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FACTOR STRUCTURE OF RETURNS IN DEVELOPING EQUITY MARKETS: THE CASE OF SAUDI ARABIA

Key Words

APT; Risk Factors; Saudi Arabia.

Abstract

This paper uses the APT of Ross (1976) to estimate the number of relevant priced risk factors for the Saudi Arabian Stock Market. We find that there is one dominant, significantly priced factor that explains returns, and intuitively confirms the almost total dependence of the economy on crude oil and oil related activity. The APT framework as an explanatory model is, however, only weakly supported, as the implied zero beta return is too low compared to the risk free rate. The existence of one factor as documented here has important implications for institutional fund managers and for investors with hedging demands.

Introduction

Explaining the return generating process for equities has been of paramount importance to the finance academia. Equally, identifying sources of risk is also important to fund managers and investors. The Capital Asset Pricing Model, or CAPM for short, has ruled the roost as an elegant while yet a tractable model of asset returns. The CAPM was introduced in the middle 60s by Sharpe (1964), Lintner (1965), and Mossin (1966), and has undergone rigorous empirical testing. While not inherent in the derivation of the model, the CAPM leads to a common sense hypothesis, stating that stock undergoes group movements, where the group driver is one underlying factor, commonly referred to as the market.

It is not surprising that researchers soon turned their attention to multiple factors that could help explain the ex-post pattern of stock

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returns, starting the analysis with the paradigm of an underlying factor structure that generates asset returns. This is in sharp contrast with the utility based equilibrium approach used to derive the CAPM. One of the earlier studies in this regard is King (1966) which attempts to use the overall market factor of the CAPM in conjunction with industry factors and other factors. This was followed, amongst others, notably by Rosenberg & Marathe (1977), who introduce 6 risk measures and 39 industry indices to explain the residuals, and Chen, Roll, & Ross (1986), who identify a number of macroeconomic factors that cross-sectionally help explain stock returns.

Initial attempts to introduce such factor structures were at best empirical in nature and lacked a coherent theoretical foundation before the seminal Arbitrage Pricing Theory (APT) work by Ross (1976). Using minimal constraints on investor behavior and an assumed linear return specification, the APT derives an expected return-risk relationship similar to the CAPM. Empirical work on multi-factor models burgeoned, partly because of the disenchantment with the underlying restrictive assumptions of the CAPM when compared with those of the APT, and the increasing empirical departures from the predictions of the CAPM.

Adopting the APT as an alternative is not without its costs. For one, the theory does not explicitly identify which and how many factors are necessary to capture the factor structure of returns. Second, implementing the APT is statistically and computationally demanding. The mere existence of factors themselves are perhaps less important than determining how many of these are in fact priced. The former analysis is normally implemented through either a principal components or factor analytic technique. It is the latter test of whether these identified factors are priced that impart the economic content to the APT.

In Section 2 we discuss the underpinnings of the APT, Section 3 describes the data used, Section 4 outlines the empirical design of our study, Section 5 provides the main results and analysis of tests, and finally Section 6 presents the conclusion.

The Arbitrage Pricing Model

The APT of Ross (1976) begins by positing an underlying linear process that generates asset returns. This marks the departure in the characterization of the APT from the CAPM. The latter uses an equilibrium framework based on a representation of investor behavior consistent with mean variance efficiency.

A k factor process is assumed to generate the random rate of return of assets. This is represented as:

$$R = E + B\delta + \varepsilon \qquad (1)$$

For an economy with N assets:

- R is an (Nx1) vector of returns.
- E is an (Nx1) vector of expected returns corresponding to the N assets.
- B is an (Nxk) matrix of asset specific factor loadings, meant to capture the sensitivity of each asset to the k common factors.
- δ is a (kx1) vector of random returns of the k systematic or common factors.
- ε is a (Nx1) vector of returns representing the non-systematic returns attributable to each asset arising from firm specific events. These are also termed as idiosyncratic returns.

In addition to the form of the return generating structure, the following assumptions are also made, where E here is used as the expectations operator:

- $E(\delta) = 0$
- $E(\delta\delta') = \Lambda$
- $E(\varepsilon) = 0$ and $E(\varepsilon\varepsilon') = D$ a diagonal matrix
- $E(\varepsilon\delta) = 0$, and
- N the number of assets is greater than k the number of factors.

Asset returns are therefore assumed to be generated by a process where the actual returns deviate from expectations due to a set of common factors and a unique asset specific factor which is independent across the class of assets. Each asset has a sensitivity to the common factor described by the coefficient matrix B.

A consequence of the above assumed structure of returns is, as shown by Ross, that the expected return on each asset is a linear combination of the risk free asset (if it exists, or else the return on a factor which is invariant to the common risk factors in the economy), and the factor loadings of each asset. In matrix notation:

$$E = [1 : b]\begin{bmatrix}\lambda_0 \\ \lambda\end{bmatrix} \qquad (2)$$

λ here is a k vector, each element of which represents the risk premium of a portfolio which has unit sensitivity to one of the k factors and zero sensitivity to all others. For this linear structure to hold it is necessary that the idiosyncratic risk can be eliminated through the dilutive effects of diversification on the asset specific risk. The equilibrium relationship, therefore, is easier to defend for portfolios that are well diversified.

The objective of any empirical analysis of the APT is essentially to estimate these factor risk premiums.

As the theory does not provide any guidance as to the form or number of factors in a given economy, the analysis consists of a two step procedure. In step one, we estimate the number of factors that are necessary to describe the return generating process. In step two, one wishes to estimate the number of these factors that are priced or carry a risk premium that is statistically different from zero.

Some indications of the nature of what these common macro-economic factors are, is provided in the empirical work on the US markets. Unanticipated changes in inflation, industrial production, spread between low vs. high grade bonds, and the slope of the term structure of interest rates are four factors that appear to have a significant risk premium. Research done for other markets, however, has been less successful in identifying more than one distinct factor that may explain the structure of returns.

Data

Assets used in the APT tests are returns of common shares of publicly traded companies in the Saudi Stock Market. One of the major concerns of the data is the extent of infrequent trading and missing observations in the data set. Therefore, we have chosen to use portfolios of securities in the analysis, where these portfolios are represented by the price index of the six major sectors of the economy. These indices were compiled by the statistical department of SAMA (Saudi Arabian Monetary Agency) and made available to us.

This limits our cross-sectional sample size; however this is a cost that we feel is necessary to bear for the analysis to have any empirical validity, in order not to compromise the quality of the data induced by infrequent trading. Moreover, some of the errors in variables problems can be attenuated by the use of portfolios as suggested in the two-stage testing of Fama and Macbeth (1973) of the CAPM. Creation of random portfolios, however, can lead to a loss of factor relevant information that may result from the averaging across the securities in the portfolio. In our case the portfolios are not randomly formed, but are based on membership in particular industries. Thus, to the extent that there may be industry-specific factors that lead to differences in returns, we are apt to lose this through our aggregation procedure. The residual matrix in our case, therefore, can be interpreted as industry-specific disturbances in contrast to firm-specific factors as would be the case in the use of individual stocks.

To point out a distinct advantage of using a portfolio approach, note that one of the assumptions of the

APT is the ability of investors to diversify away firm-specific residual risk. It is, therefore, more likely that the pricing relationship postulated in the APT is more likely to hold in the case of portfolios than for individual securities. To summarize, we justify the use of our portfolio approach in spite of the limitation in cross- sectional sample size.

Empirical Design

As stated earlier the empirical analysis consists of a two-step procedure. The first step consists of identifying the number of factors necessary to explain the return generating process. Prior research has either used a maximum likelihood factor analysis to the variance-covariance matrix of security returns, or resorted to a principal components analysis. The latter approach was motivated in the past by the computationally difficult task of employing the factor analytic methodology in a large number of assets. In this research we use both avenues: principal components analysis is used to get a feel for the number of significant factors that may be present. This serves as the input for our use of factor analysis, through which the beta coefficient matrix or factor loading is estimated.

Principal Components. In the principal components analysis, the eigen values (λ) of the variance-covariance matrix is computed by solving $\det[\sum - \lambda\ I] = 0$, where I is a conforming unit matrix. The λ's represent the proportion of the total variance explained by each principal component. If the data can be summarized by a few f factors, then a few of the eigenvalues should account for a major proportion of the variance. Associated with each eigen value is an eigen vector. Chamberlain and Rothschild (1983) have used these eigenvectors as asymptotic estimates of the factor loadings. This is motivated by the observation that if k of the eigen values increases without bound as the variance-covariance matrix is expanded sequentially, a k factor structure can be justified, and the k eigenvectors corresponding to these eigen values converge asymptotically to the true factor loadings.

In the analysis of this paper, however, we do not have the luxury of creating nested sequences of $\sum$ (given the limited sample size). Principal components, therefore, is used primarily to identify the number of common factors driving returns, while a maximum likelihood factor analysis is employed to estimate the factor loadings.

Factor Analysis. The beta coefficient matrix is estimated by factorizing the variance- covariance matrix, where the decomposition of the sample covariance matrix V takes the form;

$$V = B \Lambda B' + D \qquad (3)$$

In the jargon of factor analysis the elements of B are called the factor loadings. D is a diagonal matrix of asset variances, and Λ is a matrix of factor covariances. Unfortunately, from an estimation viewpoint the B elements are unique only up to an orthogonal transformation. To see this, if the factors are defined as $G^{-1}\delta$ and the factor loadings as BG, (where G is a orthogonal matrix, $GG' = I$), then the transformed system generates exactly the same sample covariance matrix. The typical procedure, therefore, is to place an arbitrary restriction on the factors being orthogonal, i.e. $E(\delta\delta') = I$, which forces Λ to be the unit matrix I. The empirical plan is therefore:

Step I. Use principal components analysis to identify the number of relevant factors.

Step II. Use factor analysis to estimate the loading matrix or beta coefficients through

$$E[(r - E)(r - E)'] = BB' + D \quad (4)$$

Step III. Test the cross section equation

$$E_i = \lambda_0 + \lambda_1 \hat{b}_1^i + \ldots + \lambda_k \hat{b}_k^i \quad (5)$$

for significance of the λ's. As pointed out earlier the estimated betas are not unique, in particular with respect to the sign, and consequently no importance can be attributed to the sign of the estimated λ's. The cross-sectional regressions are run on the expected or mean average return computed for each year, 1985 to 1999.

Step IV. Employing a technique analogous to Fama and Macbeth (1973), the time series values of λ are used to compute the standard error of the estimated λ, which yields an inference about whether the true λ is non zero. The mean value of λ_0 should provide an estimate of the rate of return of the risk free asset. The value of λ_0 is compared against the short term (one month) inter-bank interest rate for the corresponding period.

Results

Summary Statistics: Table 1 provides the summary statistics of the log relatives for each of the six sectoral portfolios analyzed.

Table 1
Portfolio Weekly Returns - Summary Statistics 1985 to 2000
Weekly Returns are defined as the log relatives of portfolio values and are expressed as percentages. Number of firms is the number of firms included in each sector

Portfolio	Mean	Standard Deviation	Kurtosis	Skewness	Jarque-Bera	Number of Firms
Banks	0.211	2.482	7.304	0.051	566.9	12
Industry	0.138	2.937	41.807	-0.688	46117.2	22
Cement	0.033	2.172	4.845	-0.047	104.4	9
Services	-0.122	2.250	6.166	0.319	319.0	18
Electricity	-0.046	2.311	30.332	2.548	23641.4	10
Agriculture	-0.132	2.346	9.027	-0.562	1149.6	9

Note: Number of observations in the sample is 734 weekly returns. The Jarque Bera statistics are large enough to reject the null of normality at 1% for all the sectors.

The average return over the sample period was negative for 3 of the 6 portfolios. The banking sector is the most vibrant (in terms of equity trading) recording an average weekly return of 0.211%.

Principal Components: Principal components analysis was done on the covariance matrix of the weekly returns. As is evident from table 2, one factor appears to dominate, explaining about 41% of the total variance. Other factors, if any, only have a minor incremental influence in explaining variance. Considering the undiversified nature of the Saudi Arabian economy, which is heavily dependent on oil and oil related production, it does not come as a surprise that one factor is pervasive in explaining the factor structure of returns.

Table 2
Principal Components of Portfolio Returns- Saudi Arabia, 1985-2000
Eigen values are the solutions to $|\sum - \lambda I| = 0$, where $\sum$ is the covariance matrix and I is a conforming Identity matrix. The magnitude of the eigen value determines the proportion of total variance explained by each common factor

Factor	Eigen value	% of Variance	Cumulative %
1	2.455	40.915	40.915
2	0.921	15.356	56.271
3	0.840	13.997	70.268
4	0.669	11.149	81.417
5	0.619	10.318	91.735
6	0.496	8.265	100.000

These results also seem consistent with research on other markets, (Faff (1988) on Australia, Leudecke (1984), Reinganum (1981) and Trzcinka (1986) on US data). All these attempts find strong evidence of one distinct common factor, with no obvious way to choose more than one. Crucially, it is found that it is unlikely that the number of factors is zero, lending support to the existence of a latent factor structure. Many researchers have included more than one factor at this initial stage at the risk of over-specification, hoping to weed out the extra factors by discarding factors that do not carry a statistically significant price of risk in the cross-sectional analysis. In the factor analysis done in step II of our analysis, we also include a second factor, but find that some of the communalities exceeded one. This gives us further support to use the single factor model. We, therefore, proceed with further analysis of determining the price of factor risk by using the single factor model as the maintained model for Saudi Arabia.

Factor Analysis: Given that the principal components analysis above indicates the existence of one dominant factor, a maximum likelihood factor analysis was done on the covariance matrix to identify the factor loadings consistent with one common factor driving asset returns. Table 3 reports the factor loadings corresponding to a single common factor.

Table 3
Factor Loadings for a Single Common Factor
The covariance matrix is factorized as $E[(r - E)(r - E)'] = BB' + D$ where B is the factor loadings and D is a diagonal matrix of variances

Porfolio	Factor Loading
Banks	0.733
Industry	0.618
Cement	0.509
Services	0.635
Electricity	0.286
Agriculture	0.399

Note: Extraction method used is Maximum Likelihood estimation.

The maximum likelihood methodology can also be used to compute a likelihood ratio to identify the required number of factors. The likelihood ratio is computed as the ratio of the maximum likelihood conditional on k factors to the maximum likelihood without any restrictions. Under the null of exact k factors, twice the log of the likelihood ratio is chi square distributed. The chi square statistic for $k=1$ is 16.143 with an associated probability of 0.064. Thus at a 5% confidence level we can reject the null that more than one factor is required.

Price of factor risk (cross-sectional regressions): Having identified the number of common factors and the associated factor loadings (the beta coefficients), this section estimates the excess return or price of risk corresponding to the factor. Referring to the APT equation in the previous section, OLS regressions of the form shown below is done.

$$E_i = \lambda_0 + \lambda_1 B + e_i \ ; \ i = 1, 15 \quad (6)$$

where E_i is the expected or average portfolio return for each year (1985 to 1999, comprising 15 individual years). The beta coefficients are the ones estimated from the full sample using the factor analytical methodology described in the previous section. The plan, therefore, is to obtain 15 separate estimates of λ_0 and λ_1 and evaluate the significance of the estimates by computing the time series value of their respective standard errors. This is in keeping with the Fama and Macbeth (1973) procedure for estimating the CAPM for each time period *t* in the sample. This approach is adopted over one which evaluates the significance of the estimated coefficient from a single regression which employs the full sample mean of the portfolio returns. This latter method is likely to have a low power in the present case as the number of observations is limited to only six, corresponding to the number of asset portfolios. Therefore for each year, the expected return of each asset portfolio is computed (T=51, 52, or 53), where these serve as the dependent variable. The independent variables are the six beta coefficients or factor loadings. The cross-sectional regression gives an estimate of the zero beta return (λ_0) and the price of factor risk (λ_1). The procedure is repeated 15 times, one time for each year of the sample, yielding 15 estimates of λ_0 and λ_1. The time series standard errors are then computed to permit significance tests. Table 4 provides the results of the individual regressions. For completeness we also provide the OLS values of the computed t-statistics and probabilities, bearing in mind that these statistics in the present case are of limited power in assessing significance.

When considered on a year-by-year basis, only three of the fifteen regressions have significant values for λ_1 (marked by asterisks in the table). This, however, is not fatal to the hypothesis under consideration. As we have already pointed out, the power of each individual regression is likely to have low discriminatory power. It would be more appropriate to examine the time series properties of the individual annual estimates. The mean values of λ_0 and λ_1 are -0.279% and 0.549% respectively. The standard error of λ_0 is 0.117 (associated t-value of -2.368, significant at the 5% level), while the standard error of λ_1 is 0.291 (associated t-value of 1.884, significant at the 5% level). Both estimates are, therefore, significantly different from zero.

One of the implications of the APT is that λ_0 should approximate the risk free rate in the economy. The negative sign on the estimated λ_0 and its significance level implies a considerable underestimation of the average risk free rate.

Table 4
Annual Cross-sectional Regressions of Portfolio Expected Returns against Factor Loadings. Saudi Arabia 1985 to 1999.

Regressions are of the form: $E_i = \lambda_0 + \lambda_1 B + e_i, \ i = 1, 15$

Year	λ_0 (t-value)	λ_1 (t-value)	Prob (λ_1)
1985	-0.805 (-3.19)	0.103 (0.224)	0.833
1986*	0.284 (1.753)	-1.001 (-3.411)	0.027
1987	0.096 (0.188)	0.610 (0.656)	0.548
1988*	-1.044 (-1.706)	2.450 (2.208)	0.092
1989	-0.930 (-1.493)	2.202 (1.949)	0.123
1990	-0.096 (-0.908)	-0.138 (-0.719)	0.512
1991*	-0.653 (-2.500)	3.053 (6.441)	0.003
1992	0.411 (0.932)	-0.540 (-0.676)	0.536
1993	-0.320 (-0.754)	0.084 (0.109)	0.918
1994	-0.475 (-1.365)	-0.292 (-0.463)	0.668
1995	-0.441 (-0.810)	0.740 (0.750)	0.495
1996	-0.300 (-0.643)	0.811 (0.957)	0.393
1997	0.041 (0.114)	0.537 (0.829)	0.454
1998	-0.435 (-1.298)	-0.384 (-0.632)	0.562
1999	0.463 (0.642)	-0.005 (-0.004)	0.997

There is no trading of government securities in Saudi Arabia (There is a cultural and religious bias against the use of debt securities in Saudi Arabia; government borrowing is, therefore, restricted to the sale of treasury securities to commercial banks through private placements). Hence a direct market estimate of the risk free rate is unavailable. Information was, therefore, collected on the inter-bank short term one month interest rate (referred to as SIBOR, the Saudi inter-bank offering rate), which was available for the period Jan. 1992 to Dec. 1999. SIBOR is determined in a manner analogous to LIBOR or the Fed Funds rate, where individual banks are surveyed at the end of each day, and the quoted rates averaged after discarding the highest and lowest quoted rates. The weekly average rate was estimated at 0.10% over the sample period. Our estimate of λ_0 is, therefore, not very encouraging to the APT.

The significant estimate of λ_1, however, implies that the common factor carries a risk premium and is priced. On balance it, therefore, appears that the APT enjoys mixed support. The existence of one pervasive factor is clearly demonstrated, both from the principal components analysis and the cross-sectional pricing equation.(1)

Conclusions

It is evident from casual observation that asset prices move in groups, implying common factors that influence returns. The APT begins by positing a linear factor structure, where changes in asset returns are induced by changes in economy wide common factors and factors that are unique to the asset. Assuming that firm-specific factors are uncorrelated across assets, asset-specific risk can practically be eliminated through well diversified portfolios. Portfolios of such diversified assets which have the same exposure to common factors of risk must have the same expected return to yield an economy that is arbitrage free — the bare minimum condition for a market to be in equilibrium. The APT pricing equation, therefore, shows that the expected return must be a linear function of the exposure to factor risk as measured by the covariance risk to economy wide common factors.

Most of the empirical tests of the APT in the literature have looked at the developed markets, such as the

(1) A pooled cross-sectional time series GLS regression was also done, the results were similar to the analysis done in this section using the Fama & Macbeth procedure.

US. In this study, we identify the factor structure of asset returns in the Saudi Arabian equity market, using portfolios that represent the six major sectors of the market. We find that one common factor dominates in explaining the covariance of asset returns. This result has intuitive appeal, as the Saudi Arabian economy is heavily dependent on the oil sector, where much of the common uncertainty stems from uncertainty in world crude prices and attendant revenues from this sector. Moreover the common factor carries a non-zero price as seen in the cross-sectional regression of expected returns against the common factor loadings. The APT, therefore, is seen to have mixed support.

This study may be considered a first attempt at testing the arbitrage pricing theory on an emerging market. The lack of reliable price and return data on individual securities limited our ability to conduct a factor analytical study of the constituent stocks. With the development and improvement in data collection on individual stocks, future research will inevitably advance the empirical analysis in a number of directions.

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الملخص

بنية عناصر العائد على الأسهم في أسواق الدول النامية: حالة المملكة العربية السعودية

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هذه الدراسة تستخدم نظرية التقييم الموازن APT التي أطلقها روس عام ١٩٧٦م لمعالجة العناصر المؤثرة في أسعار الأسهم السعودية بالتحديد والتقويم. لقد خلصت الدراسة إلى وجود عنصر واحد مهم ومؤثر في تفسير تباين العائد في الأسهم السعودية، ويؤكد ذلك فرضية اعتماد الاقتصاد السعودي اعتماداً كبيراً على النفط والصناعات المتعلقة به. إن إطار نظرية التقييم الموازن بوصفها نموذجاً لمعرفة تباين عوائد الأسهم السعودية، ليفسر بنجاح هذا التباين حين تم استخدام الأسعار الأسبوعية، نظراً لكون العائد الضمني على المحفظة ذات القيمة الصفرية لمعامل بيتا قليل جداً مقارنة بالعائد على الآليات الاستثمارية الخالية المخاطرة. هذا، ولوجود عنصر واحد كما استنتجته الدراسة في تفسير هذا التباين، ليعطي دلالات للمؤسسات وإدارات الصناديق الاستثمارية، وكذا المستثمرين الآخرين، فيما يتعلق بطلب الحماية من تلك التقلبات وتفعيل الآليات الاستثمارية المناسبة لذلك.

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