36**	Support services
s07	Platinum & precious metals	**s37**	Industrial transportation
s08	General mining	**s38**	Telecommunications
s09	Mining finance	**s39**	Food and drug retailers
s10	Oil & gas producers	**s40**	Fixed line telecommunications
s11	SA all share industrials	**s45**	Financials
s12	Basic materials	**s46**	Banks
s13	Chemicals	**s47**	Non-life insurance
s14	Construction & materials	**s48**	Life insurance
s15	Forestry and paper	**s49**	Equity investment instruments
s16	Industrial metals	**s50**	Real estate
s17	Industrials	**s51**	General financial
s19	General industrials	**s52**	Technology
s20	Electronic and electrical equipment	**s53**	Technology and hardware
s21	Industrial engineering	**s54**	Software and computer services
s22	Consumer goods	**s55**	Development capital
s23	Automobiles and parts	**s56**	Venture capital
s25	Health care	**s58**	Mid Cap
s26	Beverages	**s59**	Small Cap
s27	Food producers	**s62**	Top 40