# On the Unconditional and Conditional Cross Section of Expected Futures Returns

A thesis submitted for the degree of Doctor of Philosophy

by

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**A mes Parents**

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# Abstract

While most of the literature on asset pricing examines the cross section of stock and bond returns, little attention has been devoted to the analyse of the trade-off between risk and return in futures markets. Since, alike stocks and bonds, futures contracts qualify as investments on their own, the purpose of this thesis is to remedy this problem by addressing three issues related to the unconditional and conditional cross section of expected futures returns. Chapter II investigates the presence of a futures risk premium and, ultimately, the validity of the normal backwardation theory in the context of constant expected return asset pricing models and argues that the inconsistency in the literature stems from methodology problems that might result in incorrect inferences regarding the applicability of the normal backwardation theory. With methodologies free from these problems, we show that, while producers and processors of agricultural commodities transfer their risk to one another at no cost, hedgers are willing to pay a premium to induce speculators to enter financial and metal futures markets. Chapter III looks at the integration between the futures and underlying asset markets. While we fail to reject the hypothesis that the prices of systematic risk in futures markets are equal to those in the underlying currency and equity markets, we present new results that the futures and commodity spot markets are segmented. Such results are of primary importance to investors who use constant expected return asset pricing models to adjust the risk-return trade-off of their portfolio and evaluate portfolio performance. The remainder of the thesis investigates the degree of efficiency with which futures contracts are priced. Since futures returns are predictable using information available at time t-1, the purpose of chapters IV, V, and VI is to analyse whether the variation in expected futures returns reflects rational pricing in an efficient market or is the result of weak-form market inefficiency. In this respect, chapter IV investigates the profitability of a trading rule based on available information and concludes that the implemented investment strategy does not generate any abnormal return on a risk and transaction cost adjusted basis. Chapter V looks at the link between the time-varying futures risk premia and the economy and demonstrates that the information variables predict futures returns because of their ability to proxy for change in the business cycle. Finally, chapter VI makes use of time-varying asset pricing models to analyse the relationship between the predictable movements in futures returns and the conditional cross section of expected futures returns. The results indicate that conditional versions of asset pricing models capture most of the predictable movements in futures returns. Hence the predictability of futures returns seem to mirror the change in the consumption-investment opportunity set over time. Chapters V and VI also raise some interesting observations that have not been evidenced to date in the literature on predictability. First, the time-variation in the expected returns of currency and agricultural commodity futures is not consistent with the evidence from the stock and bond markets and with traditional theoretical explanations of the trade-off between risk and expected return. Second, chapter VI demonstrates that shift in the sensitivities of futures returns to the constant prices of covariance risk accounts for most of the predictable movements in futures returns. This result is somehow surprising since the change in the prices of risk is the main source of predictability in the stock and bond markets.

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# Introduction

Futures contracts were first introduced to enable farmers to lock in today the price at which they could sell their crop when harvested. Simultaneously processors started to use futures as a way to hedge against adverse fluctuations in the price of raw materials. Hedging, as defined in the early days of trading, is the practice of offsetting the risk of cash price fluctuations by taking an equal but opposite position in futures markets. Although the early notion of hedging has changed (the later concept of hedging realistically assumes that hedgers base their futures position on their expectation of the future spot price), futures markets are still considered as the marketplace where businesses can protect themselves against price fluctuations that might adversely impact on the profitability of their business.

As well as being useful hedging instruments, futures over the years have become investments on their own and are now considered as effective tools for passive and active portfolio management, arbitrage, speculation, portfolio diversification, and risk management. They are usually considered as a cheap and highly liquid investment and as a quickly implemented and highly levered alternative to investing in stocks and bonds. Given their advantages, it is not surprising then to notice that there has been a rapid growth in the type of contracts (futures are now traded not only on the traditional agricultural commodities but also on precious metal, Treasury securities, foreign currencies, as well as stock indexes), in the number of futures (in the United States alone, more than one hundred contracts were traded in 1992 (Battley (1993)), and in the volume of trading (over the period 1972-1986, the volume of futures contracts traded on the Chicago Board of Trade grew from more than 18 million to over 184 million).

Since, alike stocks and bonds, futures contracts qualify as investments, it is unexpected to notice that so little attention has been devoted to the pricing of systematic risk in futures markets, while, in the meantime, so much research was done in an attempt to explain the cross sectional variation in stock and bond returns. Similarly, over the past decade, one widespread area of research in the stock and bond markets has been to analyse the presence of time-varying risk premia and its implications in terms of market efficiency. Little attention (if any) however has been dedicated to the issue of whether this analysis extends to futures markets. My guess is that this limited interest in the pricing of futures contracts reflects the then prevailing belief that futures and equity prices are driven by the same common forces.

The purpose of this thesis is to remedy this problem by providing a thorough analysis of the trade-off between risk and return in futures markets, the efficiency of futures markets, and the conditional cross section of expected futures returns. In this respect we make use of both constant and time-varying expected return asset pricing models (such as the capital asset pricing model (CAPM) of Sharpe (1964) and the arbitrage pricing theory (APT) of Ross (1976)) and address three issues. Chapter II investigates the presence of a risk premium in futures markets and, ultimately, the validity of the normal backwardation theory. Chapter III looks at the integration between the futures and underlying asset markets and explains the importance of this assumption with respect to portfolio allocation, performance and risk assessment. Finally, chapters IV, V, and VI investigate the degree of efficiency with which futures contracts are priced.

There has been an ever lasting debate in the futures pricing literature over the presence of a risk premium in futures markets. The general message is that producers and processors of the underlying assets transfer the risk of price fluctuation to speculators who are willing to undertake it in exchange for the possibility of huge profits. Hence one way to test for the applicability of the normal backwardation theory is to search for a significant futures risk premium in an asset pricing framework. Chapter II attempts to explain why the evidence presented thus far failed to provide any unconditional inference on the validity of the normal backwardation theory. We argue that the failure of the previous tests to identify significant risk premia in futures markets stems from methodology problems. Most studies indeed investigate the presence of futures risk premia by simply regressing futures returns on the market portfolio returns or on common sources of pervasive risk and thereby assume that the rewards per unit of systematic risk are the same across markets. More research on the uniformity of the factor structure across markets is therefore needed before any valid inference can be drawn from these studies on the validity, or otherwise, of the normal backwardation theory. Alternative studies of the risk-return relationship in futures markets use the two-step methodology of Fama and MacBeth (1973) and therefore tackle the problem present in the time series tests of wrongly assuming market integration. However this methodology assumes that futures returns follow a strict factor model, introduces an error in variable problem, and does not consider the endogenous nature of the market portfolio. As such, it might also lead to incorrect conclusions regarding the applicability of the normal backwardation theory. In chapter II we thoroughly study the trade-off between risk and return in futures markets and make use of two methodologies that are free from the problems mentioned in the time series tests and in the two-step methodology. Consequently we hope to offer some clear inferences as to whether or not hedgers are willing to pay a premium to induce speculators to enter futures markets.

In chapter III we investigate the integration between the futures and underlying asset markets and test the hypothesis that the sources of systematic risk in futures markets coincide with the risk premia identified in the commodity, currency, and equity spot markets. Whilst most studies look at the integration between the futures and equity markets, we offer some novel evidence regarding the integration between the futures markets on the one hand and the commodity and currency spot markets on the other hand. As we demonstrate, such results are of primary importance to market participants who rely on constant expected return asset pricing models to adjust the risk-return trade-off of their portfolio and evaluate portfolio performance.

The remainder of the thesis addresses the issue of weak-form efficiency in futures markets. Understanding the implications of market efficiency is of primary importance to futures market participants. If futures markets are weak-form efficient, market participants can rely on futures prices since they are accurate estimates of the intrinsic value of the futures contracts. In this scenario, futures prices represent rational assessments of fundamental values and speculation, hedging, and arbitrage decisions can be based on current estimates. On the other hand, if futures markets are weak-form market inefficient, caution should be the rule while looking at futures prices since noise traders might deter them from their intrinsic values. If this is the case, futures market participants should attempt to guess the next moves of naive traders before making any speculation, hedging, and arbitrage decisions.

Given the importance of this issue, the purpose of the three last chapters is to examine the degree of efficiency with which futures contracts are priced. In this respect, we undertake three sets of tests that have been the subject of a comprehensive debate in equity and bond markets but that have received very little attention in futures markets. As should be expected if markets set prices rationally, the evidence from the stock and bond markets should extend to other markets such as the futures markets. Ultimately our purpose is to answer the following question: Does the predictability of futures returns reflect weak-form market inefficiency or rational variation in the preferences of economic agents for consumption and investment? While answering this question, we investigate some of the issues that are the foundation of the modern theory of finance. In particular, we look at the relationship between (1) time-varying futures risk premia and (2) the economy and conditional asset pricing.

The hypothesis we test in chapter IV follows from the definition of weak-form market efficiency itself. As defined by Fama (1970, page 383), "a market in which prices always "fully reflect" available information is called efficient". If one extends the early notion of past information (that focused on the past sequence of prices) to any available information, the above definition implies that no trading rule is capable of generating abnormal returns on a risk and transaction cost adjusted basis. This issue has been the subject of an extensive debate in the stock market and the evidence generally point towards the conclusion that the serial correlation in returns and the predictive power of the information variables are consistent with rational pricing in an efficient market. Little attention however has been devoted to the issue of whether trading rules that rely on *ex-ante* variables are profitable in futures markets.

As a test of the robustness of the conclusion to alternative hypothesis, we investigate market efficiency in chapter V with respect to the hypotheses that the variation through time in expected returns is common across futures markets and is related to business conditions. Doing so, we provide the first formal attempt to model the link between the time variation in expected futures returns and the economy and raise some interesting observations that have not been evidenced in the literature on the predictability of stock and bond returns.

Finally chapter VI investigates whether the pattern of forecastability is consistent with time-varying expected return asset pricing models. We use both the conditional CAPM and the conditional APT to investigate the relationship between the predictable variation in futures returns and the conditional cross section of expected futures returns. We offer the first formal link between the variation through time in expected futures returns (tracked by information variables such as dividend yield, term and default spreads...) and the time-varying risk and risk premia associated with common economic factors (for instance, unexpected change in industrial production, unexpected inflation, shock to the term structure of interest rates, default risk...). Unlike previous studies of conditional expected returns in futures markets, we do not make any strong assumptions regarding the source of return predictability and estimate conditional asset pricing models that allow for time variation in either the covariances, the prices of systematic risk, or all moments. This study is also the first attempt to estimate the proportion of the predictable variance of futures returns captured by conditional versions of asset pricing models and hence provides some clear inference with respect to the issue of market efficiency in futures markets.

In the end, we hope that this thesis will help us understand the link between (1) the predictable variation in futures returns and (2) the economy and the conditional cross section of futures returns. We hope to offer a consistent account of the predictability of futures returns. To motivate and illustrate our purpose in chapters V and VI of this thesis, may I quote Fama (1991, page 1585):

> "My view is that we should deepen the search for links between time-varying expected returns and business conditions, as well as for tests of whether the links conform to common sense and the predictions of asset-pricing models."

The tests in chapter II are joint tests of the normal backwardation theory and of the traditional CAPM and APT. Similarly in chapter III we test market integration conditional on the validity of the traditional versions of the CAPM and the APT. Chapter IV jointly assumes that the trading rule does not generate abnormal return and that the constant and time-varying expected return multifactor models are correctly specified. Finally, chapter VI tests market efficiency jointly with the hypothesis that time-varying asset pricing models capture all the predictable movements in futures returns. Given the joint hypothesis problem, it then becomes impossible to unambiguously say whether rejection of the null hypothesis results from (1) the use of a misspecified model of asset returns (and hence from the theoretical and empirical limitations of our knowledge on asset pricing) or (2) a failure of Keynes (1930) theory, market segmentation, or market inefficiency. Fama (1991) however argues that the joint hypothesis problem does not render any research useless. The empirical work that relies on joint hypotheses has indeed been a major improvement in our understanding of the time series and cross sectional behaviour of asset prices. Thus, even if it runs head-on into the problem of joint hypothesis, we believe that this thesis is a major attempt to understand the ways in which futures prices are set. Since we make use of asset pricing models to test the normal backwardation theory, market integration, and market efficiency, this thesis begins with a review of the literature on constant and time-varying expected returns asset pricing models.

# Chapter I: Constant and Time-Varying Expected Return Asset Pricing Models: A Review

## I. Introduction

Academic research for more than three decades has attempted to describe the cross section of expected returns. The general idea of modern portfolio theory is that it is the covariance of an asset's return with some variables, rather than the total variance of returns, that is meaningful to risk-averse investors holding well-diversified portfolios. These studies relate the expected return on an asset to the covariances between its returns and (i) the return on the market portfolio (in the capital asset pricing model (CAPM) of Sharpe (1964)), (ii) the factors extracted from the covariance matrix of returns (in the factor and principal component analyses emanating from the arbitrage pricing theory (APT) of Ross (1976)), (iii) some measures of macroeconomic and financial activity (Chen, Roll, and Ross (1986)), and (iv) a measure of aggregate consumption (in the consumption CAPM derived by Breeden (1979)). While all these models rely on the assumption that the sensitivity of an asset's return to some systematic sources of risk, as well as the prices of risk present in the market, are constant, more recent developments in the theory of finance incorporate the fact that expected returns are time-varying. The purpose of this chapter is to thoroughly review the theory and empirical evidence on constant and time-varying expected return asset pricing models. Sections II and III focus on the traditional CAPM and APT. Section IV looks at the predictability of stock and bond returns, addresses the issue of market efficiency, and discusses the recent developments on time-varying expected return models. The relevance of the asset pricing literature to our research is presented in section V.

## II. The Capital Asset Pricing Model

### 1. Derivation

Assuming the existence of a risk-free rate of return at which all investors can borrow or lend unlimited amounts of money and given the traditional assumptions of perfect capital markets, risk-aversion, and homogeneous expectations regarding the two-parameter probability distribution of asset returns, Sharpe (1964) derives the capital asset pricing model (CAPM), which is a simple model of market equilibrium that quantifies and prices risk.

The derivation of the CAPM follows from Markowitz's (1959) work on mean-variance efficiency, from the two-fund separation theorem, and from the assumptions mentioned above. Let us assume that we construct a portfolio with $\omega_i$ percent invested in asset i and $(1-\omega_i)$ percent invested in the market portfolio M. By definition, the mean and standard deviation of the portfolio respectively equal

$$E(R_p) = \omega_i E(R_i) + (1-\omega_i)E(R_M)$$
$$\sigma_p = \sqrt{\omega_i^2\sigma_i^2 + (1-\omega_i)^2\sigma_M^2 + 2\omega_i(1-\omega_i)\mathrm{cov}_{iM}}$$

E(.), $\sigma^2$, $\sigma$, and cov represent the mean, variance, standard deviation, and covariance operators respectively, $\omega_i$ is the proportion of total wealth invested in asset i, and $R_j$ is the return on asset j. For any combination of the asset i and the market portfolio M, the slope of the tangent of the minimum variance opportunity set IMI' equals

$$\frac{\delta(E(R_p))}{\delta(\sigma_p)} = \frac{\delta(E(R_p))}{\delta\omega_i} \Big/ \frac{\delta(\sigma_p)}{\delta\omega_i}$$

where $\delta(X)/\delta\omega_i$ represents the first derivative of X with respect to $\omega_i$. Hence, the numerator and denominator of the slope of the locus of efficient portfolios is equal to

$$\frac{\delta(E(R_P))}{\delta(\omega_i)} = E(R_i) - E(R_M) \tag{1.1}$$

$$\begin{aligned}\frac{\delta(\sigma_P)}{\delta(\omega_i)} = \frac{1}{2}&\left[\omega_i^2\sigma_i^2 + (1-\omega_i)^2\sigma_M^2 + 2\omega_i(1-\omega_i)\mathrm{cov}_{iM}\right]^{1/2} \\ &*\left[2\omega_i\sigma_i^2 - 2\sigma_M^2 + 2\omega_i\sigma_M^2 + 2\,\mathrm{cov}_{iM} - 4\omega_i\,\mathrm{cov}_{iM}\right]\end{aligned} \tag{1.2}$$

Sharpe notices that the market portfolio already contains asset i in proportion $\omega_i$ and therefore, in equilibrium, prices must adjust until the excess demand for asset i, $\omega_i$ in the above equations, equals zero. Hence, setting $\omega_i$ equal to zero in (1.1) and (1.2), the slope of the tangent to the minimum opportunity set IMI’ at point M equals

$$\frac{\delta(E(R_p))}{\delta(\sigma_p)} = \frac{E(R_i) - E(R_M)}{\left(\mathrm{cov}_{iM} - \sigma_M^2\right)/\sigma_M}$$

Finally since the slope of the tangent to IMI’ at point M must equal the slope of the capital market line, we have

$$\frac{E(R_i) - E(R_M)}{\left(\mathrm{cov}_{iM} - \sigma_M^2\right)\,\sigma_M} = \frac{E(R_M) - R_F}{\sigma_M}$$

where $R_F$ is the return on the risk-free asset. The CAPM equation then follows

$$E(R_i) = R_F + \frac{\mathrm{cov}_{iM}}{\sigma_M^2}\left(E(R_M) - R_F\right)$$

$$E(R_i) = R_F + \beta_i(E(R_M) - R_F) \tag{1.3}$$

where $E(R_i)$ is the expected rate of return on any risky asset i held in a diversified portfolio, $\beta_i$ is the quantity of risk measured through the asset's beta, and $E(R_M) - R_F$ is the price per unit of market risk.

## 2. Early Empirical Tests

Early empirical tests of the CAPM assume that the proxy of the market portfolio employed in the tests is mean-variance efficient and focus on the properties of the security market line. Namely, the hypotheses tested look at whether the relationship between risk and average returns is positive and linear, whether the intercept term of this relationship is equal to the actual risk-free rate of return, and whether beta is the only information required to price an asset.

Black, Jensen, and Scholes (1972) estimate each asset's beta over a five year period, form ten portfolios based on these pre-ranking betas, and estimate the beta of each portfolio by regressing the actual excess return on each portfolio on the market portfolio excess return. The results indicate that the intercepts of these regressions are significantly negative for the high-beta portfolios and significantly positive for the low-beta portfolios. Hence, low (high) beta securities offer an average return that is higher (lower) than the level predicted by the CAPM. A plot of the betas against the average excess returns on the ten portfolios suggests that, consistent with the predictions of the CAPM, there is a linear upward sloping relationship between risk and return. However, over the estimated sample, the slope coefficient of this relationship differs from the expected excess return on the market portfolio and the intercept term is significantly positive. On the basis of these tests, Black, Jensen, and Scholes reject the traditional version of the CAPM in favour of the Black (1972) 's more general version (that does not assume riskless borrowing opportunities).

Fama and MacBeth (1973) test three implications of the two-parameter model. First, they investigate whether the risk-return relationship presents any sign of nonlinearity by including the square of beta in the cross sectional stage of their analysis. Second, they test whether residual risk (as measured by the residuals standard deviation) is priced once systematic risk has been accounted for through beta. Third, they check whether, as implied by the model, the trade-off between risk and return is positive. The results are consistent with the two-parameter model: the relationship between risk and return is positive and linear and residual risk does not command a risk premium. Consistent with Black, Jensen, and Scholes (1972), Fama and MacBeth (1973) however notice that the cross sectional estimate of the intercept term significantly exceeds the return on the risk-free asset. Blume and Friend (1973) report similar results.

The traditional tests of the CAPM have been criticised by Roll (1977) who notices that the only testable hypothesis is the efficiency of the true market portfolio. He argues that previous empirical results are tautological and inconclusive as the properties of the security market line directly follows from the mean-variance efficiency of the portfolios used as a proxy of the true market portfolio. With a sample efficient proxy, the linear relationship between risk and return will always be observed ex-post and the price per unit of market risk will always be positive. This however does not mean that the CAPM is valid, it just means that the selected proxy is mean-variance efficient with respect to the sample analysed. Similarly, if the proxy used in the test is not mean-variance efficient, the properties of the security market line will not be supported empirically. This does not mean that the CAPM is not valid, it just means that the proxy of the market portfolio is not the true market portfolio. Testing the CAPM thus involves a joint hypothesis regarding both the validity of the model and the mean-variance efficiency of the true market portfolio.[1] Unfortunately, Roll reckons that the true market portfolio is impossible to construct. Since any unambiguous test of the CAPM should address the critical issue of the identity of the true market portfolio, it is very unlikely that such a test be ever implemented.

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[1] Black, Jensen, and Scholes (1972), Fama and MacBeth (1973), and Blume and Friend (1973) results - that the intercept term significantly exceeds the risk-free rate of return - do not therefore necessarily invalidate the CAPM. Their conclusions could simply suggest that the proxies used are not the true market portfolio.

Living with Roll's critic, Stambaugh (1982) tests whether the conclusions about the CAPM are sensitive to the proxies of the market portfolio used. He concludes that the composition of the market proxy does not seem to alter the inferences about the CAPM. Even with a proxy that includes as little as 10 percent of stocks, the tests reject the Sharpe 's version of the CAPM and support the more general two-parameter model of Black. Since Stambaugh ignores many assets - such as human capital or non-US investments - in the composition of his proxies, it might still be the case however that proxies that more closely mimic the true market portfolio produce different inferences about the two-factor model.

Shanken (1987) argues that, in spite of the unobservability of the true market portfolio, the CAPM is testable assuming some prior belief of the correlation between the true and proxy market portfolios. His test relies on the joint hypothesis that the CAPM is valid and that the correlation between the true and proxy market portfolios at least equals 0.7. The hypothesis that the proxy used is the tangency portfolio assumed by the CAPM is rejected with 95 percent confidence. Hence, either the CAPM is false or the proxy used accounts for less than $0.7^2$ (49 percent) of the variation in the true market portfolio.[2]

## 3. Empirical Anomalies

As mentioned previously, the CAPM predicts that the return on the market portfolio is the only source of priced risk. One way to challenge the CAPM consists therefore in testing whether firm-specific variables explain the cross section of stock returns too. Under the null hypothesis that the CAPM is valid, the risk premium associated with these variables should not significantly differ from zero and beta should account for all of the variation in expected returns.

To test whether firm-specific variables explain the cross section of expected returns, the general approach consists in forming portfolios on the basis of some firm-specific information such as earning price ratio (E/P), firm size, debt to equity ratio, and/or book-to-market value.

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[2] Shanken's results are however disputable as one can never be certain of the degree of correlation between, say, non-marketable assets and the true market portfolio.

Then one of the three following methodologies is employed. The first approach consists in restricting the betas of the firm ranked portfolios to be equal to one. In such a case, since the low and high sorted portfolios have the same degree of systematic risk, the null hypothesis is that their expected returns should also be identical (see, for example, Reinganum (1981a)). Alternatively, one can add an intercept term (similar to Jensen (1968) 's measure of abnormal performance) to the regression of the portfolio's excess return on the excess return on the market portfolio. Under the null hypothesis that the CAPM is a valid representation of the risk-return relationship, the intercept terms across portfolios should be jointly equal to zero (see, for example, Basu (1977, 1983)). Finally, the third and probably most famous approach consists in using the Fama and MacBeth (1973) methodology to determine which factors have explanatory power with respect to the cross section of realised returns (see, for example, Banz (1981), Reinganum (1982), Bhandari (1988), Chan and Chen (1991), Fama and French (1992), Davis (1994), Kothari, Shanken, and Sloan (1995)).

The results from such tests suggest unambiguously that the CAPM fails to describe the cross section of expected returns. These effects have been named consequently as "anomalies". For example, the return on a high E/P portfolio significantly exceeds the return on a low E/P portfolio on a risk-adjusted basis (see, for example, Basu (1977) and Reinganum (1981a)). Similarly, a positive abnormal return can be earned by investing into a portfolio of low size securities. Since these patterns persist over several months, the E/P and size anomalies probably result from some kind of misspecification of the CAPM rather than from some form of market inefficiency (Reinganum (1981a)). Reinvestigating the size and E/P anomalies, Basu (1983) constructs five size portfolios that are randomised with respect to E/P and five E/P portfolios that are randomised with respect to size. He then notices that, while the size effect disappears, the E/P anomaly persists even after accounting for beta and size. The E/P effect therefore subsumes the size anomaly. Studying the relationship between beta, leverage, size, and expected returns, Bhandari (1988) concludes that there is a positive (negative) relationship between expected returns and debt to equity ratios (size). He also finds that the relationship between expected returns and betas is positive only in January (in February to December, the relationship is flat). Keim (1990) reports that, while the size effect is only significant in January, the E/P anomaly is observed across all months.

In spite of the damages they caused on the validity of the model, these anomalies were not considered as a serious concern until Fama and French (1992) cast doubt onto the validity of beta as a measure of systematic risk. Fama and French formally study if beta, size, book-to-market value, E/P, and leverage explain the cross section of average returns. In this respect, they construct 100 size-pre ranking beta portfolios, where each stock was first assigned to one of ten size-ranked portfolios and each size decile was then subdivided into ten portfolios on the basis of the pre-ranking betas of each stock. Their main conclusions are twofold. (1) After controlling for size and pre-ranking beta, the relation between average returns and post-ranking betas becomes flat. This contradicts the central prediction of the CAPM, that average stock returns are positively related to beta. In effect, beta does not seem to matter. (2) When securities are sorted into 100 size and book-to-market equity portfolios, "... size ... and book-to-market equity provide a simple and powerful characterisation of the cross section of average stock returns for the 1963-1990 period" (Fama and French (1992, page 429)). Size and book-to-market equity indeed subsume beta, leverage, and E/P in explaining the cross section of average returns.

Kothari, Shanken, and Sloan (1995) however argue that methodology and data problems lead Fama and French to the misleading conclusion that beta is irrelevant. After accounting for these problems, they prove that beta still explain the cross section of expected returns. First, they argue that the results are sensitive to the time interval used to estimate the betas. While Fama and French find that average returns are unrelated to monthly betas, Kothari, Shanken, and Sloan prove, using annual betas, that the price per unit of market risk is significant and that the inference is robust to alternative specifications of the market portfolio, to different time periods, and to various grouping techniques. Second, once size is included in the cross sectional regression, the market portfolio is still priced but the significance level of the risk premium decreases. However beta risk does not seem to be the only priced factor since size has some explanatory power too.[3] Third, Kothari, Shanken, and Sloan notice that the data set

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[3] Note however that the presence of a size effect does not necessarily invalidate the CAPM since it could suggest that the proxy of the market portfolio used in the test is not mean-variance efficient or that size is proxying for some errors in the measurement of beta. The latter hypothesis is however unlikely as Reinganum (1982), among others, reports that the size effect remains even after accounting for measurement errors in betas due to the infrequent trading of small firms.

used by Fama and French (COMPUSTAT) is biased towards historically successful firms and most likely suffers from a survivorship bias that might create a spurious relationship between book-to-market value and expected returns. Using a data set exempt from this problem, Kothari, Shanken, and Sloan prove that book-to-market value poorly explains average stock returns. Davis (1994) also uses a dataset free of survivorship bias, look-ahead bias, and data snooping problems[4] and concludes that book-to-market equity, earning yield, and cash flow yield explain the cross section of average returns.

Since it is unlikely that the explanatory power of the firm-specific variables reflects database and methodology problems, the anomalies presented so far must either reflect rational pricing in an efficient market or result from weak-form market inefficiency. On the one hand, the conclusions might be consistent with the idea that the variables enable investors to identify mispriced securities, thus creating opportunities for abnormal returns. This alternative is however unlikely since the anomalies tend to persist over long periods of time. Therefore one can reasonably postulate that firm-specific variables explain the cross section of average returns because they are mimicking marketwide risk factors that subsume beta.[5] This gives us some incentive to study models that assume a more dissagregate risk structure such as the arbitrage pricing theory (APT) of Ross (1976).

## III. The Arbitrage Pricing Theory

### 1. Derivation

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[4] The survivorship bias arises from the use of historically successful firms. The look-ahead bias might occur if the study assumes that the information was disseminated to the public, when in fact it was not publicly available yet. Finally, the data snooping problem refers to the fact that the same data set (COMPUSTAT) is used to identify the anomaly and further document it. This calls for some new evidence using fresh data. All these biases might create a spurious correlation between average returns and the explanatory variables.

[5] For example, Chan and Chen (1991) argue that size attracts a significant risk premium because it proxies for a distress factor that is more likely to affect small firms. Because small firms tend on average to be marginal firms (in the sense that they are more levered and are more likely to cut down dividends), the size effect is just a proxy for a distress factor that reflects the poor performance of marginal firms.

The APT first derived by Ross (1976) offers an alternative to the CAPM in terms of measuring the expected return on risky assets. It relies on the assumption that the difference between an asset's expected and actual returns can be explained in terms of a systematic component, that reflects the asset's exposure to a small number of common factors, and an unsystematic or idiosyncratic component, which represents industry- or firm-specific risks. In other words, assuming that investors have homogenous beliefs regarding the linear K-factor model that governs asset returns and given the usual assumptions of perfectly competitive and frictionless markets, the asset's de-meaned returns approximate a linear combination of the factors plus its own idiosyncratic disturbance

$$R_i = E(R_i) + B_i F + \varepsilon_i \tag{1.4}$$

$R_i$ represents the random return on asset i, E(.) is the expectation operator, $B_i$ is the K-vector of sensitivities of the asset's returns to the K unpredictable factors F, and $\varepsilon_i$ is an asset specific error term which is assumed to be uncorrelated with the K common factors. More specifically, it is assumed that $E(F) = 0$, $E(\varepsilon) = 0$, $V(\varepsilon) \leq \varsigma < \infty$, $E(\varepsilon / F) = 0$, and $E(\varepsilon' \varepsilon) = \Phi$, where $\Phi$ is the covariance matrix of idiosyncratic return. (1.4) states that any difference between actual and expected return is accounted for in terms of systematic exposure to the unexpected risk factors.

The derivation of the APT from equation (1.4) relies on the no-arbitrage condition which states that in equilibrium a portfolio that requires no additional wealth and has no risk should earn on average no return. Consider an investor who alters the composition of his portfolio. From (1.4), the return on his new portfolio is defined as

$$R_p = \omega E(R_p) + \omega B_p F + \omega \varepsilon_p \tag{1.5}$$

where $\omega$ represents the change in wealth when forming the arbitrage portfolio. We satisfy the condition of no wealth by altering the composition of the initial portfolio so that only the proceeds of sales are used to purchase new shares. Therefore the total wealth of the arbitrage portfolio remains unchanged and $\omega e = 0$, where e is a vector of ones. By definition, the arbitrage portfolio has no risk. We eliminate systematic risk by selecting $\omega$ such as $\omega B_p = 0$ and eliminate unsystematic risk through diversification. This naturally invokes the law of large numbers and implies that investors can invest in a relatively large (in the limit infinite) number of assets N (namely, N is much larger than K). Hence from (1.5) and the no-arbitrage condition, $R_p = \omega E(R_p) = 0$. Since besides $\omega e = \omega B = 0$, the expected return on the arbitrage portfolio is spanned by e and B. Consequently there must exist $\lambda_0$ and $\lambda$ such as

$$E(R_i) = \lambda_0 + \lambda B_i \tag{1.6}$$

$\lambda_0$ is the return on an asset with no sensitivity to the risk factors. If there is a riskless asset, $\lambda_0$ must be its rate of return. $\lambda$ is a K-vector of prices of risk associated with the K pervasive risk factors. It is equal to the risk premium earned on a portfolio with an unique sensitivity to one of the factors and no exposure to the other factors.

Equation (1.6) states that only the part of the asset's return which is correlated with the market-wide factors is compensated by a risk premium. Moreover there is a linear relationship between the expected return on any asset and the sensitivity of its returns to the K pervasive factors that govern security returns. Given that $\lambda$ is the same for all assets, cross sectional differences in expected returns are only due to differences in the assets' exposure to the risk premium vector. In other words, arbitrage guarantees that assets with the same sensitivities offer the same expected returns, as any relative misprising should be accounted for until equation (1.6) approximately holds.[6] Finally, the factor structure implied by equation (1.6) is assumed to price adequately any subset of assets. Therefore the APT implies that an unique factor structure explains the cross sectional variation in assets' return.

## 2. On the Testability of the Theory

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[6] If, for example, two assets with the same factor loadings had different expected returns, short selling the asset with the lowest expected return and using the proceeds to purchase the asset with the highest expected return would constitute an arbitrage opportunity. This process will continue until equilibrium is restored.

The APT has been proposed as a testable alternative to the CAPM as it does not give any particular role to the market portfolio and holds for any subset of assets (see, for example, Roll and Ross (1980), Dybvig and. Ross (1985)). However its testability has still been questioned in the literature on many grounds.

The view that the APT is susceptible to empirical verification has been challenged by Shanken (1982). One of the main implications of the model is that residual risk is eliminated through diversification. In other words, with an infinite set of assets, the model assumes that there exist $\lambda_0$ and $\lambda$ such as the sum of squares of residuals is finite. Thus, following Ross (1976) and Chamberlain and Rothschild (1983),

$$RSS = \sum_{i=1}^{\infty} \left(E(R_i) - \lambda_0 - \lambda B_i\right)^2 < \infty \tag{1.7}$$

However Shanken argues that equation (1.7) will necessarily hold as any empirical test performed on a finite set of assets will result in a finite residual sum of squares. Roll's critique on the empirical testability of the CAPM therefore holds for the APT too. As we cannot measure the whole universe of assets, (1.7) will never be supported empirically. In an attempt to proxy the sum of squares of residuals, Dybvig (1983) shows that the deviation from the APT pricing satisfies the following bound

$$\left|\delta(R_i)\right| < A\sigma^2\alpha_i \tag{1.8}$$

$\left|\delta(R_i)\right|$ is the pricing error measured as the difference between actual and expected returns, A represents the degree of relative risk aversion of the representative investor, $\sigma^2$ the variance of idiosyncratic returns, and $\alpha_i$ the supply of asset i as a proportion of total wealth. Proxying each of the three components in the right hand side of (1.8), Dybvig proves that the bound on returns is less than 0.04 percent on an annualised basis. He concludes that the deviation is trivial enough to be neglected, especially since each of the three elements in the right hand side of equation (1.8) are systematically overestimated. Since we need to consider the whole universe of assets to be able to estimate $\alpha_i$, the proportion of total wealth invested in asset i, one might argue that Roll's (1977) critique (and Shanken's (1982) extension of Roll's argument to the APT) regarding the unobservability of the true market portfolio applies to the bound derived by Dybvig. However any evaluation of $\alpha_i$ using a proxy of the true market portfolio necessarily overestimates the actual value of $\alpha_i$ and therefore the actual pricing error is even smaller that the one estimated by Dybvig (Dybvig and Ross (1985)).

Traditionally researchers tested the hypothesis that if the linear factor model (1.4) holds then expected returns are a linear combination of an unit vector and the factor loadings (as in (1.6)). While a failure to reject this proposition would be consistent with the model, the proposition in itself is not literally an implication of the APT. Consequently rejecting the above proposal does not necessarily invalidate the APT. Shanken (1982) however argues that one of the testable implications of the theory is the uniqueness of the factor structure. He challenges it using two original assets and two transformed assets. The original assets are supposed to follow a one-factor model. The transformed assets are merely a different repackaging of the original assets: the first one is obtained by leaving the first original asset unaltered and the second one is obtained by combining the two original assets so that the returns on the two transformed assets are uncorrelated. Since the transformed assets then conform to a zero-factor model, while the original assets (by assumption) follow a one-factor model, Shanken refutes the uniqueness of the factor structure that underpins the APT. As a reply, Dybvig and Ross (1985) point out that repackaging the original assets into portfolios as in Shanken (1982) substantially increases the idiosyncratic variance of the transformed assets and thus leaves no role for the factor to explain the cross section of the derived portfolios. The transformation therefore violates the basic assumption of a small idiosyncratic variance and destroys the unique factor structure. Had Shanken used transformations that do not exemplify the idiosyncratic variance of the transformed assets, the factor structure would have been preserved.

The theoretical debate surrounding the testability of the APT should not impair the tribute of Ross's contribution to our understanding of the pricing of assets. After all, the validity of any asset pricing model should be based on its ability to explain the cross section of expected returns, not on its testability. The proposition that expected returns can be expressed as a linear combination of an unit vector and the factor loadings has empirical content for market participants interested in timing decisions and portfolio performance evaluation. It is also intuitively appealing in the light of evidence regarding the response of asset prices to economic news.

## 3. Estimation of the Model

The APT does not specify which macroeconomic factors should be included in the return generating process, neither does it tell us how many factors are priced in the economy. Answering the above questions is therefore an empirical issue and there is still some controversy in the literature regarding the number and the nature of the pervasive factors that govern a risk premium in all asset markets. To address these issues, three methodologies are usually used. The two first ones, called factor analysis and principal components, are statistical methods that extract statistically significant factors from the covariance matrix of assets' returns, the third one relies on macroeconomic theory to proxy the unknown APT factors.

### *Strict Factor Structure and Factor Analysis*

Factor analysis is a statistical tool that splits the covariance matrix of assets returns into two submatrices, implicitly recognising that there is no correlation between idiosyncratic returns and the pervasive factors

$$\Sigma = B'B + \Phi \tag{1.9}$$

where $\Sigma$ is the covariance matrix of asset returns, B'B is the covariance matrix of pervasive risk, and $\Phi$ is the covariance matrix of idiosyncratic risk.

The APT, like any pricing model, relies on the assumption that investors hold perfectly diversified portfolios and only require a premium to compensate them for pervasive risk (as idiosyncratic risk can be diversified away). Hence firm-specific risk should not be priced in an economy with no arbitrage opportunities and diversification across a large number of assets should ensure that $\Phi$ is diagonal. That is, there is no correlation between the idiosyncratic components of the covariance matrix of returns and the diagonal elements of $\Phi$ are bounded; i.e., the variance of idiosyncratic return is finite. Hence, $\operatorname{cov}(\varepsilon_i \varepsilon_j) = 0$ and $\sigma^2(\varepsilon_i) \leq \varsigma < \infty$. This version of the APT has been named a strict factor model.

In an attempt to define the number of factors that explain the cross section of realised returns, researchers traditionally used a two-step procedure that is in the spirit of the Fama and MacBeth (1973) methodology. In the first step, a maximum likelihood factor analysis is performed on the covariance matrix of a group of asset's returns in order to simultaneously estimate the matrix of loadings B'B and the matrix of idiosyncratic risk $\Phi$.[7] The return generating process thereby estimated produces estimates of the factor loadings that are used in the second stage to explain the cross sectional variation in security returns. A test of joint significance is then performed to examine the statistical significance of the resulting vector of risk premia. Applying this procedure to the covariance matrix of US stock returns, Roll and Ross (1980) find that three, possibly four, factors are priced, while Brown and Weinstein (1983) show evidence in favour of three to five pervasive sources of risk. Chen (1983) reports that five factors explain the cross section of US returns.

Some problems, identified by Roll and Ross (1980, 1984) and Dhrymes, Friend, and Gultekin (1984) - hereafter DFG -, however remain when estimating a strict factor model. First, the matrix of factor risk is subject to rotational indeterminacy. The factor loadings are only determined up to left multiplication by any orthogonal matrix Q. For example, the result of factor analysis would be unaltered if B in (1.9) was replaced by QB. In other words, we just select one factor structure as the relevant one but alternative estimates of B'B would yield equally accurate security pricing. It is therefore impossible to test the significance of a specific risk premium and only a test of joint significance of the vector of risk premia, such as the F-

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[7] The basic approach consists in testing the significance of the remaining N-K roots of $\Sigma$ after the extraction of the first K factors. If security returns follow a strict K factor structure, the remaining roots should not add any explanatory power to the model and can be statistically ignored.

test, the asymptotic $\chi^2$-test or the Hotelling $T^2$-statistic, is appropriate. There is also no guarantee that the same factors are priced in different groups. For example, the first factor in group 1 could coincide with the third factor in group 2 and could well not be priced at all in group 3. It is therefore meaningless to try and attach any economic interpretation to the factors.

DFG (1984) underline a second pitfall in factor analysis present in Roll and Ross (1980) seminal paper: partitioning the universe of securities into small groups cannot yield the same result as if the whole universe of assets was considered. Assuming that the size of the group does not matter actually implies that the covariations between the returns on the assets not considered in the sample can be ignored, as if these assets were not sensitive to the common sources of risk hypothesised by the model. This result obviously conflicts with the basic predictions of the APT. As an answer, Roll and Ross (1984) reply that they had to consider subsets as it is beyond computer and human abilities to factor analyse the whole universe of assets.

A further problem inherent in factor analysis is, as DFG notice, that the number of extracted factors increases as both the number of securities and the length of the time series increase. For example, a two factor structure seems to be appropriate when factor analysing groups of 15 securities, while a three, four, and nine factor model would more accurately price groups of 30, 45, and 90 securities respectively. The results of factor analysis seem then to be very sensitive to the size of the group of securities being considered. This result conflicts with the predictions of the APT which assumes the uniqueness of the factor structure. As a reply, Roll and Ross (1984) explain that, as the number of securities increases, non priced factors are extracted while partitioning $\Sigma$ into B'B and $\Phi$ as in (1.9). To illustrate this point, they give the following example:

> "Suppose that a group of 30 securities contains just one cosmetics company. Factor analysis produces, say, three significant factors. Now add a 31st company, a second cosmetics producer If the time series sample is large enough, we would

> certainly anticipate finding a fourth significant factor, a factor for the cosmetic industry." (Roll and Ross (1984, page 349)).

This fourth (industry-specific) factor might affect many firms within the same industry but is not broad enough to explain variation in expected returns across industries. Therefore it should not be considered as a pervasive source of uncertainty and should not be priced in a diversified portfolio. As a result the only concern should be whether the number of factors priced in the second stage of the analysis - and not the number of factors extracted through factor analysis - increases with the size of the group. Testing this hypothesis, Dhrymes, Friend, Gultekin, and Gultekin (1985) find that the number of priced factors does increase with the number of securities considered in the sample. Of course, the uniqueness of the factor structure that underpins the APT implies that the number of factors identified in the second stage of the analysis is invariant to the sample considered. More than discrediting the APT as a theoretical model, these tests largely question the ability of factor analysis to identify the number of priced factors and detect the relevant factor structure of security returns.

As a solution to the above problem, Cho (1984) proposes to use maximum likelihood inter-battery factor analysis. This approach consists in extracting only the factors priced between two groups of securities (i.e., we no longer consider the return covariance matrix of each group but only the inter-group correlation matrix). Hence inter-battery factor analysis only picks out those factors that are present in the two groups of securities and omits the ones that are only priced in one group. With stocks sorted according to their industry classification, this approach therefore rules out the risk of extracting industry-specific factors and guarantees that only market-wide common factors will be selected. Not surprisingly, Cho confirms that the number of priced factors extracted through inter-battery factor analysis does not depend on the number of assets included in the sample. In other words, his results seem to confirm the inadequacy of the traditional factor analysis approach in extracting only market-wide common factors.

### *Approximate Factor Structure and Principal Components*

Chamberlain and Rothschild (1983) propose an alternative methodology, called principal component, to extract the common risk factors from the covariance matrix of returns. They weaken the diagonality assumption imposed on the residual covariance matrix and prove that the APT still holds if we allow for some weak correlations between the idiosyncratic components of the return covariance matrix.[8] Stated differently, Φ is no longer diagonal but a sequence of positive semi-definite matrices. Chamberlain and Rothschild (1983) then look for conditions on Σ that ensure that idiosyncratic risk is diversifiable while factor risk is not. They conclude that, as long as there is a bound on each eigenvalue of Φ, unsystematic risk will be eliminated through diversification. Moreover, as the eigenvalues of the covariance matrix of factor risk B'B grow without bound with the number of assets, only pervasive risk will be priced and security returns will be linearly related to the K factors. This version of the APT has been named an approximate factor structure.

The approximate factor structure offers many advantages over the strict factor model. First, an approximate factor structure is likely to give a more accurate representation of security returns as it will not pick up industry-specific factors as pervasive sources of risk as would a strict factor model. Connor and Korajczyk (1993, page 1264) give the following example:

> "It seems possible that a few firms in the same industry might have industry-specific components to their returns which are not pervasive sources of uncertainty for the whole industry. For example, awarding a defence contract to one aerospace firm might affect the stock prices of several firms in the industry. Assuming a strict factor structure would force us to treat this industry-specific uncertainty as a pervasive factor."

To overcome the risk of considering industry-specific factors as systematic sources of risk, tests of the APT should preferably be undertaken in the context of an approximate factor structure. In addition, as a strict factor model may select too many factors, a proof in favour of

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[8] Factor analysis makes the unrealistic assumption that Φ is diagonal and implicitly recognises that there is no industry-specific unsystematic source of uncertainty. Since the APT only requires that the number of assets be large enough for the law of large numbers to apply, the strict factor model imposes too severe restrictions on the matrix of idiosyncratic risk.

at least one eigenvalue is a stronger evidence in favour of the APT than the same conclusion with respect to one factor.

Second, Shukla and Trzcinka (1990) notice that the approximate factor structure solves the problem of rotational indeterminacy. Therefore the first principal component in one group of securities corresponds to the first principal component in another group and the t tests on any specific risk premium provide some insight as to whether a specific component is priced.

Third, as mentioned by Chamberlain and Rothschild (1983), we do no longer need to estimate $\Phi$ to determine the number of priced factors. Security returns follow an approximate K factor structure if exactly K eigenvalues of the sample covariance matrix increase without bound with the number of assets while all the other eigenvalues are bounded. A test for the appropriate number of factors therefore simply involves looking at the behaviour of the eigenvalues of the sample covariance matrix of relatively wider groups of securities. Although the procedure may look straightforward, there is no consensus regarding the number of principal components that govern an approximate factor structure. Luedecke (1984) and Trzcinka (1986) find that, whereas the first eigenvalue - probably the return on the equally weighted market portfolio (Connor and Korajczyk (1988)) - seems to dominate all the other ones, all sample eigenvalues increase with the number of securities. Therefore according to one criterion (the dominance of eigenvalues) a one factor model seems to accurately price security returns, while according to another criterion (the rise without bound in eigenvalues) there would not be any strong evidence in favour of a specific number of factors. Nevertheless Trzcinka concludes that, since the first five eigenvalues dominate the return covariance matrix, the return generating process postulated by the APT most probably comprises five factors.

These results have been questioned by Brown (1989) and Connor and Korajczyk (1993) who notice that the true population might still follow a K factor structure although the sample data do not seem to favour any specific number of factors. To prove this, Brown simulates a four factor economy and regresses the twenty first eigenvalues on the number of securities. As the slope coefficients were all significant, he concludes that it is more a property of all sample eigenvalues to increase with the number of assets than a proof regarding the actual process generating security returns. Stated differently, the fact that all of the sample eigenvalues increase with the number of assets should not be interpreted as evidence in favour of a large number of factors. Therefore, instead of looking at the behaviour of eigenvalues, Connor and Korajczyk (1993) propose to analyse the change in the variance of idiosyncratic returns when moving from a K to a K+1 factor structure. If the economy follows an approximate K factor structure, the K+1st eigenvalue should not add any explanatory power to the model as it should only reflect industry- or firm-specific influences not priced in the economy. It follows that the change in the squared idiosyncratic returns when moving from a K to a K+1 factor structure should be zero as the number of assets rises. Connor and Korajczyk (1993) evaluate this proposition for different values of K and find evidence in favour of one to six systematic sources of uncertainty on the NYSE and AMEX markets.

In an attempt to find out which of the two statistical methods the data actually favour, Shukla and Trzcinka (1990) first estimate the eigenvectors and the factor loadings of different size covariance matrices and then run cross sectional regressions of mean returns on the first factor loading, the first five factor loadings, the first eigenvector, and the first five eigenvectors respectively. They also compare the performance of the APT-based measures of systematic risk to the market model betas. The comparison is made on the basis of the explanatory power and the pricing error of each model. The first eigenvector explains the cross sectional variation in mean returns as well as the value-weighted beta and better than the first factor loading or the equally-weighted market beta. Surprisingly, the one vector model also produces lower pricing errors than the five factor or the five vector model. However the multi factor or multi vector models seem to fare better than the single factor or vector models in terms of explanatory power. Altogether the evidence presented in Shukla and Trzcinka (1990) seem to suggest that the approximate factor structure provides a better description of the behaviour of security returns.

Notwithstanding the above problems and difficulties, both the strict and approximate factor structures suffer from the drawback that they do not attach any economic interpretation to the extracted factors. As such they are of little interest to investors willing to speculate on or hedge against a specific market risk factor, say, unexpected inflation. Ever since Chen, Roll, and Ross (1986) seminal paper, various economic and financial measures have been used in an attempt to give an economic and financial content to the factors that underline the APT.

### *Macroeconomic and Financial Factors*

A casual analysis of the stock market or a glance at the economic press reveals that equity prices respond to external forces such as unexpected changes in macroeconomic and financial factors. As a result, factors commonly believed to influence the pricing of a large cross section of assets have been used in an attempt to give an economic content to the APT. Relying on the dividend discount model, Chen, Roll, and Ross (1986) postulate that any macroeconomic or financial shock that affects either the discount rate factor or expected dividends should be priced in the market. Natural candidate include, for example, shocks to the term structure of interest rates, unanticipated change in the default premium, the change in expected inflation, inflation shocks, the innovation in the change in industrial production, unexpected change in oil prices...

To estimate the risk premia associated with these factors, Chen, Roll, and Ross use a variant of the Fama and MacBeth (1973) two-step methodology. In the first stage, a time series of stock returns is used to estimate the sensitivity of asset prices to the prespecified factors. These estimates are then used in the second step to explain the cross section in mean returns and t-tests are performed on the estimated factor risk premia to test for their significance. This methodology however introduces an error in variables (EIV) problem arising from the use of estimated betas instead of actual betas in the second step of the analysis. This might lead to incorrect inferences regarding the pricing of a specific risk factor. The traditional approach to corner this issue consists in grouping securities into portfolios. The risk premia are then more accurately estimated and the risk of wrongly pricing a factor is thereby reduced.

Following this methodology, Chen, Roll, and Ross prove that shocks to term and default spreads, unexpected inflation, the change in expected inflation, and the innovation in the change in industrial production are sources of priced risk in the equity market. They also notice that the results are robust to the inclusion of a market index, a measure of aggregate consumption, and unexpected change in oil prices: once the macroeconomic and financial factors mentioned above are included, the return on the market portfolio, the innovation in per capita consumption, and the unexpected changes in oil prices do not command a significant risk premium. Chan, Chen, and Hsieh (1985) find that investors require a reward for exposure to unexpected inflation, shocks to default spread, and unexpected change in industrial production. Studying the UK stock market, Poon and Taylor (1991) observe that the factors that explain the cross section of US expected returns are not priced in the UK, while Clare and Thomas (1994) conclude that the results are very sensitive to the portfolio ordering technique used.

The studies mentioned so far rely on the Fama and MacBeth methodology and hence suffer from the EIV problem discussed above. To overcome it, McElroy, Burmeister, and Wall (1985) and Burmeister and McElroy (1988) propose to use two classes of non-linear least squares techniques called non-linear seemingly unrelated regression (NLSUR) and non-linear three-stage least squares (NL3SLS). Both techniques are based on a set of non-linear equations that simultaneously estimate the sensitivity matrix and the risk premia vector. As such, they eliminate the risk of obtaining biased estimates of the parameters' standard errors and, thereby, overcome the traditional EIV problem present in the Fama and MacBeth (1973) two-step methodology. They do not require therefore the construction of arbitrary portfolios and provide besides consistent and asymptotically normal estimates of the sensitivities and risk premia. Using NLSUR, McElroy and Burmeister (1988) show that shocks to default spread, a measure of the term structure of interest rates, unexpected growth in sales, a residual market risk factor,[9] and, to a lesser extent, unexpected inflation explain the cross sectional variation in average stock returns.

NL3SLS offers the additional advantage of addressing the issue of the endogeneity of the market portfolio. This problem arises when one considers an APT model with observed as well as unobserved factors (see Burmeister and McElroy (1988)) and proxies the

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[9] McElroy and Burmeister (1988) simply define the residual market factor as the residuals from a regression of the market portfolio on the other pre-specified factors. The rationale for this extra factor is that it may proxy for any omitted variables.

unobserved factors with, say, the market portfolio return. Treating this portfolio as exogenous produces inconsistent parameter estimates. Therefore Burmeister and McElroy propose to use a non-linear instrumental variable estimator that recognises the endogenous nature of the market portfolio. They show that the estimates of the APT prices of risk and sensitivities depend crucially on the assumption of endogeneity of the market portfolio. Stated differently, using NLSUR to estimate an APT model that considers the market portfolio as one of the prespecified factors yields inconsistent estimates of the factor risk premia and incorrect inferences regarding the pricing of a specific risk factor. Such a model should be estimated through NL3SLS.

A further superiority of the non-linear least squares techniques is that it considers the nature of the factor structure in tests of the APT using prespecified pervasive factors. It can be set up so as to restrict the covariance matrix of idiosyncratic returns to be.diagonal, thereby assuming that returns follow a strict factor structure or it can allow for the specification of an approximate factor structure, where the idiosyncratic components of security returns have free covariances across assets. This feature of non-linear least squares is particularly appealing since, as mentioned above, an approximate factor structure provides a better description of the behaviour of security returns than a strict factor structure. Hence restricting the idiosyncratic covariance matrix to be diagonal, as the Fama and MacBeth methodology does, might result in wrong inferences regarding the pricing of a prespecified economic and financial factor.

Testing this hypothesis, Burmeister and McElroy (1988) notice that methods that rely on the assumption that the residual covariance matrix is diagonal produce similar estimates than methods that do not impose the diagonality assumption on the residual covariance matrix. They conclude that "the diagonality of the covariance structure does not seem to be a key issue" (Burmeister and McElroy (1988, page 731)). Using NL3SLS, Garrett and Priestley (1996) however finds that, when they allow for free covariance in the idiosyncratic components of the return covariance matrix, default and exchange rate risks, the unexpected change in industrial production, unexpected inflation, money supply shocks, and the return on the market portfolio are priced in the UK stock market. On the other hand, when a strict factor structure is imposed none of the prespecified pervasive factors carry a significant risk premium. Hence the nature of the return generating process seems to matter. Clare, Priestley, and Thomas (1997) report similar results. They also study the robustness of the APT to two alternative estimation procedures: the Fama and MacBeth (1973) two-step methodology and the NL3SLS proposed by Burmeister and McElroy (1988). They prove that the APT is sensitive to the chosen estimator.

Notwithstanding the above considerations, a further problem that arises while estimating the APT using prespecified pervasive factors comes from the generation of the shocks in the APT factors. One of the crucial assumptions of the APT is that only innovations in the factors are priced. Provided the efficient market hypothesis holds, this sounds quite reasonable: any expected change in the factors should already be incorporated in share prices and should not be associated with a significant risk premium. Therefore only macroeconomic and financial news should be priced in an efficient market.

In an attempt to select unexpected components that meet the requirement of being white noise innovations, three different prewhitening processes have been proposed in the literature. The first approach relies on the implicit assumption that the economic time series follow a random walk and assumes that the rate of change in the variable of interest measures the innovation in the APT factors (see Chan, Chen, and Hsieh (1985) and Chen, Roll, and Ross (1986)). Since the best forecast of a variable is the level that prevails today, this methodology assumes that investors have an information window only equal to two trading periods. As previous information also enters into the decision making process, the rate of change approach cannot accurately generate surprises. Moreover given the highly significant correlation contained in the lags, the unexpected components from the rate of change methodology cannot meet the requirement of providing serially uncorrelated factors (see Clare and Thomas (1994) and Priestley (1996)).

The second approach therefore attempts to remove any serial dependence in the unexpected components generated from the rate of change methodology. The autoregressive time series approach considers the serially uncorrelated error term as the innovation in the APT factor (see Clare and Thomas (1994)). While the derived factors then satisfy the property of being news in the sense that they are serially uncorrelated, the parameters of the model have to be stable over time for the autoregressive methodology to generate innovations. Using recursive estimation and the Chow test, Priestley (1996) however shows that the parameters derived from the autoregressive time series approach are subject to instability.

Since the implied stability in the parameter estimates rules out the possibility that investors update their information set regularly, a third prewhitening process has been proposed that not only provides zero mean, serially uncorrelated factors but also takes into account the learning process followed by investors when making expectations. This approach, called the Kalman filter, therefore estimates parameters that are updated whenever a structural change, such as a change in monetary policy, induces agents to reassess their expectations. As such, it rules out the possibility of agents making systematic forecast errors. Priestley (1996) illustrates the weaknesses of the rate of change methodology and the autoregressive approach in specifying unexpected components and shows that the results from estimating multifactor models are sensitive to the method chosen to specify the factors.

## 4. Other Empirical Implications

The empirical studies mentioned above estimate APT models to define the number and the nature of the pervasive factors. In sum, as postulated by the APT, the results seem to be consistent with the presence of, at least, one priced factor in the return generating process. Using these estimated models as a starting point, attempts have then been made to (1) test the uniqueness of the factor structure that underpins the APT and (2) test the APT against specific hypotheses (such as the own variance, the firm, and the turn-of-the-year effects). We now review these evidence. It is important to remember first that the tests mentioned in this section rely on a joint hypothesis that stipulates that the APT is a valid representation of the risk-return relationship and is correctly estimated. Namely, rejecting the null hypothesis does not necessarily imply the inadequacy of the APT in pricing securities, as any error in defining the trade-off between risk and return may lead to invalid inference regarding the validity of the APT.

### *Tests of the Uniqueness of the Factor Structure*

One of the main predictions of the APT is that the estimated return generating process prices all assets. Namely, the APT states that the same set of pervasive factors explains the cross section of expected returns and hence that the factor structure is unique. As mentioned above, there does not seem to be any consensus regarding the number and the nature of the priced factors. Hence it seems reasonable to question the uniqueness of the return generating process. Some direct tests of the uniqueness of the factor structure have been implemented. Surprisingly enough, these tests seem to support the predictions of the APT.

In the context of a strict factor model, only weak tests of the uniqueness of the factor structure can be undertaken since one cannot guarantee that the same factors are priced across different groups of assets. The intercept term however, equal to the return generated on an investment with no sensitivity to the common factors, is not subject to rotational indeterminacy. Hence a testable hypothesis of the uniqueness of the return generating process consists in testing the equality of the intercept terms across groups of assets. The results of this test are mixed. Using the Hotelling's $T^2$ test, Roll and Ross (1980) find no evidence that the intercepts differ across groups. Using inter-battery factor analysis, Cho (1984) reports similar results and also proves that the intercept terms significantly differ from zero. On the other hand, Dhrymes, Friend, and Gultekin (1984) conclude that the intercepts are equal to zero and significantly differ from the risk-free rate. This result obviously conflicts with the predictions of the APT.

Burmeister and McElroy (1988) offer a more thorough approach to the testing of the uniqueness of the factor structure. The NLSUR and NL3SLS techniques they introduce are based on a set of regression equations that imposes the non-linear restrictions that the prices of risk associated with the factors are equal across assets. The approach consists in testing the validity of the restrictions imposed when moving from the linear factor model (1.4) to

$$R_t = \lambda_0 + B\lambda + BF_t + \varepsilon_t \quad (1.10)$$

((1.10) is obtained by substituting (1.6) into (1.4)). The restrictions that $E(R_t) = \lambda_0 + B\lambda$ are fundamental to the APT. They state that the vector of prices of risk must be the same for all securities. Using 70 randomly selected US stocks, Burmeister and McElroy (1988) fail to reject the APT restrictions.

*Test of the APT against Specific Hypotheses*

Another prediction of the APT is that firm specific variables (such as residual standard deviation, total variance, or firm size) are not priced. These variables have been used in an attempt to challenge the validity of the APT. The methodologies employed in this respect are in the spirit of the CAPM tests mentioned above.

The first unsystematic factor that was investigated is the standard deviation of individual returns. It should not affect security returns as the pervasive component of security returns should be accounted for by the factors while the unsystematic elements should be eliminated through diversification. After correcting for the problem that skewness in the distribution of returns can occasion spurious relationship between sample mean and sample standard deviation, Roll and Ross (1980) notice that total variance carries an insignificant risk premium. Chen (1983) constructs two portfolios with the same factor loadings, the first one including securities with a variance higher than average, the second one containing low variance securities. Since the two portfolios have insignificantly different returns, he concludes that own variance adds no explanatory power to the APT. Lehmann and Modest (1988) estimate the linear pricing relationship implied by the APT as a regression of stock returns on the payoffs of K mimicking portfolios and test whether the arbitrage pricing relationship accounts for well-documented empirical anomalies. Under the joint null hypothesis that the mimicking portfolios are reliable estimates of the factors and that the APT holds exactly, the intercept terms from cross sectional regressions of the own variance portfolios excess returns on the mimicking portfolios betas should jointly equal zero. Lehmann and Modest (1988, page 244) conclude that "the failure to reject the APT pricing restriction suggests that the theory provides an adequate account of the risk and return of the own-variance portfolios" While the studies mentioned so far suggest that own variance is not priced, Dhrymes, Friend, Gultekin, and Gultekin (1985) and Gultekin and Gultekin (1987) find results that are inconsistent with the implications of the APT. They show that own variance and residual standard deviation command a significant risk premium in the second stage of the factor-analytic approach and that the vector of factor risk premia becomes insignificant once own variance and residuals standard deviation are added to the model.

Since the ultimate relevance of any asset pricing model lies on its ability to accurately price security returns, the validity of the APT has been challenged on the ground that it can explain anomalies such as the size and January anomalies. For the size anomaly, it is argued that the APT will be supported empirically if it explains the differences in average returns between small and large firms in terms of risk exposure. Using a methodology similar to the one employed to test for the presence of a own variance effect, Chen (1983) concludes that size ranked portfolios have similar average returns on a risk-adjusted basis. Hence the factor loadings capture the size effect. Chan, Chen, and Hsieh (1985) *use prespecified pervasive* factors to test the hypothesis that the residuals from the small firm portfolio are not statistically different from the residuals from the high firm portfolio. They confirm that the APT explains the size anomaly. Two empirical studies however conclude that the firm size anomaly persists after accounting for risk through the APT factors. First, Reinganum (1981b) groups securities into control portfolios and measure excess returns by subtracting the control portfolio returns to the security returns These risk-adjusted excess returns are used to form ten size portfolios Since all securities within a control portfolio have the same risk characteristics, the excess returns on the small and large firm control portfolios should not statistically differ from zero if the APT is to account for the size anomaly The evidence do not seem to support the APT: the size effect persists even after controlling for APT risk. Second, Lehmann and Modest (1988) find that, as suggested by the size effect, the intercept from a cross sectional regression of the small (large) size portfolios excess returns on the mimicking portfolios betas is positive (negative).

Another anomaly that has been used to challenge the validity of the APT is the turn-of-the year effect. Once again, the rationale behind these tests is that the APT, if valid, should account for January seasonals in security returns in terms of risk exposure. Gultekin and Gultekin (1987) estimate the prices of risk associated with the factors extracted through factor analysis for each calendar month separately and find that the risk premia are only significant in January. They also split the sample into January and non-January months and conclude that, although the APT captures the January seasonal, the relationship between risk and return is flat for the other eleven months. Cho and Taylor (1987) also notice that the risk premia vector associated with the factor analytic approach are more often significant in January than in any other months and that the factors fail to describe the cross section of average returns over the whole sample. Hence the evidence from the US equity market seem to indicate that the APT pricing relationship only holds in January. Reassessing the evidence for the UK stock market, Priestley (1994) first adds to the APT a dummy variable equal to one for the month under investigation and zero otherwise. If the dummy is not significant, the seasonal pattern will be explained by the APT in terms of risk exposure. Second, as any accurate model should explain all and any variations in expected returns, a valid representation of the APT is expected not only to pick up seasonal effects but also to explain the behaviour of security returns in any other month. This hypothesis is tested by comparing the explanatory power of the models that includes and excludes the seasonal data. Using prespecified pervasive factors, Priestley finds that the APT explains the UK seasonality (in January, April, and December) and has explanatory power in nonseasonal months

## 5. The Relative Performance of the CAPM and the APT

Since the ultimate pertinence of an asset pricing model rests on its adequacy to price assets, the APT will supplant the CAPM if it better explains the cross sectional variation in security returns To find out which of the two models the data actually favour, direct comparisons of the models can be undertaken. For example, Chen (1983) proposes to regress actual returns on the fitted returns measured by the CAPM and the APT and to consider the estimated parameters as an indication of which models the data favour. Since the APT coefficient was close to one while the CAPM coefficient was close to zero, the result seems to support the

APT more than the CAPM. An alternative comparison consists in regressing the CAPM residuals on the factor loadings and the APT residuals on the market beta. If the CAPM (APT) is misspecified, the factor loadings (market beta) could explain the variation in the CAPM (APT) residuals. Following this procedure, Chen finds that the factor loadings capture the variation in the CAPM residuals while the market beta does not pick up any variation in the APT residuals. He concludes that the APT performs better than the CAPM. Priestley (1994) reports similar results for the UK.

Another test consists in comparing the ability of both models to explain anomalies. As mentioned above, the APT seems to account for anomalies like the size and January effects better than the CAPM. On these grounds alone, the evidence suggest that the APT should be put forward as the best representation of the trade-off between risk and return. Comparative studies of the ability of the two models to account for such effects have been reported by Lehmann and Modest (1988), Connor and Korajczyk (1988), and Mei (1993). Lehmann and Modest (1988) fail to reject the restriction that the intercepts from cross sectional regressions of the own variance portfolios excess returns on the mimicking portfolios betas is jointly equal to zero. The same test using a CAPM risk adjustment however suggests that the CAPM pricing relationship does not hold. With respect to the size anomaly however, the conclusions are neither in favour of the APT nor in favour of the CAPM since none of the models could explain the differences in returns between small and large firm portfolios. Connor and Korajczyk (1988) compare the ability of the CAPM and the APT to explain the size effect by looking at the sign and the significance level of the mispricings in both January and non-January months. Although it does not totally explain the size anomaly, the five factor model fares at least as well as the equally-weighted CAPM and performs better than the value-weighted CAPM in non-January months. In January months the five factor model has lower mispricing than any of the two specifications of the CAPM. Therefore, even if some statistically significant mispricing remains, the APT seems to capture the size related variation in stock returns better than the CAPM. Mei (1993) reports similar results. Using historical excess returns as proxies for systematic risk, he notices that the CAPM exhibits more mispricing than the APT. Moreover the APT explains up to 42 percent of the cross sectional variation in mean excess returns, while the proxies of the market portfolio only describe up to 28 percent of the same variation. Therefore his results tend to back the APT too.

The literature mentioned so far concentrates on constant expected return asset pricing models. These models explain cross sectional differences in average returns in terms of different exposures to either the return on the market portfolio or some pervasive factors that govern the return generating process of all stocks. In both the traditional versions of the CAPM and the APT it is assumed that the price(s) of risk, as well as the sensitivities, are constant over time. More recently, conditional versions of the traditional asset pricing models have been developped. As explained below these new developments in the theory of asset pricing attempt to explain the predictability of stock and bond returns in terms of time-varying risk and risk premia.

## IV. Market Efficiency and Time-Varying Expected Return Models

### 1. Evidence of Predictable Movements in Stock and Bond Returns

There is considerable evidence that stock and bond returns are predictable. In the early stage research focuses on the predictability of stock returns using past returns. This directly contradicts the then prevailing idea that stock prices follow a random walk. However since the autocorrelation in daily and weekly returns was small, the past sequence of returns could not be used to earn economically significant returns in excess of a buy-and-hold strategy on a transaction cost adjusted basis. Hence the weak form of the efficient market hypothesis (EMH) was then considered as a sustainable hypothesis. Fama and French (1988a) challenge the view that returns are unpredictable using past sequence of returns. They show that stock prices follow a random walk and a slowly mean decaying stationary process and that the presence of the stationary transitory component induces negative autocorrelation in two- to five-year returns. Poterba and Summers (1988) report similar results for long horizon returns and also document the presence of a positive serial correlation in short period returns.[10]

Variables issued from the stock and bond markets have also been used to forecast stock and bond returns. The dividend yield, for example, is assumed to explain expected returns because of the implicit relationship between dividends and discount rates embedded in the dividend discount model. The general message is that stock prices are low relative to dividends when discount rates and hence expected returns are high. Hence a higher than average dividend yield should convey information to the market that stock returns are expected to increase in the future. Testing this hypothesis, Fama and French (1988b) show that most of the slope coefficients of a regression of returns on dividend yields are positive and significant. They conclude that dividend yield captures variation in expected returns.

Alternatively bond market variables, such as term and default spreads, have been proved to measure expected returns. Keim and Stambaugh (1986) show that the predictable variation in stock, bond, and bill excess returns is captured by default spread and two variables from the stock market. Since unconditional stock and bond risk premia are typically higher in January, they further investigate whether the state variables have the same predictive power in January and non-January months. The evidence suggest that the variables contain information about changes in expected risk premia on small firms and low-grade bonds only in January. Campbell (1987) shows that the one month Treasury bill rate and variables measuring the slope of the yield curve at the beginning of the month predict excess stock and Treasury bill returns, the evidence is weaker for Treasury bonds. Chen (1991) reports similar evidence and also documents that production growth predicts stock excess returns.

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[10] Poterba and Summers also argue that the tests of serially independent returns are low in power. The probability of failing to reject the null when it is false exceeds 0.8. This means that there is at least a 80 percent chance of accepting the null hypothesis of serial independence when stock prices contain a transitory AR(1) component.

## 2. Implications in Terms of Market Efficiency

The predictability of stock returns using the past sequence of returns and historical information raises some interesting questions regarding market efficiency. The predictable movements in returns imply either rational variation in expected returns or price deviations caused by noise traders. To tell apart which of the two explanations the data favour, three hypotheses have been tested in the literature. First, if the predictability of stock and bond returns reflect rational pricing in an efficient market, a trading rule based on available information should not generate any return on a risk and transaction cost adjusted basis. Second, under the null hypothesis of market efficiency, the *ex-ante* variables should have parallel effects across markets and should be a good proxy for changes in the business cycle. Finally, if markets are efficient, the pattern of forecastability should be captured by time-varying expected return asset pricing models.

With respect to the first hypothesis, a vast literature summarised in Fama (1970) has with few exceptions been unable to reject the hypothesis of market efficiency. Fama observes that

> "it is unlikely that the small absolute levels of serial correlation that are always observed can be used as the basis of substantially profitable trading systems" (page 394). Therefore he concludes that "the statistical significant evidence for dependence in ... returns ... do not appear to be sufficient to declare the market inefficient" (page 414).

The second type of tests looks at whether the variation in expected returns is related to business conditions and have parallel effect across assets. The evidence suggest that the state variables predict equity returns because they are proxies for recent and future economic activity (Chen (1991)). This in turn suggests that the predictable movements in stock and bond returns are consistent with rational pricing in an efficient market.

Finally, the third type of tests examines whether conditional asset pricing models explain the observed predictability. This line of research relates the variation through time in expected returns to the conditional cross section of expected returns. The general message is as follows: the *ex-ante* variables forecast returns because they proxy for a change in the systematic risk of the asset and/or for a change in the risk premia present in all asset markets. The implications are twofold. First, if conditional asset pricing models capture the variation in expected returns, the predictability of stock and bond returns supports the EMH. Second, the predictability of stock and bond returns rules out the possibility that constant expected returns asset pricing models accurately describe the cross sectional variation in expected returns. Hence the time variation in expected returns offers some incentive to study conditional asset pricing models.

## 3. Time-Varying Expected Returns Asset Pricing Models

If expected returns are not constant, asset pricing models should be rewritten in a conditional framework. This implies that either the risk premia vector, the assets' sensitivities to the prices of risk, or both parameters are changing as functions of the information set available at time t-1. Equations (1.3) and (1.6) then become

$$E(R_{it} / Z_{t-1}) = \lambda_0/Z_{t-1} + (\lambda_t/Z_{t-1})(B_{it}/Z_{t-1}) \qquad (1.11)$$

$E(R_{it} / Z_{t-1})$ is the time t expected return on asset i conditioned on the information set Z available at time t-1, $\lambda_0/Z_{t-1}$ is the conditional expected return on an asset with no sensitivity to the risk factors (if available, it is equal to the conditional rate of return on a risk-free asset), $\lambda_t/Z_{t-1}$ is a K-vector of conditional risk premia associated with the K pervasive factors, and $B_{it}/Z_{t-1}$ is the conditional sensitivity of the return on asset i to the risk factors. In an attempt to explain the predictability of stock and bond excess returns, one can assume that only the factor risk premia in (1.11) are time-varying; alternatively, one can test whether the pattern of forecastability is consistent with a model with time-varying betas; finally, as suggested by equation (1.11), one can examine whether the variation in expected returns implies that all parameters vary with the available information set.

### *Conditional Asset Pricing Models with Time-Varying Prices of Risk*

The specification of a conditional asset pricing model with time-varying risk premia is well motivated only if $\lambda_t / Z_{t-1}$ in (1.11) change with the information set available at time t-1. Using a variant of the two step methodology, Ferson and Harvey (1991) test this hypothesis by regressing the fitted risk premia associated with the Chen, Roll, and Ross (1986) factors on a set of information variables. They confirm that the factor risk premia are predictable using information available at time t-1. Harvey (1989) tests the hypothesis that the price of covariance risk associated with the market portfolio[11] is constant and reports strong evidence against the null hypothesis.

Can the predictable movements in the factor risk premia account for all of the variation in expected returns? One way to examine this hypothesis consists in testing whether stock returns follow a K *latent variable model with constant betas and K time-varying* risk premia. Under these assumptions, the expected excess return on any asset can be expressed as a linear combination of the time-varying risk premia on the K unobserved factors. Hence, equation (1.11) becomes

$$E\left(r_{it} / Z_{t-1}\right) = \sum_{k=1}^{K} \beta_{ik} E\left(\lambda_{kt} / Z_{t-1}\right) \tag{1.12}$$

If we further assume that expectations are linear in the information set (so that $E\left(\lambda_{kt} / Z_{t-1}\right) = \sum_{j=1}^{L} \alpha_{kj} X_{jt-1}$, where X is the L-vector of instruments), (1.12) yields

$$E\left(r_{it} / Z_{t-1}\right) = \sum_{k=1}^{K} \beta_{ik} \left[ \sum_{j=1}^{L} \alpha_{kj} X_{jt-1} \right] \tag{1.13}$$

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[11] The price of covariance risk (also called the reward to covariance risk ratio) is defined as the ratio of the conditional expected excess return on the market portfolio divided by the conditional variance of the market.

(1.13) imposes the non-linear restrictions that $\pi_{ij} = \sum_{k=1}^{K} \beta_{ik} \alpha_{kj}$ on the *ex-ante* model

$$E(r_{it}/Z_{t-1}) = \sum_{j=1}^{L} \pi_{ij} X_{jt-1}.$$

To test for the ability of the K latent variable model to account for the predictable movements in stock and bond excess returns, one first chooses K securities as reference securities and assumes that the expected excess return on these K reference assets are a good proxy for the K time-varying risk premia present in the market. One then tests whether the expected excess returns on the N-K remaining assets can be expressed as a linear combination of the expected excess returns on the K reference securities (as implied by equation (1.13)). If the non-linear constraints hold, a model with K latent variables accurately describes the predictable variation in returns. The model is estimated for different values of K (generally K equals 1, 2, or 3) and the restrictions that the expected excess returns on the remaining assets are related to the expected excess returns on the reference assets through their conditional betas are tested for each value of K.

Following this procedure, Campbell (1987) concludes that latent variable models with one or two time varying risk premia do not account for the variation through time in the expected excess returns on stocks, Treasury bonds, and Treasury bills (captured by the one month Treasury bill rate and variables measuring the term structure of interest rates). This result is at odds with the earlier findings of Gibbons and Ferson (1985) who conclude that a single latent variable model captures the predictable movements in the Dow Jones stock index returns that are related to the lagged returns on NYSE stock index and a Monday dummy variable. Ferson (1990) proves that the restrictions that a single latent variable model captures the variation in expected excess returns on bonds, bills, and stocks are rejected. However he cannot reject the restrictions when K equals two or three. Trying then to give an economic interpretation to the risk the premia are supposed to be a compensation for, Ferson rejects the hypothesis that the latent variables are proxying for change in the risk premia associated with consumption risk and stock market risk. Finally, Campbell and Hamao (1992) use latent variable models to test the integration between the US and Japanese stock markets. The restrictions imposed by a single factor model on the forecasting equation are rejected; hence, the expected excess returns on the two markets are not perfectly correlated and the null hypothesis of market integration is rejected. The presence of common movements in the Japanese and US expected returns however suggests some degree of integration between the two stock markets.

Alternatively, one can test whether the variation through time in the prices of risk associated with the factors accounts for the predictability of returns by allowing the excess returns on the factor mimicking portfolios to vary with the information set available at time t-1. Using this framework, Harvey (1991) tests if the variation in the excess returns on the stock indices of 17 countries is described by an international conditional CAPM with constant betas and time-varying world price of market risk. The restrictions imposed by the conditional CAPM are rejected for only 4 countries. This suggests that for most countries the variation over time in the world price of market risk is a good approximation of the predictability of stock returns. Ferson and Korajczyk (1995) also test whether the variation through time in the excess returns on factor mimicking portfolios explains the predictability of stock excess returns. To proxy for the risk factors they use the Standard & Poor's 500 index, the pervasive economic factors that have been proved to explain the unconditional cross section of expected returns (Chen, Roll, and Ross (1986)), and the first five principal components extracted from the covariance matrix of asset returns. Although the predictability explained by the conditional single and multifactor models represents a large part of the total variation in expected returns, the overidentifying restrictions imposed by the models with constant beta and time-varying risk premia are rejected at conventional significance level for short-horizon returns. Altogether the evidence point toward the conclusion that, although the factor risk premia are changing through time, their stochastic movement might not properly account for the total predictable variation in security excess returns.

### *Conditional Asset Pricing Models with Time-Varying Measures of Risk*

The evidence on return predictability make it attractive to allow for time variation in the assets' sensitivities to the risk factors. Assuming constant conditional factor risk premia enables then to look at the implications of changing betas. Harvey (1989) allows for the conditional covariance of asset returns with the market returns to vary with the information variables. Although there is strong evidence that conditional covariances change over time, the overidentifying restrictions imposed by the conditional CAPM with constant reward to covariance risk ratio and time-varying covariances are rejected. This suggests that the conditional CAPM with time-varying covariances fails to capture the predictable variation in stock returns. Ferson (1989) reports similar results. He concludes that the conditional CAPM and the conditional consumption CAPM with time-varying covariances fail to explain the predictable movements in stocks, bonds, and bills excess returns: the conditional covariances do not fluctuate enough to explain the variation in expected returns related to the one month Treasury bill rate. Using an international conditional CAPM framework, Harvey (1991) models the time-varying covariances of 17 countries' excess returns with the world market excess returns as a function of the information variables available at time t-1. Assuming that the world price of covariance risk is constant, the null hypothesis that the variation through time in conditional covariances explains the predictability of international stock index excess returns is rejected for 12 out of 17 countries at the 5 percent level.

### *Conditional Asset Pricing Models with Time-Varying Moments*

There are convincing evidence that the factor risk premia and the sensitivities are time-varying. However the restrictions embedded in conditional asset pricing models that allow for movements in either betas or the factor risk premia are usually rejected at conventional level. The fact that all of the predictable movements in assets returns are not described in a rational asset pricing framework can be interpreted as a proof against the EMH. Alternatively, the rejection of the restrictions embedded in these models could suggest that the versions of the conditional asset pricing models used in the previous studies are misspecified. Since both the sensitivities and the risk premia appear to change over time, it is intuitively appealing to test whether a version of the conditional asset pricing model that allows for variation in both parameters accounts for the predictable variation in excess returns.

Evans (1994) allows for time variation in the factors' risk premia and in the betas. The former are conditioned on a set of instrumental variables. The latter are modelled from the conditional covariance matrix of securities' and hedge portfolios' excess returns. With the NYSE stocks as a proxy for the hedge portfolio, the results indicate that the conditional asset pricing model does not account for the total variation in the expected excess returns on stocks, bills and bonds. When a corporate bond is considered as an additional hedge portfolio, the conditional asset pricing model fares better for the stocks and bonds portfolios. However there are still some evidence that the time-varying risk premia, combined with the dynamics of the betas, do not capture the whole variance in the expected excess return on two-month Treasury bill. Nor surprisingly then, the conditional model with two hedge portfolios does a good job at tracking the predictable variation in stock and bond returns and only accounts for 5 to 8 percent of the predictable movements in the Treasury bill returns. Evans also notices that the stock market risk premium captures most of the predictability of stock returns, while the expected variation in the returns on fixed-income securities is mostly picked up by the bond risk premium. He also proves that most of the predictable variation in excess returns results from a change in the prices of risk rather than a change in betas. This suggests that models with constant betas and time-varying prices of risk may give a good approximation of the predictable movements in asset prices. Ferson and Harvey (1991) and Ferson and Korajczyk (1995) find similar results.

Harvey (1991) studies whether a conditional CAPM with time-varying expected excess returns, variances, and covariances is a good approximation of the predictable components in world-wide stock returns. Country per country tests reject the null hypothesis for only 4 of the 17 countries considered: the expected variation in stock excess returns in Japan, Norway, Austria, and to a lesser extent, in the US is too wide to be accounted for in terms of time-varying conditional risk premia and time-varying risk exposures. However he fails to reject the overidentifying restrictions for the G7 countries.

Using an international conditional multi factor model, Ferson and Harvey (1993) reports similar conclusions: (1) the variation in expected factor risk premia proxied by global information variables and the movement in betas modelled with local instruments do a good job at capturing the predictable variation in 18 equity excess returns, (2) the variation in the prices of risk associated with the pervasive factors is the primary source of predictability in international equity markets.

Where do these evidence leave us in terms of market efficiency? On the one hand, some could possibly argue that, since all of the predictable variation in returns is not captured by conditional asset pricing models, it is a sign that there is some irrationality in the way prices are set. On the other hand, we cannot possibly expect to explain 100 percent of the predictable variation in returns in terms of rational changes in expected returns. Hence a proof that conditional asset pricing models explain up to 80 percent of the predictability of returns can be interpreted as evidence in favour of the EMH.

## V. Relevance of the Asset Pricing Literature to our Research

The above review presents a thorough analysis of the evidence on constant and time-varying expected return asset pricing models in the stock and bond markets. Such a review is essential to the purpose of this thesis. Our focus here indeed is to make use of traditional and conditional asset pricing models to formally test the normal backwardation theory, the integration between the futures and underlying asset markets, and the efficiency of the futures market.

The first focus that is addressed is the validity of the normal backwardation theory (chapter II). Our research is original in the sense that, as opposed to other studies of the risk-return relationship in futures markets, we make use of methodologies that are free from (1) assumptions regarding the integration between the futures and equity markets implicit in the time series tests and (2) the error in variables problem present in the two-step methodology.

With such methodologies, it is hoped that some clear inferences regarding the notion of normal backwardation will be drawn.

The second purpose of this thesis is to use constant expected return asset pricing model to test the integration between the futures and underlying spot markets (chapter III). The issue of market integration is investigated with respect to the hypothesis that the prices of risk in futures markets coincide with the prices of risk identified in the underlying commodity, currency, and equity markets. We explain the implications of market integration for investors and clearly demonstrate that such an issue is of primary importance to market participants who use traditional asset pricing models to adjust the risk-return trade-off of their portfolio and evaluate portfolio performance.

Since futures returns are predictable using a set of instruments available at time t-1, the purpose of the rest of the thesis is to analyse whether the variation in expected futures returns reflects rational pricing in an efficient market or is the result of weak-form market inefficiency. The issue is investigated with respect to three hypotheses. First, we test whether a trading rule based on available information generates abnormal returns (chapter IV). Second, we examine whether the predictability of futures returns is common across futures and is related to business conditions (chapter V). Third, we use time-varying expected return asset pricing models to test the hypothesis that the variation in expected futures returns reflects the presence of rational changes in the market-wide prices of risk and risk exposures (chapter VI). The view that the predictability in futures markets reflect rational pricing in an efficient market will be encouraged if (1) the trading rule does not generate any abnormal return on a risk and transaction cost adjusted basis, (2) the forecast power of the information variables over futures returns reflect their ability to forecast economic activity, and (3) the predictable movements in futures returns are picking up the time-varying risk and risk premia evidenced in the stock and bond markets.

The tests undertaken in this thesis therefore rely on some joint hypotheses. The tests in chapter II are joint tests of the normal backwardation theory and of the traditional CAPM and APT. In chapter III, the joint hypothesis stipulates that markets are integrated and the traditional asset pricing models are valid and correctly specified. In chapters IV and VI, it is assumed that markets are efficient and that the conditional asset pricing models are valid representations of the predictable variation in futures returns. As is always the case in tests that involve a joint hypothesis, inferences from the tests are subject to the validity of the underlying asset pricing theory

# Chapter II: Risk and Expected Return in Futures Markets: The Normal Backwardation Theory

## I. Introduction

Ever since Keynes (1930) first formulated the normal backwardation theory, there has been a controversy in the literature over the presence of a futures risk premium that compensates speculators for bearing hedgers' price risk. Consistent with the Keynesian approach is the idea that futures prices depend on hedgers' net positions and their degree of risk aversion. Whenever the supply and demand of futures contracts by equally risk adverse short and long hedgers are balanced, hedgers transfer their risks to one another at no cost. Thus, they are not willing to pay a premium to induce speculators to enter the futures market. In this scenario, the futures price is an unbiased estimate of the spot price expected at maturity. Conversely, if hedgers are net short, or if short hedgers are more risk-averse than long hedgers, the futures price will be a downward biased estimate of the expected spot price in order to entice speculators to open long futures positions. The increase in the futures price as maturity approaches that follows is referred to as normal backwardation. Similarly, if hedgers are net long, or if long hedgers are more risk-averse than short hedgers, the futures price will exceed the expected spot price. The falling price pattern that results is traditionally called normal contango. Thus, normal backwardation and normal contango arise as a result of *the inequality between long and short hedging* positions, which requires the existence of speculators to restore equilibrium (see, for example, Anderson and Danthine (1983)). That is why, in spite of a continuing debate, it is generally accepted that futures markets provide an insurance to hedgers by ensuring the transfer of price risk to speculators. The insurance hedgers are willing to pay equals the premium earned by speculators for this risk-bearing.

Studies of the normal backwardation theory in an asset pricing framework traditionally search for the presence of futures risk premia that compensate speculators for undertaking the risk of price fluctuation hedgers fail to transfer to one another at no cost. In this respect, one of the two following methodologies is traditionally employed. The first approach simply uses time series analysis to estimate the sensitivity of the futures returns to the return on the market portfolio and to the extracted factors. No attempt is made to estimate the price per unit of market risk or the vector of risk premia associated with the factors. The existence of statistically significant elements of beta has lead to the inference that futures contracts are subject to systematic risk factors. Importantly, this methodology omits to test the crucial hypothesis that for a significant element of beta to be a systematic risk factor, investors must receive a reward for bearing this risk. That is, the corresponding element of the risk premia vector must be significant such that there is a price of risk associated with this risk factor. The time series approach however relies on the hypothesis that the risk premia vector in futures markets coincides with the vector of prices of risk in equity markets and concludes that, because a particular contract is sensitive to the market portfolio or to one of the factors, investors will receive a risk premium in futures markets for bearing the systematic risk of the futures contract. If the rewards per unit of risk are the same across equity and futures markets, a finding of a significant beta in futures market will lead to accurate inferences regarding the presence of a risk premium in futures market. On the other hand, if the market portfolio and the derived factors are not priced in futures markets, there will not be any risk premia for systematic risk in futures markets. This suggests that more evidence on the estimate and significance of the risk premia vector in futures markets are needed before any conclusion can be drawn on the riskiness of futures contracts and on the validity, or otherwise, of the normal backwardation theory.

The second approach relies on the two-step methodology of Fama and MacBeth (1973) to directly estimate the market risk premium and the prices of risk associated with the factors. It therefore relaxes the assumption regarding the uniformity of the risk premia vector across markets and overcomes the problem of wrongly assuming that the prices of risk are the same across markets. This methodology examines whether the observed sensitivities to risk factors are a source of priced risk. For example, while futures returns may be sensitive to, say, shocks in inflation, a necessary condition for this to be a source of systematic risk is that investors receive a reward for bearing this risk; namely, that the risk is priced. The implication of the above on the validity of the normal backwardation theory is that speculators will require a risk premium in futures markets whenever the prices of risk associated with the factors, as well as the corresponding sensitivities, significantly differ from zero. Similarly the absence of a futures risk premium will be evidence in favour of the hypothesis that the futures price is an unbiased predictor of the maturity spot price. As mentioned hereafter, the two-step methodology however introduces an error in variable problem, suffers from the drawback of wrongly assuming that security returns follow a strict factor structure, and does not address the issue of the endogeneity of the market portfolio. As such it might lead to incorrect inferences regarding the pricing of a specific factor, the significance of a beta coefficient, and therefore the validity of the normal backwardation theory.

The purpose of this chapter is to thoroughly study the trade-off between risk and return in futures markets and to make use of two methodologies that are free of these problems. These methodologies, called non linear seemingly unrelated regression (NLSUR) and non linear three-stage least squares (NL3SLS), jointly estimate the sensitivities of futures returns to the return on the market portfolio and the derived factors and, crucially, the prices of risk associated with these factors, thereby eliminating the error in variable problem present in the two-step methodology. They also accurately allow for some weak correlation in the residual covariance matrix and enable us to test one of the crucial restrictions of constant expected return asset pricing models; namely, the uniformity of the factor structure across assets. Finally, NL3SLS offers the additional advantage of addressing the issue of the endogeneity of the market portfolio. To the best of our knowledge, the ability of constant expected return asset pricing models to price a wide cross section of futures contracts in the context of NLSUR and NL3SLS has never been addressed. With specifications of the risk-return relationship that are free of the problems present in the time series and cross sectional methodologies, it is then possible to make clear inferences regarding the notion of normal backwardation.

The rest of this chapter is organised as follows. Section II reviews the literature on the relationship between risk and expected return in futures markets. Section III introduces the NLSUR and NL3SLS techniques and explains their advantages compared to the traditional two-step methodology. Section IV describes the data set used in this thesis, displays some summary statistics of futures returns, and focuses on the key macroeconomic and financial factors that are assumed to explain the cross section of futures returns. Section V investigates the pricing of 26 futures contracts in the context of the CAPM and analyses the sensitivity of the results to the use of alternative proxies of the market portfolio. Along with the derivation of the shocks in the derived factors, section VI concentrates on the APT. Since robust interpretations regarding the presence of a futures risk premia can only be obtained within a well specified model, section VII presents some misspecification tests and also provides some complementary information regarding the fit of the models. Only then is it possible to draw some clear conclusions onto the validity of the normal backwardation theory. This is the focus of section VIII. Some concluding remarks are offered in section IX.

## II. The Cross Section of Expected Futures Return: A Review

Alike any other assets, futures contracts can be included in well-diversified portfolios. As a result, they should be priced according to their level of systematic risk (if any). As opposed to any other asset however, futures contracts do not require any initial investment. As a result the intercept term, traditionally included in asset pricing models to refer to the financial or opportunity costs of the initial investment, should not significantly differ from zero (for a discussion on this issue, see, for example, Dusak (1973)). Since traders in futures markets do not require any compensation for deferred consumption, the expected percentage change in the futures price only equals the price per unit of market risk (or the risk premia vector) times the contribution of the futures contract to the riskiness of the market portfolio (or the sensitivity of the futures contract to the derived factors).

In recent years, tests of normal backwardation have focused on the presence of risk premia in futures markets. This line of research usually takes on one of the following three approaches. First, the issue of whether futures returns are significantly related to the returns on a benchmark portfolio has been examined (i.e., a CAPM framework). Second, attempts have been made to extract common factors through the use of factor analysis or principal components (i.e., an unobserved multifactor model). Third, attempts have been made to relate returns in futures markets to observed macroeconomic and financial factors (i.e., an observed multifactor model).

Attempts have first been made to investigate whether the pricing of futures contracts conforms to the CAPM of Sharpe (1964). The results are twofold. First, commodity futures contracts are not risky when they are held as part of a well-diversified portfolio. Hence, since investors in commodity futures markets do not receive a compensation for bearing hedgers' risk of price fluctuation, the evidence mainly fail to support the normal backwardation theory. Second, the CAPM fails to describe the cross section of futures returns. The relationship between risk and average returns is either negative or flat.

With respect to the first hypothesis, Dusak (1973) estimates the sensitivities of wheat, corn, and soybeans futures returns to the return on the market portfolio. Since the betas do not significantly differ from zero, she concludes that long speculators over the period 1952 - 1967 did not require any premium for bearing hedgers' risk of price change. This implies that there is no risk transfer between hedgers and speculators in futures markets and hence that the normal backwardation theory is not valid. These findings were criticised by Carter, Rausser, and Smith (1983) on the two following grounds. (1) Dusak assumes stationarity of the regression relationships - differential return (intercept) and systematic risk (slope) - over the entire period. Carter, Rausser, and Smith argue that the stationarity assumption Dusak made rules out the possibility of changing speculative positions. They therefore express the intercepts and slope coefficients as functions of net speculative positions and consider the significance of the stochastic parameters as a test of the validity of the normal backwardation theory. (2) They dispute Dusak's choice of the Standard and Poor's as a proxy of the market portfolio, arguing that a proxy giving an equal weight to the Standard & Poor's and the Dow-Jones commodity futures index should better account for the degree of systematic risk present in commodity futures markets. They find that the returns on wheat, corn, and soybeans futures are positively related to the return on their market proxy and depend on net speculative positions. To be more specific, long (short) speculators require an expected return above (below) the amount predicted by the security market line. This result supports systematic risk and hedging pressure as determinants of futures risk premium.

Since the Standard & Poor's 500 does not reflect the agricultural sector, it can be reasonably argued that commodity indices should be included in the proxy of the benchmark portfolio when pricing agricultural futures contracts. However, as noticed by Marcus (1984) and Baxter, Conine, and Tamarkin (1985), considering an equally weighted portfolio yields overstated estimates of the degree of systematic risk present in futures markets and hence biases the results toward the acceptance of the normal backwardation theory. The weight given to commodities in the proxy of the market portfolio should not exceed the market value of commodities as expressed by their percentage of total wealth. Not surprisingly, Baxter, Conine, and Tamarkin (1985) notice that their measures of systematic risk are no longer significant once the benchmark portfolio consists of 6.3 percent of the Dow-Jones commodity cash index and 93.7 percent of the Standard & Poor's 500. Note however that, using a combination of 10 percent of the Dow-Jones cash commodity index and 90 percent of the CRSP stock index as a proxy of the market portfolio, Chang, Chen, and Chen (1990) find a significantly positive relationship between copper, platinum, and silver futures returns and the return on their benchmark portfolio. The Chang, Chen, and Chen study therefore claims support to the Keynesian hypothesis.

The studies reported so far estimate the systematic risk of futures contracts through time series regressions of futures returns on the market returns. These studies do not investigate the ability of the CAPM to describe the cross section of expected futures returns: they do not test the positive relationship between beta and mean futures returns. With respect to this hypothesis, the evidence fail to support the predictions of the model.

For example, Bodie and Rosansky (1980) find that the price per unit of market risk is both negative and significant.[1] Studying a cross section of 17 commodity futures, Park, Wei, and Frecka (1988) report similar results: they fail to reject the hypothesis that the market risk premium is equal to zero. Even more damaging for the CAPM is their finding that residual risk (as measured by the residuals standard deviation) is priced in the second step of their analysis. Finally Kolb (1996) reinvestigates the pricing of 45 futures contracts in the context of the CAPM over the period 1969-1992 and finds that the relationship between beta and realised return is either flat or negative.[2]

Recently studies of the normal backwardation theory have centred on the search for risk premia using multifactor models of risk premia emanating from the Arbitrage Pricing Theory (APT) of Ross (1976). The interest in multifactor models stems from the failure of the single factor CAPM to price futures contracts and from the controversy over the nature of the market portfolio. The rationale for the use of multifactor models in this context is that a more dissagregate risk structure may be useful in relating futures returns to systematic risk measures.

Using factor analysis, Ehrhardt, Jordan, and Walking (1987) extract two systematic risk factors from the covariance matrix of commodity futures returns. Since the risk premia vector associated with these factors is statistically insignificant, they conclude that speculators do not require a risk premium for underwriting hedgers' price risk and fail to support the normal backwardation theory. Park, Wei, and Frecka (1988) extract three principal components from the covariance matrix of commodity futures returns and show that their associated risk premia are statistically insignificant. They also test the

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[1] Since their sample include a maximum of 27 observations, asymptotic theory can hardly be applied to the test statistics used by Bodie and Rosansky (1980) and caution should be the rule while interpreting their results.

[2] Kolb uses the traditional t test and a non-parametric Theil test to examine the significance of the market risk premium. Because of the uneven arrival of information in futures markets, futures returns follow a leptokurtic distribution. As opposed to the traditional t-test, the Theil test does not assume that futures returns are normally distributed. It might hence present more reliable inferences regarding the pricing of systematic risk in futures markets. Kolb finds that the conclusions are not sensitive to the test used.

assumption that unsystematic risk is not priced and conclude that the pricing relationship does not hold. They conclude that the APT fails to describe the cross section of average returns in commodity futures markets.

The success of multifactor models using observed macroeconomic and financial factors in the stock market (see, for example, Chen, Roll, and Ross (1986) and McElroy and Burmeister (1988)) has led to this approach being adopted in futures markets. Using corn, soybeans, and wheat futures, Young (1991) finds that, while unexpected inflation and term spread account for some of the variation in corn futures returns, none of the macroeconomic variables specified in McElroy and Burmeister (1988) explains the behaviour of soybeans and wheat futures returns. The futures on soybeans and wheat therefore do not seem to exhibit any significant risk premium. Chen, Cornett, and Nabar (1993) find that returns on Treasury bill and Treasury bond futures are sensitive to inflation shocks, the Standard & Poor's 500 stock index, and the Dow-Jones commodity futures and spot indices. Additionally, Treasury bills futures returns are found to be sensitive to the term structure of interest rates. Bessembinder (1992) offers the most thorough analysis of the pricing of systematic risk and net hedging[3] in futures markets. The results from the second stage of the cross sectional analysis indicate that residual risk conditioned on net hedging is priced in agricultural and foreign currency futures. In these markets long (short) speculators receive a premium in excess of (below) the systematic risk of the contract for underwriting hedgers' risk of price fluctuation. This result indicates that the normal backwardation theory has some merits in describing the way the prices on commodity and currency futures are set. The evidence also suggest that speculators in financial and metal futures do not require any premium conditioned on net hedging. In these markets, the normal backwardation theory does not seem to prevail.

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[3] Bessembinder (1992) defines residual risk conditioned on net hedging as the product of (1) the standard deviation of the residuals from a regression of futures returns on a set of prespecified factors and (2) a net hedging variables set equal to 1 in months where speculators are net long, -1 in months where speculators are net short, and 0 when speculators' positions change over the month or when data are unavailable.

The relationship between risk and expected returns in futures markets and its implication in terms of the normal backwardation theory have been the subject of an increasing debate over the past two decades. Unfortunately most authors conduct their research in a time series framework and implicitly assume that the prices of risk identified in equity markets coincide with the systematic risk premia present in futures markets. Alternatively other authors use the Fama and McBeth methodology, thereby relaxing the assumption underlying the time series tests. As explained subsequently, this approach wrongly assumes that security returns follow a strict factor model and suffers from an error in variable problem that may lead to wrong inferences regarding the pricing of a specific risk factor and the validity of the normal backwardation theory. Our purpose in this chapter is to make use of two methodologies that tackle these problems by allowing for some weak correlation in idiosyncratic returns and by jointly estimating the risk premia vector and the sensitivity matrix. Then, and only then, will it be possible to draw some clear inferences regarding the presence of a risk premium in futures markets and the applicability, or otherwise, of the normal backwardation theory. The methodologies employed in this respect are explained in the following section.

## III. Methodology

We assume that returns are driven by the following linear multifactor model

$$R_t = E(R) + BF_t + \varepsilon_t \tag{2.1}$$

where $R_t$ is a N-vector of raw returns, E(.) is the expectation operator, B is the N*K-matrix of sensitivities of the returns to the K-vector of factors $F_t$ or the N-vector of beta coefficients in the context of the CAPM, $\varepsilon_t$ is a N-vector of error terms, N is the number of assets, and K is the number of factors. Given a set of simplifying assumptions and under the no-arbitrage condition (see Ross (1976)), the following risk-return relationship holds

$$E(R) = \lambda_0 + B\lambda \qquad (2.2)$$

where $\lambda_0$ is the return on the risk-free asset and $\lambda$ is a K-vector of risk premia associated with the risk factors or the price per unit of market risk. The methodology employed to formally estimate the beta coefficients, the price per unit of market risk, the sensitivities to shocks in the factors, and the prices of risk associated with these factors in equation (2.2) are the non linear seemingly unrelated regression technique (NLSUR) and the non linear three stage least squares technique (NL3SLS) introduced by McElroy, Burmeister, and Wall (1985) and Burmeister and McElroy (1988). These procedures are based on a set of non linear regression equations that simultaneously estimates the sensitivities matrix B and the risk premia vector $\lambda$, allows for some cross sectional variation in the residuals covariance matrix, and imposes the non linear restrictions that the elements of $\lambda$ are equal across all assets. The NL3SLS methodology offers the additional advantage of addressing the issue of the endogeneity of the market portfolio.

## 1. The Non linear Seemingly Unrelated Regression Technique

The NLSUR approach, proposed by McElroy, Burmeister, and Wall (1985) and applied to the stock market by McElroy and Burmeister (1988) and Burmeister and McElroy (1988), jointly estimates the risk premia vector and the sensitivity matrix, solving hence the error in variable (EIV) problem present in the Fama and MacBeth (1973) two-step methodology. In the first stage, a time series of stocks' returns is used to estimate the sensitivities of each asset to the derived factors (or the return on the market portfolio) over an initial estimation period of T years. In other words, actual excess returns are regressed on a constant and on a K-vector of APT factors to yield estimates of the N-vector of intercept terms $B_0$ and of the N*K matrix of sensitivities B

$$R_t = B_0 + BF_t + u_t$$

where $R_t$ is the N-vector of holding period excess returns, $F_t$ is a K-vector of risk factors, $u_t$ is a N-vector of error terms, and $t = 1, \ldots, T$. The return generating process thereby estimated produces estimates of B that are used in the second stage (along with a constant) to explain the cross sectional variation in security excess returns for each month in year T+1 (i.e., there is one regression per month). This step yields 12 estimates of the intercept term and an estimate of the 12*K matrix of risk premia $\lambda$. Hence for each month in year T+1 and for $i = 1, \ldots, N$,

$$R_i = \lambda_0 + \lambda B_i + v_i$$

$R_i$ is the monthly excess returns on asset i for each month in year T+1, $B_i$ is the K-vector of sensitivities estimated in the first stage of the analysis, $v_i$ is an error term, $\lambda_0$ and $\lambda$ are the parameters to estimate. $\lambda$ is a K-vector of monthly prices of risk associated with the pervasive factors. Finally the sample is increased by one calendar year at a time and each time the two-step procedure is rolled over to produce new estimates of B and hence new estimates of $\lambda$. A t-test is then performed on the resulting $\lambda$ time series to test for the significance of the estimated prices of risk.

The EIV problem mentioned above arises from the use of estimated betas instead of actual betas in the second stage of the estimation procedure. Since the measurement errors in the sensitivities can be reduced by considering well-diversified portfolios instead of individual securities, the traditional approach to corner this issue consists in grouping securities into portfolios. Provided that the measurement errors in individual betas are not perfectly correlated, the betas, and hence the risk premia, are more precisely estimated and the risk of wrongly pricing a factor is thereby reduced. Constructing portfolios certainly reduces the EIV problem but does not completely eliminate it To tackle the problem further, Shanken (1992) proposes a correction for the standard errors in the estimated risk premia that takes into consideration the measurement error in the betas. He proves that the non-adjusted standard errors are biased and may hence lead to wrong inferences regarding the pricing of a specific risk factor in the return generating process.

For example, he shows that the price of risk associated with unexpected inflation that was found to be significant by Chen, Roll, and Ross (1986) becomes insignificant once the standard error and t-statistic are adjusted to consider the EIV problem. Another way to eliminate the risk of wrongly pricing a factor consists in jointly estimating the vector of risk premia and the matrix of sensitivities through NLSUR. Since the EIV problem is no longer an issue, we no longer need to arbitrarily construct portfolios (the NLSUR technique can be directly applied to individual assets); neither do we need to choose a specific basis to order securities into portfolios. This is of particular interest if one recalls that results regarding the pricing of a specific factor are sensitive to the grouping technique used (see Clare and Thomas (1994)).

The non linear least squares methodology offers the additional advantage of addressing the issue of the appropriate factor structure of securities' returns. On the one hand, one can restrict the return idiosyncratic covariance matrix $\Phi$ to be diagonal. We thereby implicitly assume that the return generating process follows a strict factor structure, hence recognising that there is no correlation between the idiosyncratic components of the covariance matrix of security returns. On the other hand, one can define an approximate factor structure and allow for some weak correlation between the elements of $\Phi$. Evidence suggest that returns do not follow a strict factor structure and that factor analysis fails to extract the relevant pervasive factors from the covariance matrix of security returns[4]. Consequently constant expected returns asset pricing models should be estimated in the context of an approximate factor structure. The non linear least squares regression technique is once again an useful tool since, as opposed to the Fama and MacBeth methodology, it can be set up such that the disturbances of the non linear system have free covariances across equations. Evidence from the stock market suggest that inferences regarding the pricing of systematic risk are sensitive to the restrictions imposed

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[4] For one thing, because of rotational indeterminacy, one cannot test whether a specific factor is priced and only a test of joint significance can be undertaken. For another, the number of factors extracted through factor analysis and the number of factors priced in the second stage of the two-step methodology increase with the number of securities factor analysed and with the time period under investigation (see Dhrymes, Friend, and Gultekin (1984) and Dhrymes, Friend, Gultekin, and Gultekin (1985)). Finally, because a diagonal idiosyncratic covariance matrix wrongly treats industry-specific factors as pervasive sources of uncertainty, factor analysis may identify too many factors.

on the idiosyncratic covariance matrix (see Garrett and Priestley (1996)). Since the nature of the return generating process matters in tests of the APT, the results presented here rely on the more realistic assumption that futures returns follow an approximate factor structure. In this context, the NLSUR estimator is used.

Finally and maybe most importantly, a further advantage of NLSUR is that it allows for the testing of the asset pricing crucial restriction that the price of risk associated with a factor or with the market portfolio is the same for all assets. To see why NLSUR allows for the testing of the uniqueness of the return generating process, we substitute (2.2) into (2.1). This yields

$$R_t = \lambda_0 + B\lambda + BF_t + \varepsilon_t \tag{2.3}$$

To see how these restrictions arise, we consider the following unrestricted linear factor model where $E(R_t)$ in (2.1) is replaced by a constant vector $\alpha$

$$R_t = \alpha + BF_t + \varepsilon_t \tag{2.4}$$

Clearly equation (2.3) places the non linear restrictions that $\alpha = \lambda_0 + B\lambda$ on equation (2.4). Consequently equation (2.3) can be considered as a system of N non linear seemingly unrelated regression equations which imposes the cross sectional restriction that the elements of $\lambda$ are equal across all assets.

In terms of estimation, the T equations for the excess return on the $i^{th}$ asset are (see McElroy, Burmeister, and Wall (1985) and McElroy and Burmeister (1988))

$$R_i = \left[(\lambda' \otimes \iota_T) + F\right]B_i + \varepsilon_i = X(\lambda)B_i + \varepsilon_i \tag{2.5}$$

where $R_i$ is a T-vector of excess returns, $\lambda$ is a K-vector of prices of risk, $\otimes$ denotes the Kronecker product operator, $\iota_T$ is a T-vector of ones, F is a T*K matrix of macroeconomic and financial factors, $B_i$ is a K-vector of sensitivities, $X(\lambda) = (\lambda'\otimes\iota_T) + F$ is a T*K matrix, and $\varepsilon_i$ is a T-vector of error terms. Stacking the N asset returns in (2.5) gives

$$R = \left[I_N \otimes X(\lambda)\right]B + \varepsilon \tag{2.6}$$

where $E(\varepsilon) = 0$, $E(\varepsilon\varepsilon') = \Sigma \otimes I_T$, and $\Sigma$ is a N*N positive definite matrix with element $\sigma_{ij}$, i, j = 1, ..., N. Hence it is assumed that there are some weak correlation across the idiosyncratic components of the covariance matrix. We select N and T such as NT > K(N+1) and further assume that the T*K matrix of factors F and the N*K matrix of sensitivities B are of full column rank.

The estimation of the system of equations (2.6) through NLSUR proceeds in three steps:

(1) In the first step, we use OLS to estimate equation (2.5) for each asset and replace the then unknown risk premia vector by a constant $k_i$ ($k_i = \lambda' B_i$). We then choose B so as to minimise each equation's residual sum of squares

$$\frac{\left[R_i - (k_i\iota_T + FB_i)\right]'\left[R_i - (k_i\iota_T + FB_i)\right]}{T}$$

(2) The second step focuses on the residuals $\varepsilon_i = R_i - \left(k_i\iota_T + FB_i\right)$ to estimate $\Sigma = \sigma_{ij} = \left(\varepsilon_i'\varepsilon_j\right)/T$, the covariance matrix of idiosyncratic returns.

(3) In the third step, we select the vector of risk premia $\lambda$ and the matrix of sensitivities B, so as to minimise the objective function: $\varepsilon'\left(\Sigma^{-1} \otimes I_T\right)\varepsilon$, where $\varepsilon$ is the vector of stacked residuals from equation (2.6); namely, $\varepsilon = R - \left(I_N \otimes X(\lambda)\right)B$. This procedure delivers estimators that are consistent and asymptotically normally distributed.

NLSUR is used to determine the sources of systematic risk in futures markets in the context of the CAPM and the APT. Three specifications of the multifactor model are estimated. The first version assumes that the five factors identified in Chen, Roll, and Ross (1986) are a good proxy for the sources of priced risk present in the economy. The second representation of the risk-return relationship consists in adding into the five factor model a residual market factor which is simply the residuals from a regression of the market portfolio on the Chen, Roll, and Ross's factors. The rational for this is that the residual market factor may proxy for any omitted factors (see, for example, McElroy and Burmeister (1988)). The final specification considers the return on the Standard and Poor's composite index as an extra source of uncertainty. There are three reasons for doing so. First, because the APT collapses to the two-factor model when the market portfolio proxy is the only priced factor, the inclusion of the market portfolio into the Chen, Roll, and Ross model provides a weak test of the performance of the two-factor model *vis-à-vis* the APT.[5] Second, the controversy surrounding the role of the market portfolio in explaining the cross section of equity returns in a multifactor framework[6] gives us some further motivation to assess whether the market portfolio enters the risk-return relationship in futures markets. Third, the market portfolio can be used as a proxy for any unobserved factors as in Burmeister and McElroy (1988).

## 2. The Non linear Three Stage Least Squares Technique

While the CAPM and the versions of the APT with the Chen, Roll, and Ross factors and the residual market factor can be estimated through NLSUR, using NLSUR to estimate the multifactor model with the market portfolio can lead to inconsistent estimates of the

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[5] With a mean-variance efficient portfolio, the CAPM pricing relationship should hold exactly (see Roll (1977)), leaving no role for the factors to explain the trade-off between risk and expected returns. If however the proxy of the market portfolio fails to be efficient, the factors might be priced as they may correct errors in the measurement of the true market portfolio.

[6] Results from the two-step methodology often suggest that the market portfolio, when combined with prespecified pervasive factors, does not play any role in explaining the cross section of equity returns (see, for example, Chen, Roll, and Ross (1986) for the US and Clare and Thomas (1994) for the UK). However, in the context of the one-step methodology proposed by Burmeister and McElroy (1988), the market portfolio seems to be priced (see Garrett and Priestley (1996) for the UK).

matrix of sensitivities and of the vector of prices of risk. In this representation, the market portfolio proxies for any unobserved factors and hence should be treated as endogenous. To understand how this matter arises, we reproduce here the basic framework presented by Burmeister and McElroy (1988). We assume that the K-vector of factors consists of J unobserved factors $G_t$ and K-J observed factors $F_t$ and that the N-vector of returns consists of a first (N-M)-vector of returns $r_t = (r_{1t}, \ldots, r_{N-Mt})'$ and a last M-vector of returns $R_t = (R_{N-M+1}, \ldots, R_N)'$. Under these notations, the linear factor model (2.1) becomes

$$r_t = E(r_t) + BG_t + CF_t + \varepsilon_t \tag{2.7}$$

$$R_t = E(R_t) + B_M G_t + C_M F_t + \varepsilon_{Mt} \tag{2.8}$$

where B and C are the (N-M)*J and (N-M)*(K-J) matrices of sensitivities of the first N-M returns to the J unobserved factors $G_t$ and to the (K-J) observed factors $F_t$ respectively and the subscript M refers to the second subset of assets. If we further assume that $B_M$ is non-singular, we can solve equation (2.8) for the vector of unobserved factor $G_t$

$$G_t = B_M^{-1}\left(R_t - E(R_t) - C_M F_t - \varepsilon_{Mt}\right) \tag{2.9}$$

After substituting (2.9) into (2.7) and rearranging terms, the returns on the N-M first assets can be expressed as a linear combination of the M last returns and the K-J observed factors. Hence,

$$r_t = \beta_{0t} + \beta R_t + \gamma F_t + \eta_t \tag{2.10}$$

where

$$\beta_{0t} = E(r_t) - BB_M^{-1}E(R_t)$$

$$\beta = BB_M^{-1}$$

$$\gamma = C - BB_M^{-1}C_M$$

$$\eta_t = \varepsilon_t - BB_M^{-1}\varepsilon_{Mt}$$

One of the main properties of $\eta_t$ in (2.10) is that, because $\varepsilon_{Mt} \neq 0$ for all t, $E(\eta_t / R_t) \neq 0$: the residuals $\eta_t$ are not orthogonal to the vector of returns on the M last assets.

Following the previous notations, we define the vector of prices of risk associated with the unobserved factors as $\lambda_G = \left(\lambda_G^1, \ldots, \lambda_G^J\right)$ and the vector of prices of risk associated with the observed factors as $\lambda_F = \left(\lambda_F^{K-J+1}, \ldots, \lambda_F^K\right)$. Hence, in the absence of arbitrage opportunities, equations (2.7) and (2.8) become

$$E(r_t) = \lambda_0 \iota_{N-M} + B\lambda_G + C\lambda_F \tag{2.11}$$

$$E(R_t) = \lambda_0 \iota_M + B_M\lambda_G + C_M\lambda_F \tag{2.12}$$

where $\iota_Z$ is a Z-vector of ones. Taking expectations of (2.10), the expected return on $r_t$ is also equal to

$$E(r_t) = \beta_{0t} + \beta E(R_t) \tag{2.13}$$

Substituting (2.11) and (2.12) into (2.13) and solving for $\beta_{0t}$ yields

$$\beta_{0t} = (\iota_{N-M} - \beta\iota_M)\lambda_0 + (B - \beta B_M)\lambda_G + (C - \beta C_M)\lambda_F$$

$$\beta_{0t} = (\iota_{N\;M} - \beta\iota_M)\lambda_0 + \gamma\lambda_F \tag{2.14}$$

since $B - \beta B_M^1 = 0$ and $C - \beta C_M = C - BB_M^{-1}C_M = \gamma$. Therefore the specification of the APT with observed and unobserved factors imposes the restrictions (2.14) on the linear factor model (2.10). Substituting (2.14) into (2.10) and rearranging terms yields the APT specification

$$r_t - \lambda_0 \iota_{N-M} = \beta(R_t - \lambda_0 \iota_M) + \gamma(F_t + \lambda_F) + \eta_t \qquad (2.15)$$

which imposes the restriction that $\alpha_0 = \gamma\lambda_F$ on the linear factor model

$$r_t - \lambda_0 \iota_{N-M} = \alpha_0 + \beta(R_t - \lambda_0 \iota_M) + \gamma F_t + \eta_t \qquad (2.16)$$

Under the additional assumption that unobserved factors affect the pricing of security returns, (2.3) and (2.1) are similar to (2.15) and (2.16). The non linear across equation restrictions imposed on (2.3) to obtain (2.1) are the same as the restrictions imposed on (2.16) to obtain (2.15). These restrictions force the prices of risk associated with the observed factors to be the same across equations. Namely, the restrictions are $\alpha_0 = \gamma\lambda_F$.

Burmeister and McElroy (1988) propose to use the return on a stock index as a proxy for $R_t$ in (2.15) and (2.16). This however raises the problem of the endogeneity of the market portfolio. To see how this matters arises, recall that, because $\varepsilon_{Mt} \neq 0$ for all t, $\eta_t = \varepsilon_t - BB_M^{-1}\varepsilon_{Mt} \neq \varepsilon_t$ in (2.10) and, hence, $E(\eta_t/R_t) \neq 0$. The residuals $\eta_t$ are not orthogonal to the return on the market portfolio. Hence the fact that the presence of measurement errors in the definition of the unobserved factors ($\varepsilon_{Mt} \neq 0$) renders void any assumption that the market portfolio return is independent of the disturbance term $\eta_t$. It follows that the NLSUR estimates of the parameters in (2.15) and (2.16) will not tend in probability to their true values; namely, will failed to be consistent. To corner this issue of regressor-disturbance correlation, one needs a non linear instrumental variable estimator that recognises the endogenous nature of the market portfolio. This estimator, called non linear three stage least squares (NL3SLS), produces consistent estimates of the sensitivity matrix and the vector of risk premia.

To obtain the NL3SLS estimators of the risk premia vector and sensitivity matrix, we assume that there are (N-M) assets only and no unobserved factors but the market portfolio is priced. NL3SLS is an instrumental variables method that estimates non linear simultaneous equations and allows for the presence of endogenous variables on the right-hand side of the system. It aims to produce joint estimates of $\lambda$ and B by minimising the objective function

$$\eta'\left[\Sigma^{-1} \otimes \left(Z(Z'Z)^{-1}Z'\right)\right]\eta$$

where $\eta$ is a T*(N-M) stacked vector of $\eta_t$s, $\Sigma$ is the estimated residual covariance matrix,[7] Z is a T*H matrix of instruments, T is the number of observations, and H the number of instruments. To be admissible, the set of instruments must be asymptotically uncorrelated with the residuals $\eta_t$ and asymptotically correlated with the market portfolio returns. Following Amemiya (1977), we choose the fitted values and squared fitted values of a regression of the Standard & Poor's returns on the exogenous variables, the exogenous variables themselves and their squared values as instruments.

## IV. Data

The data, downloaded from Datastream International, comprise end of the month settlement prices on 26 U.S. futures contracts over the period May 1982 - October 1996. More specifically, thirteen agricultural commodities, four metal and oil commodities, and nine financial futures (two stock indices, four currency, and three interest rate related futures contracts) are included in our sample. The choice of time period used reflects the need to have a sufficiently long time series of returns such that asymptotic theory can be applied to the test statistics. This limits the number of contracts that can be used. The

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[7] For consistency purpose with the CAPM results and with the results from alternative specifications of the APT, we do not restrict the residual covariance matrix to be diagonal and hence assume that there is some weak correlation in the residuals across equations.

choice of the particular contracts used is governed by the sample period and the requirement that a cross section of different futures contracts is used.

Time series of futures prices are obtained by compiling the settlement prices on the nearest maturity futures contract, except in the maturity month where the prices on the second nearest futures contract are collected. This choice is primarily governed by the need of linking together the prices of consecutive futures contracts into one time series. The time to switch from the near to the next near contract is decided on the basis that trading volumes are low in the early months of trading and at maturity (when traders close their positions to avoid making or taking delivery of the underlying asset). As a result, settlement prices in periods distant from maturity and in the delivery months might not reflect the equilibrium prices determined by supply and demand forces and are not considered in this study. We compute futures returns as the percentage change in these settlement prices. Our definition of returns implies that $F_{t-1}$, the futures price, is the sum invested at the end of each month. However at the time the contract is traded, there is no cash payments (apart from the initial margins) and hence a definition of returns that assumes that $F_{t-1}$ is invested is necessarily inaccurate. Since the definition of return as $(F_t - F_{t-1})/S_{t-1}$ would require to collect the spot price $S_{t-1}$ as well as the futures price, we simply define futures returns as $(F_t - F_{t-1})/F_{t-1}$. By doing so, we create a return series which represents the monthly return to an investor who is long in the contract which is the nearest or the next nearest to maturity.[8]

Table 2.1 reports the specific contracts used in this thesis, the trading markets, and some summary statistics of the percentage returns on the contracts. In all cases, the mean return is positive. In common with the ideas of modern portfolio theory, the contracts

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[8] One might possibly argue that the margin requirements embedded in futures markets could be considered as some kind of initial investment on behalf of investors. In such a case one could be tempted to compute the rate of return on futures contracts as the rate of return on the margin. Treating the margin requirements as such however implies that the margins can be compared to any other asset, while they are just good-faith deposits that guarantee the clearing house against default on behalf of either party: had the clearing house any other way to protect itself, no margin would be required and transactions in futures markets would still take place.

with the highest mean returns tend, on average, to have higher standard deviations and higher absolute values of maximum and minimum values.

Following previous empirical studies we estimate the CAPM with different proxies of the market portfolio: the returns on the Standard and Poors' composite index, the returns on the Dow-Jones cash commodity index, an equally-weighted benchmark, and a proxy constructed with 90 percent of the returns on the Standard & Poor's index and 10 percent of the returns on the Dow-Jones cash commodity index. These proxies of the market portfolio along with the time series of futures returns form the data set on which our analysis of the CAPM relationship is performed.

The set of potential risk factors we use follows directly from Chen, Roll, and Ross (1986) and was adopted also in the analysis of futures markets by Young (1991) and Bessembinder (1992). If we view assets as the discounted streams of future dividends (as in Chen, Roll, and Ross (1986)), then one can consider any variable that affects either expected dividends or the discount factor as a potential source of priced risk. To capture some of the uncertainty regarding expected dividends, we use the unanticipated change in the log of industrial production as a proxy of any unanticipated change in the business cycle. This variable could be a source of priced risk because of the impact it might have on a firm's profits and hence on its expected returns. One can also reasonably expect investors to be willing to pay a premium (in the form of a negative expected return) on assets that are good hedges against unexpected inflation. If this is the case, inflation risk should be priced and associated with a negative risk premium. An alternative natural candidate for the pervasive factors is the monthly change in expected inflation. The incentive for considering this variable as a potential priced factor is that the change in this expectation should be unanticipated and related to expected dividends and nominal returns. Sources of risk that may influence the discount factor include unanticipated changes in debt instruments such as shocks to default spread and to the term structure of interest rates. Default spread, measured as the difference between the yields on AAA-rated bonds and long-term government bonds, could affect the discount factor, because, in periods of uncertainty, a sudden increase in default spread should have a similar impact on security returns. It is also usual to think of the term spread (defined as the difference between the yield on long-term government bond and the lag in the three-month Treasury bill discount rate) as an additional source of systematic risk since unexpected changes in the yield curve can affect the discounted value of future cash flows and hence security returns.

Using a variant of the Fama and MacBeth (1973) two-step methodology, Chen, Roll, and Ross explain that the unexpected components in the aforementioned variables are sources of priced risk in the stock market. Following Chen, Roll, and Ross, we specify unexpected inflation, the change in expected inflation, unexpected change in industrial production, shocks to default and term spreads as potential sources of systematic risk and test the hypothesis that these factors are priced in futures markets. As mentioned above, we also specify two alternative representations of the APT. The first one consists in adding the residual market factor into the five factor model. The second alternative specification considers the return on the Standard and Poor's composite index as an extra source of priced risk. Table 2.2 recapitulates the measures of macroeconomic and financial activity that are expected to explain the cross section of expected futures returns, along with their definitions and their stationary forms in the estimation procedure.

Since investors respond to announcements in economic and financial news, the impact of any unexpected change in the variables on asset returns must be measured at the time announcements become public information. Financial variables such as the return on the Standard & Poor's index and interest rate spreads are market determined and available to investors with almost no time lag: the interest rate figures determined in, say, January, correspond to the interest rates that prevail in January. However for economic variables (such as inflation and industrial production) there is approximately a month lag between the time the figure is measured and the time it is disclosed to the public. Hence, for example, the February inflation figure corresponds to the inflation that prevailed in January. To consider this time lag, our data set is constructed so that investors respond to the economic announcements and to the disclosure of financial news.

## Table 2.1: Glossary of Futures Contracts and Summary Statistics of Returns

| Futures | Exchange | Mean | Std. Dev. | Minimum | Maximum |
|---|---|---|---|---|---|
| Panel A: Commodities Futures Contracts | | | | | |
| Cocoa | Coffee, Sugar, and Cocoa Exchange | 0.0025 | 0.0800 | -0.1689 | 0.2746 |
| Coffee | Coffee, Sugar, and Cocoa Exchange | 0.0049 | 0.1121 | -0.3053 | 0.5060 |
| Corn | Chicago Board of Trade | 0.0027 | 0.0759 | -0.3138 | 0.4582 |
| Cotton | New-York Cotton Exchange | 0.0047 | 0.0837 | -0.5491 | 0.3053 |
| Oats | Chicago Board of Trade | 0.0042 | 0.1104 | -0.2309 | 0.9343 |
| Soybeans | Chicago Board of Trade | 0.0019 | 0.0577 | -0.1826 | 0.2878 |
| Soybean Meal | Chicago Board of Trade | 0.0030 | 0.0644 | -0.1791 | 0.2156 |
| Soybean Oil | Chicago Board of Trade | 0.0036 | 0.0757 | -0.1996 | 0.4344 |
| Sugar | Coffee, Sugar, and Cocoa Exchange | 0.0121 | 0.1537 | -0.3419 | 0.7194 |
| Wheat | Chicago Board of Trade | 0.0027 | 0.0695 | -0.2424 | 0.2849 |
| Lean Hogs | Chicago Mercantile Exchange | 0.0026 | 0.0830 | -0.2111 | 0.2831 |
| Lumber | Chicago Mercantile Exchange | 0.0112 | 0.1015 | -0.2047 | 0.4524 |
| Pork Bellies | Chicago Mercantile Exchange | 0.0073 | 0.1394 | -0.3223 | 0.7551 |
| Panel B: Metal and Oil Futures Contracts | | | | | |
| Gold | Commodity Exchange | 0.0018 | 0.0438 | -0.1758 | 0.1922 |
| Heating Oil | New-York Mercantile Exchange | 0.0037 | 0.1092 | -0.4221 | 0.6245 |
| Silver | Commodity Exchange | 0.0015 | 0.0779 | -0.2772 | 0.3038 |
| Platinum | New-York Mercantile Exchange | 0.0043 | 0.0752 | -0.2137 | 0.3403 |
| Panel C: Financial Futures Contracts | | | | | |
| NYSE | New-York Stock Exchange | 0.0112 | 0.0413 | -0.2097 | 0.1329 |
| SP500 | Chicago Mercantile Exchange | 0.0116 | 0.0418 | -0.2041 | 0.1322 |
| Treasury-Bill | Chicago Mercantile Exchange | 0.0004 | 0.0053 | -0.0184 | 0.0272 |
| Treasury-Note | Chicago Board of Trade | 0.0027 | 0.0234 | -0.0524 | 0.0702 |
| Treasury-Bond | Chicago Board of Trade | 0.0039 | 0.0334 | -0.0701 | 0.1134 |
| Deutsch Mark | Chicago Mercantile Exchange | 0.0031 | 0.0349 | -0.1101 | 0.1008 |
| Japanese Yen | Chicago Mercantile Exchange | 0.0050 | 0.0350 | -0.0970 | 0.1257 |
| Swiss Franc | Chicago Mercantile Exchange | 0.0033 | 0.0377 | -0.0967 | 0.1128 |
| UK Pound | Chicago Mercantile Exchange | 0.0001 | 0.0354 | -0.1179 | 0.1482 |

Table 2.2: Glossary, Symbol, and Form of the Factors

| Factor | Symbol | Stationary Form |
|---|---|---|
| Term Spread | TS | Spread between the Yield on U.S. *Long-Term* (over 10 years) Treasury Bond and the U.S. Three-Month Bill Auction Discount Rate (lagged once) |
| Inflation | I | Percentage Change in the Consumer Price Index |
| Change in Expected Inflation | $\Delta EI$ | $E_t(I(t+1)) - E_{t-1}(I(t))$ |
| Default Spread | DS | Spread between the Yield on U.S. Domestic Corporate AAA-Rated Bond and the Yield on U.S. Long-Term Treasury Bond |
| Industrial Production | IP | First Difference in the Log of Industrial Production |
| Return on the Standard and Poor's Index | SP | Percentage Change in the Standard and Poor's Composite Index |
| Return on the Dow-Jones Commodity Index | DJ | Percentage Change in the Dow-Jones Commodity Index |
| Residual Market Factor | RM | Residual from a Regression of the Standard and Poor's Returns on the Five Chen, Roll, and Ross' Derived Factors |

Normal backwardation is tested with respect to the hypothesis that the futures risk premium is positive and significant. We do not consider the net positions of speculators, as in Carter, Rausser, and Smith (1983) or Bessembinder (1992). The choice of this methodology was primarily dictated by the unavailability of data on net hedging.

## V. Empirical Results: The Capital Asset Pricing Model

We now turn our attention to the estimation of the CAPM. Table 2.3 reports estimate of the price per unit of market risk when the Standard and Poor's composite index is used as a proxy of the market portfolio. The market risk premium is insignificant in both statistical and economic terms. The estimate of 0.0001 indicates that the market as a whole offered a monthly excess return to investors equal to 0.01 percent (or a yearly return of 0.12 percent) over the period June 1982 - October 1996. This result is inconsistent with the CAPM which predicts a positive trade-off between risk and expected return. Consistent with previous empirical evidence (see Bodie and Rosansky (1980), Park, Wei, and Frecka (1988), and Kolb (1996)), we find that the CAPM fails to explain the unconditional cross section of expected futures returns.

The CAPM predicts that the market risk premium explains all the systematic variation in expected futures returns. Therefore differences in expected returns can only result from different exposures to the market risk premium. Table 2.4 reports the sensitivities of futures returns to the price per unit of market risk. The significance level of the beta estimates depends widely on the nature of the futures contract under investigation. The contracts that are the most sensitive to the return on the market are the stock index and interest rate futures. Currency futures returns are weakly related to the return on the market. If existent at all, the relationship is negative. Agricultural and metal commodity futures exhibit little evidence of systematic risk. Apart from two contracts (lumber and platinum), the estimates are insignificant. Altogether the evidence in tables 2.3 and 2.4 suggest that futures contracts cannot be considered as risky when they are held as part of a diversified portfolio.

These results are in line with previous empirical studies. The extant literature indeed suggests that, while stock index and interest rate futures are sensitive to the return on the market portfolio, currency and agricultural commodity futures exhibit little evidence of systematic risk (see, for example, Bessembinder (1992) or Kolb (1996)).[9] We report similar results. The results for the metal futures group however might be inconsistent with the evidence presented in the literature. While Bessembinder (1992) and Chang, Chen, and Chen (1990) conclude that metal futures contracts are sensitive to the return on the market, the relationship between metal futures and spot equity returns in table 4.2 is significant for platinum only.

Figure 2.1 plots the relationship between beta and actual mean return. As implied by the CAPM, risk and return seem to be commensurate for eleven futures. At least as far as these futures are concerned, the security market line is upward-sloping, which suggests that investors earned higher return for exposing themselves to higher risk. Consistent with the absence of initial investment in futures markets, the intercept of the security market line seems to equal zero. Therefore a contract with no sensitivity to the market portfolio earns on average no return. However, two of the predictions of the CAPM seem to be violated. First, the security market line appears to be non linear. Second, thirteen futures earn a positive return despite the fact that the estimated betas are negative. A careful look at the data suggests that currency and commodity futures contracts mainly present a risk-return relationship that fails to be consistent with the trade-off assumed by the CAPM.

The evidence presented so far suggest that the CAPM fails to describe the trade-off between risk and return in futures markets. The return on the Standard & Poor's composite index is not priced, only six out of 26 betas are significant, and the plot of the relationship between beta and actual mean return is not consistent with the upward sloping characteristic of the security market line. Given these poor results and the fact

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[9] Dusak (1973) finds little positive relationship between the returns on corn, soybeans, and wheat futures contracts and the return on the Standard & Poor's index. Bodie and Rosansky (1980) show that the betas of 15 out of 23 commodity futures excess returns are negative and insignificant in spite of the fact that the corresponding mean excess returns are positive. Similar results are reported by Park, Wei, and Frecka (1988).

that alternative proxies of the true market portfolio might better explain the cross section of futures returns, we now estimate the CAPM with three different benchmarks: the Dow-Jones cash commodity index, a benchmark that equally weights the returns on the Standard and Poors' composite index and the returns on the Dow-Jones cash commodity index, and a proxy constructed with 90 percent of the returns on the Standard & Poor's index and 10 percent of the returns on the Dow-Jones cash commodity index. Ultimately we expect to address the following question: Are the poor results obtained so far a consequence of the use of an inaccurate proxy for the market portfolio or are these results robust to the specification of the benchmark used in the tests?

The rationale for including commodities into our benchmark portfolio stems from the fact that any proper theoretical construct of the true market portfolio should include all assets present in the economy. Hence, provided that the Standard and Poor's composite index does not already account for the contribution of the agricultural sector to total wealth, commodities should be included in the proxy of the market portfolio. Inasmuch as very few (if at all) U.S. farms are traded on the stock exchange, it is likely that the Standard & Poor's index underestimates the share of agriculture in the economy. Hence a correction that adjusts the proxy toward the agricultural sector seems required. Similarly it can easily be argued that the Standard & Poor's index underestimates the contribution of currencies to the true market portfolio. Hence a construction of the market portfolio that adjusts the proxy towards an exchange rate index should better account for the role of that sector in the total market wealth. Since it is however difficult to estimate the weight that should be allocated to such an index, no correction is implemented.

What can we expect? Since commodity futures represent a large proportion of our cross section, it is likely that a proxy of the market portfolio that incorporates commodity index will account for more of the cross sectional variation in commodity futures returns than would the Standard & Poor's index on its own. Therefore we expect the sensitivities of commodity futures returns to be an increasing function of the weight allocated to commodities in the benchmark portfolio. Similarly the more the proxy is weighted toward the Standard & Poor's index, the more we can expect the sensitivities of financial futures

## Table 2.3: Estimate of the Price per Unit of Risk Associated with the Return on the Standard and Poor's Composite Index

$$R_t = B_M \lambda_M + B_M R_{Mt} + \varepsilon_t$$

| Proxy of the Market Portfolio | $\lambda_M$ | Standard Error | t-ratio |
|---|---|---|---|
| Return on the Standard and Poor's Composite Index | 0.0001 | 0.0005 | 0.18 |

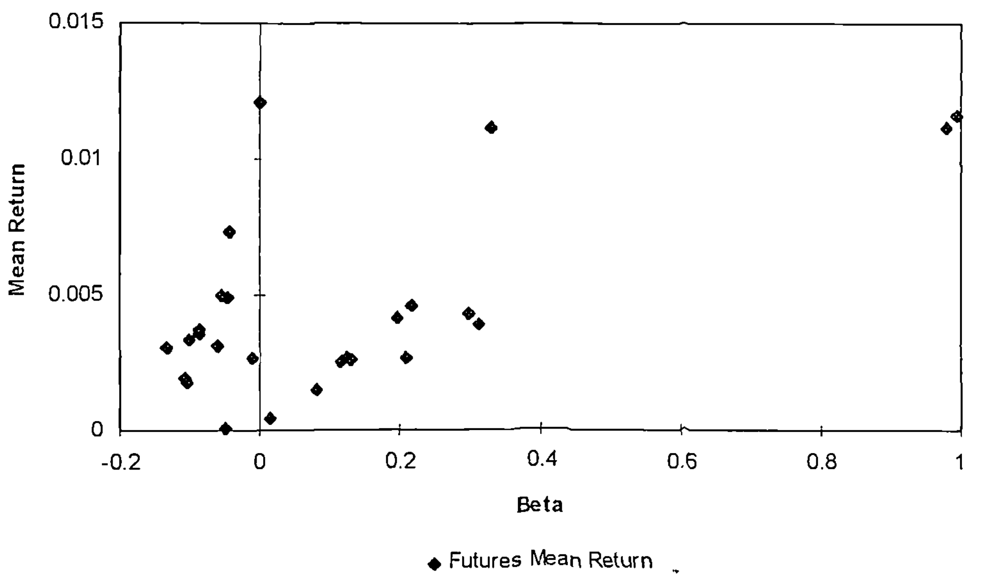
## Table 2.4: Sensitivities of Futures Returns to the Market Risk Premium

$$R_t = B_M \lambda_M + B_M R_{Mt} + \varepsilon_t$$

| Futures Contracts | $B_M$ | Standard Error | t-ratio |
|---|---|---|---|
| **Panel A: Agricultural Commodities** | | | |
| Cocoa | 0.1163 | 0.1417 | 0.82 |
| Coffee | -0.0457 | 0.1990 | -0.23 |
| Corn | 0.1226 | 0.1345 | 0.91 |
| Cotton | 0.2155 | 0.1478 | 1.46 |
| Oats | 0.1963 | 0.1953 | 1.01 |
| Soybeans | -0.1078 | 0.1020 | -1.06 |
| Soybean Meal | -0.1334 | 0.1139 | -1.17 |
| Soybean Oil | -0.0876 | 0.1342 | -0.65 |
| Sugar | -0.0014 | 0.2735 | -0.01 |
| Wheat | -0.0116 | 0.1233 | -0.09 |
| Lean Hogs | 0.1305 | 0.1469 | 0.89 |
| Lumber | 0.3287*** | 0.1794 | 1.83 |
| Pork Bellies | -0.0448 | 0.2475 | -0.18 |
| **Panel B: Metal and Oil** | | | |
| Gold | -0.1039 | 0.0773 | -1.34 |
| Heating Oil | -0.0878 | 0.1937 | -0.45 |
| Silver | 0.0803 | 0.1380 | 0.58 |
| Platinum | 0.2980** | 0.1317 | 2.26 |
| **Panel C: Financial** | | | |
| NYSE | 0.9788* | 0.0144 | 67.92 |
| SP500 | 0.9954* | 0.0128 | 77.62 |
| Treasury Bill | 0.0129 | 0.0094 | 1.37 |
| Treasury Note | 0.2078* | 0.0387 | 5.37 |
| Treasury Bond | 0.3111* | 0.0547 | 5.69 |
| Deutsch Mark | -0.0611 | 0.0619 | -0.99 |
| Japanese Yen | -0.0562 | 0.0625 | -0.90 |
| Swiss Franc | -0.1008 | 0.0666 | -1.51 |
| UK Pound | -0.0491 | 0.0626 | -0.78 |

* denotes significant at 1 percent.
** denotes significant at 5 percent.
*** denotes significant at 10 percent.

Figure 2.1: Security Market Line in Futures Markets



returns to be significant. Since we have not incorporated any currency index into our proxies, we can finally reasonably expect the beta estimates for currency futures to be either insignificant, or at best weakly significant, irrespectively of the proxy used.

Table 2.5 displays the sensitivities of futures returns to the market risk premium estimated with different proxies of the market portfolio. The previous analysis seems to be confirmed by the data. Our results indeed are consistent with the hypothesis that the sensitivities of commodity (financial) futures returns increase (decrease) with the weight given to commodities in the proxy of the market portfolio. For instance the sensitivities of soybeans futures returns to the different proxies distinctively support our hypothesis: when the Dow-Jones commodity index proxies the true market portfolio on its own (column 1), the estimated beta is significant at a 1 percent level; with the equally weighted benchmark (column 2), the significance level rises up to 5 percent; finally the estimated coefficient against the proxy constructed with 90 percent of the Standard & Poor's returns and 10 percent of the Dow-Jones commodity returns becomes insignificant according to any standard levels (column 3).[10] As expected also, the sensitivities of currency futures returns to the three proxies of the market portfolio turn up to be insignificant. Note finally that while the betas of stock index futures against the Standard and Poor's proxy were insignificantly different from 1 in table 2.4, the betas of some commodity futures against the Dow-Jones index are very close to 1. This result stems from the construction of the Dow-Jones cash commodity index itself and from the fact that futures and cash prices track one another very closely because of the absence of arbitrage opportunities between both markets.

Table 2.6 recapitulates the estimates of the risk premia associated with the different proxies of the market portfolio. For comparison purpose we include the results with respect to the Standard & Poor's proxy displayed in table 2.3. The equally-weighted proxy pictures better than any other benchmark the cross section of expected futures returns with an estimated t-ratio of 1.77. Marcus (1984) and Baxter, Conine, and

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[10] The results regarding the heating oil futures contract is a bit unanticipated. We presume that the insignificance of the beta in column 1 stems from the fact that heating oil is not included in the Dow-Jones index.

Tamarkin (1985) present convincing arguments in favour of the benchmark that incorporates 90 percent of the Standard & Poor's returns and 10 percent of the Dow-Jones commodity returns. They argue that the share of commodities in the benchmark portfolio should not exceed the contribution of commodities to the total wealth of the economy; namely 10 percent. Therefore the results associated with this benchmark should give the best description of the risk-return relationship in the context of the CAPM. Once again the conclusions are toward the rejection of the CAPM: the risk premium associated with this benchmark is insignificant at traditional levels of statistical significance.

## VI. Empirical Results: The Arbitrage Pricing Theory

In the light of the failure of the traditional CAPM to describe the cross section of mean futures returns and given the debate surrounding the proper construct of the market proxy, the purpose of this section is to further investigate the pricing of systematic risk in futures markets employing an alternative asset pricing model, the arbitrage pricing theory of Ross (1976). The APT does not give any role to the market portfolio and therefore bypasses the issue of the market proxy present in the CAPM tests. A further reason for considering an APT model is that a dissagregate risk structure might do a better job at pricing futures contracts than a model that assumes a single source of uncertainty.

### 1. Generating Unexpected Components

If agents are rational, all information contained in the current and past values of the macroeconomic and financial variables, as well as their expected values, will be already incorporated into current prices. As a result only unexpected changes in these variables should be priced. Since data on expectations are not available, the issue of expectations formation needs first to be explicitly addressed. We require an expectation generating mechanism which satisfies the assumptions that $E(u_i)=0$, $u_{it}$ is serially uncorrelated, and $u_i$ is orthogonal to $u_j$, where $u_i$ is the innovation in the variable under consideration.

## Table 2.5: Sensitivities of Futures Returns to Different Proxies of the Market Portfolio

$$R_t = B_M \lambda_M + B_M R_{Mt} + \varepsilon_t$$

| Futures Contracts | 100% DJ[1] | | | 50%DJ + 50%SP[2] | | | 10%DJ + 90%SP | | |
|---|---|---|---|---|---|---|---|---|---|
| | Beta | Std Error | t-ratio | Beta | Std Error | t-ratio | Beta | Std Error | t-ratio |
| **Panel A: Agricultural Commodities** | | | | | | | | | |
| Cocoa | 0.5575** | 0.2199 | 2.53 | 0.4974** | 0.2396 | 2.08 | 0.1572 | 0.1574 | 1.00 |
| Coffee | 1.0784* | 0.3030 | 3.56 | 0.5674*** | 0.3372 | 1.68 | 0.0043 | 0.2211 | 0.02 |
| Corn | 0.8387* | 0.2028 | 4.13 | 0.6716* | 0.2245 | 2.99 | 0.1780 | 0.1492 | 1.19 |
| Cotton | 0.5388** | 0.2309 | 2.33 | 0.6316** | 0.2495 | 2.53 | 0.2666 | 0.1640 | 1.63 |
| Oats | 0.8868* | 0.3015 | 2.94 | 0.8077** | 0.3290 | 2.46 | 0.2625 | 0.2168 | 1.21 |
| Soybeans | 0.9104* | 0.1460 | 6.24 | 0.3774** | 0.1725 | 2.19 | -0.0738 | 0.1136 | -0.65 |
| Soybean Meal | 0.8942* | 0.1671 | 5.35 | 0.3308*** | 0.1937 | 1.71 | -0.1026 | 0.1268 | -0.81 |
| Soybean Oil | 0.9721* | 0.1987 | 4.89 | 0.4436*** | 0.2271 | 1.95 | -0.0478 | 0.1493 | -0.32 |
| Sugar | 1.4094* | 0.4176 | 3.37 | 0.8281*** | 0.4630 | 1.79 | 0.0719 | 0.3039 | 0.24 |
| Wheat | 0.5649* | 0.1897 | 2.98 | 0.3153 | 0.2094 | 1.51 | 0.0160 | 0.1371 | 0.12 |
| Lean Hogs | 0.5476** | 0.2285 | 2.40 | 0.5123** | 0.2485 | 2.06 | 0.1723 | 0.1631 | 1.06 |
| Lumber | 1.2529* | 0.2692 | 4.65 | 1.2174* | 0.2956 | 4.12 | 0.4293** | 0.1987 | 2.16 |
| Pork Bellies | 0.7345*** | 0.3863 | 1.90 | 0.3675 | 0.4219 | 0.87 | -0.0111 | 0.2751 | -0.04 |
| **Panel B: Metal and Oil Commodities** | | | | | | | | | |
| Gold | 0.7164* | 0.1099 | 6.52 | 0.2693** | 0.1312 | 2.05 | -0.0790 | 0.0862 | -0.92 |
| Heating Oil | -0.4652 | 0.3037 | -1.53 | -0.4000 | 0.3296 | -1.21 | -0.1191 | 0.2152 | -0.55 |
| Silver | 1.6468* | 0.1790 | 9.20 | 1.0837* | 0.2211 | 4.90 | 0.1709 | 0.1530 | 1.12 |
| Platinum | 0.9756* | 0.1973 | 4.94 | 1.0082* | 0.2151 | 4.69 | 0.3795* | 0.1457 | 2.61 |

## Table 2.5 - *Continued*

| Futures Contracts | 100% DJ[1] | | | 50%DJ + 50%SP[2] | | | 10%DJ + 90%SP | | |
|---|---|---|---|---|---|---|---|---|---|
| | Beta | Std Error | t-ratio | Beta | Std Error | t-ratio | Beta | Std Error | t-ratio |
| **Panel C: Financial** | | | | | | | | | |
| NYSE | -0.0349 | 0.1198 | -0.29 | 1.4101* | 0.0740 | 19.05 | 1.0853* | 0.0170 | 63.74 |
| SP500 | -0.0550 | 0.1213 | -0.45 | 1.4226* | 0.0756 | 18.82 | 1.1028* | 0.0158 | 69.88 |
| Treasury Bill | -0.0022 | 0.0150 | -0.14 | 0.0177 | 0.0162 | 1.09 | 0.0143 | 0.0105 | 1.37 |
| Treasury Note | -0.1439** | 0.0651 | -2.21 | 0.2194* | 0.0696 | 3.15 | 0.2238* | 0.0433 | 5.17 |
| Treasury Bond | -0.2051** | 0.0928 | -2.21 | 0.3345* | 0.0986 | 3.39 | 0.3355* | 0.0611 | 5.49 |
| Deutsch Mark | -0.0040 | 0.0980 | -0.04 | -0.0907 | 0.1059 | -0.86 | -0.0670 | 0.0688 | -0.97 |
| Japanese Yen | 0.1018 | 0.0984 | 1.03 | -0.0209 | 0.1070 | -0.20 | -0.0557 | 0.0695 | -0.80 |
| Swiss Franc | 0.0981 | 0.1055 | 0.93 | -0.0886 | 0.1143 | -0.77 | -0.1058 | 0.0741 | -1.43 |
| UK Pound | -0.0149 | 0.0990 | -0.15 | -0.0803 | 0.1070 | -0.75 | -0.0550 | 0.0696 | -0.79 |

[1] DJ: Returns on the Dow-Jones Commodity Cash Index,
[2] SP: Returns on the Standard and Poor's Composite Index,
* denotes significant at 1 percent,
** denotes significant at 5 percent,
*** denotes significant at 10 percent.

## Table 2.6: Estimate of the Market Risk Premium for Different Proxies of the Market Portfolio

$$R_t = B_M \lambda_M + B_M R_{Mt} + \varepsilon_t$$

| Proxy of the Market Portfolio | Estimate | Standard Error | t-ratio |
|---|---|---|---|
| 100% Dow-Jones Commodity Returns | 0.0025 | 0.0017 | 1.48 |
| 50% Dow-Jones and 50% Standard & Poor's Returns | 0.0014* | 0.0008 | 1.77 |
| 10% Dow-Jones and 90% Standard & Poor's Returns | 0.0002 | 0.0005 | 0.48 |
| 100% Standard & Poor's Returns | 0.0001 | 0.0005 | 0.18 |

* denotes significant at 10 percent.

Following Chen, Roll, and Ross (1986), many authors have simply considered the first difference in the macroeconomic factors and the difference in interest rates for the term and default spreads as the innovations in the factors, implicitly assuming that economic time series follow a random walk. This approach however fails to meet the basic requirements of providing white-noise residuals. Alternatively, one can use an expectation generating process based on autoregressive time series models and consider the zero mean, serially uncorrelated error term as the factor's unexpected component (see, for example, Bessembinder (1992) or Clare and Thomas (1994)). While extrapolating the past might accurately generate expectations under a fixed policy regime, structural changes, such as a change in monetary policy, may induce agents to reassess their expectations. Autoregressive models with fixed parameters cannot pick up these structural changes which consequently rules out the possibility that agents update their expectations whenever a structural change occurs. This may result in agents making systematic forecast errors.

To generate white-noise innovations in the APT factors that closely mirror the learning process followed by agents when forming expectations, we use unobserved component and time-varying parameters models derived through the Kalman filter. The Kalman filter assumes that individuals update their expectations constantly and almost immediately adjust the parameters of the model in the light of any structural information. Assuming rational expectations, as the Kalman filter does, implies then that any persistent error that can be perceived at the time expectations are formed is used to amend expectations. This in turn rules out the possibility that agents make systematic, perceivable forecast errors.

The unobserved component model arises as a simple case of signal extraction. Assuming $X_i$ is the variable of interest, $X_i^*$ the unobserved expectation of $X_i$, assuming further that changes to $X_i^*$ are time-varying with parameter $\gamma$ which evolves as a random walk and that shocks to $X_i$ and $X_i^*$ are statistically independent, then the unobserved component model is defined as

$$X_{it} = X_{it}^{*} + u_{it} \tag{2.17}$$

$$X_{it}^{*} = X_{it-1}^{*} + \gamma_{t-1} + e_{it} \tag{2.18a}$$

$$\gamma_t = \gamma_{t-1} + \omega_t \tag{2.18b}$$

where $u_{it}$, $e_{it}$, and $\omega_t$ are white-noise processes. (2.17) is termed the measurement equation and (2.18a) and (2.18b) are the transition equations which determine the variation through time in the unobserved expected component. As new information arrives, at each point in time, the unobserved expected component is updated. The residual in (2.17) is the unobserved unexpected component. This simple model is estimated for all factors under consideration and the unexpected components are extracted. The adequacy of the model in terms of generating unexpected factors is judged according to the time series properties of $u_{it}$ in (2.17). In particular, the condition required is that $u_{it}$ is serially uncorrelated. In the case where this condition is rejected by the data, we use an autoregressive model with time varying parameters that ensures zero serial correlation in the unexpected components and enables agents to reassess their expectations whenever new information arises. In this case we estimate

$$X_{it} = \beta_{0t} + \sum_{j=1}^{12} \beta_{it} X_{it-j} + \varepsilon_{it} \tag{2.19}$$

$$\beta_{jt} = \beta_{jt-1} + \varsigma_t \tag{2.20}$$

where $X_{it}$ is the variable of interest, $\beta_{it}$ is the time-varying parameter, $\zeta_t$ is a white-noise residual, and $\varepsilon_{it}$ is the error term which we test for serial correlation. The model above is also estimated using the Kalman filter.

Table 2.7 reports first order autocorrelation tests for the derived factors. Panel A reports the Ljung-Box test statistic for first order serial correlation in the residuals of the unobserved component model (equations (2.17), (2.18a), and (2.18b)), Panel B summarises the results for the time-varying parameter model (equations (2.19) and (2.20)). It is clear from this table that, while unexpected inflation satisfies the basic assumption of being white-noise, the residuals from industrial production, term and default spreads, and the change in expected inflation fail to be serially uncorrelated and hence cannot be considered as unexpected APT factors. We treat the variables that fail to provide white-noise unexpected components as time-varying parameter models and extract the unobserved expectations. Once again the residuals of the measurement equation (equation (2.19)) are tested for first order serial correlation. The results, reported in panel B, suggest that the derived factors exhibit the properties of being news in the sense that they are unanticipated at the 1 percent significance level.

An additional assumption of the APT is that the derived factors are orthogonal; namely that there is no correlation between the unexpected components. This is to be expected if we are to obtain independent inferences regarding the impact of each unobserved component on the returns series. Besides the variance of the estimators tends to increase in the presence of multicollinearity and this in turn might result in an underestimation of the impact of each variables on futures returns. Table 2.8 displays the correlation matrix for the derived factors. The results indicate that, as assumed by the APT, the derived factors are weakly, if at all, correlated. The only correlation that exceeds 0.25 in absolute value is that between shocks to default risk and shocks to the term structure of interest rates. This is however to be expected since both factors are constructed from the same time series, the yield on long-term government bond. Since the correlation between UTS and UDS is still fairly weak (-0.28), none of the prespecified pervasive factor is redundant and the issue of multicollinearity is not considered as being a problem.

## 2. APT Results

In this section we estimate the prices of risk associated with the factors and the sensitivities of futures returns to the factors. As mentioned previously, we first assume that the factors derived in table 2.7 are the only sources of systematic risk in futures markets. To assess the robustness of this model to alternative specifications of the risk-return relationship, a version of the APT with the residual market factor as an additional factor is also estimated. An alternative robustness check is to add into the five factor

## Table 2.7: Residuals First Order Serial Correlation

| Unexpected Risk Factor | Autocorrelated Coefficient | Ljung-Box Statistic[1] |
|---|---|---|
| **Panel A: Unexpected Component Model** | | |
| Shock to the Term Structure (UTS) | 0.4140* | 30.17 |
| Unexpected Inflation (UI) | 0.0349 | 0.21 |
| Change in Expected Inflation ($\Delta$EI) | -0.2570* | 11.63 |
| Shock to Default Spread (UDS) | 0.4190* | 30.90 |
| Unexpected Change in Industrial Production (UIP) | -0.3505* | 21.62 |
| **Panel B: Time-Varying Parameter Model** | | |
| Shock to the Term Structure (UTS) | 0.4092 | 0.40 |
| Change in Expected Inflation ($\Delta$EI) | -0.0136 | 0.32 |
| Shock to Default Spread (UDS) | 0.0202 | 0.07 |
| Unexpected Change in Industrial Production (UIP) | -0.1645 | 5.28 |

[1] The Ljung-Box statistic is distributed as $\chi^2(1)$, the critical value is 6.63 at a 1 percent significance level,
* denotes significant at 1 percent.

## Table 2.8: Correlation Matrix of the Derived Factors

| | UTS | UI | ΔEI | UDS | UIP |
|---|---|---|---|---|---|
| UTS | 1 | | | | |
| UI | 0.20 | 1 | | | |
| ΔEI | -0.24 | 0.10 | 1 | | |
| UDS | -0.28 | -0.12 | -0.17 | 1 | |
| UIP | 0.05 | 0.13 | 0.15 | -0.21 | 1 |

model the return on the Standard and Poor's composite index. The system of non-linear equations (2.6) is estimated through NLSUR for the original version and the model with the residual market factor. Since using NLSUR to model the specification with the market portfolio would produce inconsistent estimates of the vector of prices of risk and sensitivity matrix, we use NL3SLS and thereby consider the endogenous nature of the proxy of the market portfolio.

The resulting estimates of the prices of risk for the three specifications of the APT are reported in table 2.9. It is clear from this table that, in the context of the five factor model, unexpected inflation, unexpected change in industrial production, the shock to term and default spreads have statistically significant prices of risk. The change in expected inflation however does not seem to command a risk premium in futures markets. The residual market factor is priced. Hence, when the effect of the other variables is removed from the market return, there is some remaining systematic influence that is captured by this factor.[11] Finally table 2.9 indicates that, once the return on the market portfolio is considered as one of the APT factors, the t-ratios associated with unexpected inflation and with shocks to the change in industrial production drop in significance. Consistent with the results presented in section V however is the finding that the market portfolio is not priced.

It appears that investors in futures markets receive a reward for bearing systematic risk. The magnitude of the reward in turn depends on the sensitivity of futures returns to the factors. Given that the prices per unit of risk are restricted to be the same across the 26 equations, cross sectional differences in expected futures returns are only due to differences in the exposure of futures returns to the risk premia vector. Table 2.10 reports the estimated sensitivities of the returns to the five APT factors. Tables 2.11 and 2.12 summarise the results for the models with the residual market factor and the return on the Standard and Poor's index. Bessembinder (1992) notices that the sensitivities of US

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[11] Note that the significance level and the sign of the initial factors are robust to the inclusion of the residual market factor. The residual market factor only renders the estimates of the price of risk associated with unexpected inflation insignificant and marginally alters the significance level of the other factors. This is to be expected since the residual market factor is by construction orthogonal to the original factors.

futures returns to the return on the market portfolio and the Chen, Roll, and Ross (1986) factors depend widely on the nature of the contract under investigation. Consistent with his results, we find that the returns on fixed-income and equity futures are the most sensitive to the derived factors (Panels C). Currency futures exhibit little sign of systematic risk. Metal futures returns tend to be related to shocks to the term spread and to the change in expected inflation. On average agricultural futures as a group show very little evidence (if at all) of systematic risk.

## VII. Misspecification Tests and Fit of the Models

Before drawing any conclusion about the normal backwardation theory, it is important to select the model that best describes the risk-return relationship in futures markets. In that respect, we test whether the non-linear cross sectional restrictions imposed on the linear factor models to obtain the CAPM and APT specifications hold. The decision is also made on the basis of some misspecification tests and with respect to the ability of each model to explain the cross section of futures returns.

For each specification of the risk-return relationship in futures markets, we first test the non-linear cross sectional restrictions that the prices of risk are the same across equations. Under the null hypothesis, $E(R) = B\lambda$. In this respect, the linear factor model is first estimated in unrestricted form and then estimated under the restriction that the intercepts in (2.4) and (2.16) are equal to the cross product of the sensitivities and the factor risk premia. The decision to accept or reject the null hypothesis is made by comparing the difference in the minimised values of the objective functions of the restricted and unrestricted models to a $\chi^2$ table with degrees of freedom equal to the difference in the number of parameters between the two models. This results in $\chi^2$ calculated values of 14, 17, 11, and 9.76 for the CAPM, the five factor model, the residual market model, and the specification with the market portfolio respectively. With 25, 21, 20, and 20 degrees of freedom respectively, the corresponding probability values equal 0.96, 0.71, 0.94, and 0.97. Hence we fail to reject the hypothesis that the cross

# Table 2.9: Estimates of the Prices of Risk for the Three Specifications of the APT

$$R_t = B\lambda + BF_t + \varepsilon_t$$

| Factor | Five Factor Model | | | Residual Market Factor | | | Market Portfolio | | |
|---|---|---|---|---|---|---|---|---|---|
| | Estimate | SE | t-ratio | Estimate | SE | t-ratio | Estimate | SE | t-ratio |
| Shock to the Term Structure | -0.0610*** | 0.0346 | -1.77 | -0.0177*** | 0.0101 | -1.75 | -0.0262*** | 0.0140 | -1.87 |
| Unexpected Inflation | -0.0017*** | 0.0009 | -1.84 | -0.0004 | 0.0003 | -1.49 | -0.0004 | 0.0004 | -1.10 |
| Change in Expected Inflation | 0.0031 | 0.0022 | 1.45 | 0.0005 | 0.0006 | 0.80 | 0.0011 | 0.0009 | 1.24 |
| Shock to Default Spread | 0.0154*** | 0.0086 | 1.79 | 0.0088** | 0.0037 | 2.39 | 0.0087*** | 0.0048 | 1.81 |
| Unexpected Change in Industrial Production | -0.0027*** | 0.0016 | -1.69 | -0.0010 | 0.0007 | -1.55 | -0.0008 | 0.0009 | -0.88 |
| Residual Market Factor | | | | 0.0106* | 0.0012 | 8.55 | | | |
| Return on the Market Portfolio | | | | | | | 0.0002 | 0.0008 | 0.20 |

* denotes significant at 1 percent,
** denotes significant at 5 percent,
*** denotes significant at 10 percent.

## Table 2.10: Sensitivities of Futures Returns to the Prices of Risk of the Five Factor Model

$$R_t = B\lambda + BF_t + \varepsilon_t$$

| Futures Contracts | Shock to Term Spread | | Unexpected Inflation | | Change in Expected Inflation | | Shock to Default Spread | | Unexpected Change in Industrial Production | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio |
| **Panel A: Agricultural Commodities** | | | | | | | | | | |
| Cocoa | -0.0019 | -0.02 | 2.8302 | 0.68 | 1.1810 | 0.58 | -0.1885 | -0.78 | -2.1065 | -1.27 |
| Coffee | -0.1750 | -1.05 | 3.5773 | 0.61 | 0.9888 | 0.34 | -0.3180 | -0.93 | -0.6619 | -0.28 |
| Corn | -0.1020 | -0.91 | -4.9059 | -1.23 | -3.1423 | -1.61 | 0.0846 | 0.37 | 1.0976 | 0.70 |
| Cotton | -0.0463 | -0.37 | -6.7963 | -1.53 | -0.4532 | -0.21 | -0.1878 | -0.74 | 1.7897 | 1.03 |
| Oats | -0.0557 | -0.34 | -0.3660 | -0.06 | -2.7124 | -0.97 | 0.5498 | 1.64 | 0.1408 | 0.06 |
| Soybeans | -0.1083 | -1.27 | 1.1063 | 0.37 | -0.0145 | -0.01 | 0.1888 | 1.09 | 1.9474 | 1.64 |
| Soybean Meal | -0.0915 | -0.96 | -0.4995 | -0.15 | -0.9356 | -0.57 | 0.2216 | 1.14 | 1.2156 | 0.92 |
| Soybean Oil | -0.0693 | -0.62 | -0.5964 | -0.15 | 0.4793 | 0.25 | 0.3418 | 1.50 | 2.7480*** | 1.77 |
| Sugar | -0.1963 | -0.86 | 5.9982 | 0.75 | -2.8032 | -0.71 | 0.2475 | 0.53 | -4.9663 | -1.57 |
| Wheat | -0.1491 | -1.46 | 4.1121 | 1.14 | -1.7411 | -0.99 | 0.2111 | 1.02 | -1.6119 | -1.14 |
| Lean Hogs | 0.1231 | 1.00 | -2.9658 | -0.68 | 0.8329 | 0.39 | 0.3235 | 1.29 | 1.3923 | 0.81 |
| Lumber | 0.0300 | 0.20 | -3.7841 | -0.71 | 0.1205 | 0.05 | 0.0317 | 0.10 | -1.6758 | -0.79 |
| Pork Bellies | 0.1366 | 0.66 | -4.5247 | -0.62 | 0.6012 | 0.17 | 0.0047 | 0.01 | -1.8649 | -0.64 |
| **Panel B: Metal and Oil Commodities** | | | | | | | | | | |
| Gold | 0.2373* | 3.72 | -1.0112 | -0.43 | 2.5872** | 2.27 | 0.1566 | 1.23 | -1.2914 | -1.47 |
| Heating Oil | -0.0780 | -0.48 | -1.7422 | -0.30 | 0.1852 | 0.07 | -0.3780 | -1.14 | -1.5888 | -0.70 |
| Silver | 0.4085* | 3.63 | -4.9254 | -1.21 | 4.1904** | 2.10 | -0.1302 | -0.58 | -1.9677 | -1.27 |
| Platinum | 0.2284** | 2.07 | -2.0253 | -0.51 | 3.6112*** | 1.87 | -0.1592 | -0.71 | -2.3500 | -1.54 |

## Table 2.10 - *Continued*

| Futures Contracts | Shock to Term Spread | | Unexpected Inflation | | Change in Expected Inflation | | Shock to Default Spread | | Unexpected Change in Industrial Production | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio |
| **Panel C: Financial** | | | | | | | | | | |
| NYSE | -0.0016 | -0.03 | -3.8070*** | -1.67 | -0.4573 | -0.41 | 0.0825 | 0.66 | -1.1547 | -1.34 |
| SP500 | -0.0025 | -0.04 | -4.2775*** | -1.85 | -0.4258 | -0.38 | 0.0752 | 0.59 | -1.0731 | -1.23 |
| Treasury Bill | 0.0134*** | 1.77 | -0.4976*** | -1.79 | -0.1081 | -0.79 | 0.0675* | 4.46 | 0.0709 | 0.68 |
| Treasury Note | -0.0116 | -0.36 | -0.1906 | -0.16 | -0.8025 | -1.37 | 0.3395* | 5.28 | -0.0816 | -0.18 |
| Treasury Bond | -0.0546 | -1.19 | -0.6184 | -0.37 | -1.9094** | -2.31 | 0.4437* | 4.89 | -0.1599 | -0.26 |
| Deutsch Mark | -0.0622 | -1.21 | 1.5126 | 0.82 | 0.3087 | 0.34 | 0.2157** | 2.07 | 1.0480 | 1.47 |
| Japanese Yen | -0.0492 | -0.94 | 0.7209 | 0.39 | 0.1853 | 0.20 | 0.0836 | 0.79 | -0.4153 | -0.57 |
| Swiss Franc | -0.0309 | -0.55 | 1.3960 | 0.71 | 0.3112 | 0.32 | 0.1959*** | 1.72 | 0.1132 | 0.15 |
| UK Pound | -0.0374 | -0.71 | 2.4341 | 1.31 | 0.9487 | 1.04 | 0.0765 | 0.72 | 0.7836 | 1.08 |

* denotes significant at 1 percent,
** denotes significant at 5 percent,
*** denotes significant at 10 percent.

## Table 2.11: Sensitivities of Futures Returns to the Prices of Risk of the Model with the Residual Market Factor

$$R_t = B\lambda + BF_t + \varepsilon_t$$

| Futures Contracts | Shock to Term Spread | | Unexpected Inflation | | Change in Expected Inflation | | Shock to Default Spread | | Unexpected Change Industrial Production | | Residual Market Factor | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio |
| **Panel A: Agricultural Commodities** | | | | | | | | | | | | |
| Cocoa | 0.0102 | 0.08 | 3.4589 | 0.72 | 0.8338 | 0.35 | -0.1833 | -0.76 | -2.0414 | -1.21 | 0.1275 | 0.87 |
| Coffee | -0.1790 | -1.01 | 3.1953 | 0.48 | 1.0772 | 0.32 | -0.2907 | -0.86 | -0.7982 | -0.34 | -0.0251 | -0.12 |
| Corn | -0.1061 | -0.89 | -5.1353 | -1.14 | -3.0268 | -1.35 | 0.0855 | 0.38 | 1.0651 | 0.67 | 0.0899 | 0.65 |
| Cotton | -0.0696 | -0.53 | -8.1359 | -1.63 | 0.1951 | 0.08 | -0.1760 | -0.70 | 1.5788 | 0.90 | 0.2141 | 1.40 |
| Oats | -0.0302 | -0.17 | 1.0613 | 0.16 | -3.4282 | -1.06 | 0.5435 | 1.64 | 0.3456 | 0.15 | 0.1516 | 0.75 |
| Soybeans | -0.1171 | -1.30 | 0.5458 | 0.16 | 0.2256 | 0.13 | 0.2015 | 1.17 | 1.8345 | 1.53 | -0.1059 | -1.01 |
| Soybean Meal | -0.1039 | -1.03 | -1.2745 | -0.33 | -0.5998 | -0.32 | 0.2382 | 1.24 | 1.0627 | 0.79 | -0.1584 | -1.35 |
| Soybean Oil | -0.0910 | -0.77 | -1.8842 | -0.42 | 1.0783 | 0.48 | 0.3591 | 1.59 | 2.5262 | 1.60 | -0.0965 | -0.70 |
| Sugar | -0.1561 | -0.65 | 7.9828 | 0.87 | -3.9744 | -0.88 | 0.2825 | 0.61 | -4.8204 | -1.50 | -0.0797 | -0.28 |
| Wheat | -0.1560 | -1.44 | 3.7095 | 0.90 | -1.5505 | -0.76 | 0.2157 | 1.04 | -1.6786 | -1.16 | -0.0531 | -0.42 |
| Lean Hogs | 0.1371 | 1.05 | -2.2035 | -0.45 | 0.4375 | 0.18 | 0.3234 | 1.29 | 1.4914 | 0.86 | 0.1283 | 0.84 |
| Lumber | 0.0386 | 0.24 | -3.4601 | -0.57 | -0.1440 | -0.05 | 0.0556 | 0.18 | -1.7098 | -0.80 | 0.2931 | 1.57 |
| Pork Bellies | 0.1313 | 0.59 | -4.9945 | -0.60 | 0.7230 | 0.17 | 0.0350 | 0.08 | -2.0222 | -0.69 | -0.0931 | -0.36 |
| **Panel B: Metal and Oil Commodities** | | | | | | | | | | | | |
| Gold | 0.2336* | 3.53 | -1.2818 | -0.51 | 2.6811** | 2.15 | 0.1682 | 1.33 | -1 3633 | -1.55 | -0.1228 | -1.59 |
| Heating Oil | -0.1361 | -0.79 | -5.0632 | -0.77 | 1.8064 | 0.56 | -0.3524 | -1.07 | -2.1003 | -0.91 | -0.1213 | -0.61 |
| Silver | 0.4092* | 3.48 | -4.9198 | -1.10 | 4.165*** | 1.88 | -0.1247 | -0.55 | -1 9843 | -1.26 | 0.0819 | 0.60 |
| Platinum | 0.212*** | 1.85 | -2.9221 | -0.67 | 4.059*** | 1.88 | -0.1548 | -0.71 | -2.4801 | -1.62 | 0 2970** | 2.22 |

## Table 2.11 - *Continued*

| Futures Contracts | Shock to Term Spread | | Unexpected Inflation | | Change in Expected Inflation | | Shock to Default Spread | | Unexpected Change Industrial Production | | Residual Market Factor | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio |
| **Panel C: Financial** | | | | | | | | | | | | |
| NYSE | 0.0363* | 2.89 | -1.6566* | -3.43 | -1.5177* | -6.39 | 0.0686* | 2.86 | -0.8318* | -4.96 | 0.9788* | 66.41 |
| SP500 | 0.0318* | 2.84 | -2.3299* | -5.40 | -1.3856* | -6.54 | 0.0624* | 2.93 | -0.7802* | -5.23 | 0.9938* | 75.60 |
| Treasury Bill | 0.0121 | 1.54 | -0.57*** | -1.89 | -0.0712 | -0.48 | 0.0673* | 4.47 | 0.0623 | 0.59 | 0.0059 | 0.65 |
| Treasury Note | -0.0180 | -0.57 | -0.4961 | -0.41 | -0.6152 | -1.04 | 0.3324* | 5.55 | -0.0986 | -0.24 | 0.1771* | 4.83 |
| Treasury Bond | -0.0610 | -1.39 | -0.9066 | -0.54 | -1.717** | -2.07 | 0.4330* | 5.17 | -0.1631 | -0.28 | 0.2646* | 5.16 |
| Deutsch Mark | -0.0577 | -1.07 | 1.6745 | 0.81 | 0.1701 | 0.17 | 0.2292** | 2.21 | 1.0260 | 1.42 | -0.0621 | -0.98 |
| Japanese Yen | -0.0514 | -0.93 | 0.4754 | 0.23 | 0.2266 | 0.22 | 0.1050 | 0.99 | -0.5150 | -0.70 | -0.0747 | -1.16 |
| Swiss Franc | -0.0320 | -0.54 | 1.2403 | 0.56 | 0.3278 | 0.30 | 0.2119*** | 1.88 | 0.0423 | 0.05 | -0.12*** | -1.70 |
| UK Pound | -0.0383 | -0.69 | 2.3647 | 1.12 | 0.9706 | 0.93 | 0.0800 | 0.75 | 0.7635 | 1.03 | -0.0331 | -0.51 |

* denotes significant at 1 percent.
** denotes significant at 5 percent.
*** denotes significant at 10 percent.

## Table 2.12: Sensitivities of Futures Returns to the Prices of Risk of the Model with the Return on the Market Portfolio

$$R_t = B\lambda + BF_t + \varepsilon_t$$

| Futures Contracts | Shock to Term Spread | | Unexpected Inflation | | Change in Expected Inflation | | Shock to Default Spread | | Unexpected Change Industrial Production | | Standard & Poor's Return | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio |
| **Panel A: Agricultural Commodities** | | | | | | | | | | | | |
| Cocoa | -0.0007 | -0.01 | 3.2888 | 0.65 | 1.1146 | 0.49 | -0.1789 | -0.73 | -2.0468 | -1.16 | 0.0008 | 0.00 |
| Coffee | -0.1640 | -0.92 | 5.6383 | 0.78 | 1.0403 | 0.32 | -0.3524 | -1.00 | -0.0821 | -0.03 | 0.4780 | 0.91 |
| Corn | -0.1243 | -1.02 | -6.6201 | -1.34 | -2.7798 | -1.24 | 0.1230 | 0.51 | 0.6619 | 0.38 | -0.2964 | -0.81 |
| Cotton | -0.0785 | -0.60 | -8.4434 | -1.60 | 0.4084 | 0.17 | -0.1681 | -0.65 | 1.5233 | 0.83 | -0.0235 | -0.06 |
| Oats | -0.0604 | -0.34 | -0.9993 | -0.14 | -2.9350 | -0.90 | 0.5957*** | 1.70 | -0.1884 | -0.08 | -0.3800 | -0.72 |
| Soybeans | -0.1180 | -1.32 | 0.0221 | 0.01 | 0.0480 | 0.03 | 0.2140 | 1.21 | 1.6368 | 1.30 | -0.2517 | -0.94 |
| Soybean Meal | -0.1112 | -1.09 | -2.2785 | -0.55 | -0.6940 | -0.37 | 0.2628 | 1.31 | 0.7334 | 0.51 | -0.3619 | -1.19 |
| Soybean Oil | -0.0846 | -0.73 | -1.6876 | -0.36 | 0.8414 | 0.39 | 0.3536 | 1.55 | 2.5356 | 1.55 | -0.0847 | -0.24 |
| Sugar | -0 1879 | -0.79 | 7.8064 | 0.81 | -3.2152 | -0.74 | 0.2868 | 0.61 | -4.7644 | -1.42 | -0.0574 | -0.08 |
| Wheat | -0 1667 | -1.50 | 2.3637 | 0.53 | -1.5491 | -0.76 | 0.2492 | 1.14 | -2.0872 | -1 33 | -0.3616 | -1.08 |
| Lean Hogs | 0.1214 | 0.93 | -2.9588 | -0.56 | 0.7544 | 0.32 | 0.3426 | 1.33 | 1.3185 | 0.72 | -0.1133 | -0.29 |
| Lumber | 0.0327 | 0.21 | -0.9639 | -0.15 | 0.5691 | 0.20 | -0.0063 | -0.02 | -0.8387 | -0.37 | 0.7489 | 1.61 |
| Pork Bellies | 0.1412 | 0.63 | -1.9881 | -0.22 | 1.0065 | 0.25 | -0.0403 | -0.09 | -1.0775 | -0.34 | 0.7230 | 1.10 |
| **Panel B: Metal and Oil Commodities** | | | | | | | | | | | | |
| Gold | 0.2305* | 3.53 | -1.2099 | -0.46 | 2.7447** | 2.25 | 0.1663 | 1.31 | -1.3363 | -1 47 | -0 0163 | -0.08 |
| Heating Oil | -0.1336 | -0.79 | -5.5674 | -0.81 | 1.5505 | 0.50 | -0.3403 | -1.02 | -2.3035 | -0.96 | -0.2461 | -0.48 |
| Silver | 0.4056* | 3.47 | -4.0571 | -0.86 | 4.4937** | 2.07 | -0.1459 | -0.64 | -1.6657 | -1.02 | 0.3080 | 0.85 |
| Platinum | 0.197** | 1.68 | -3.5788 | -0.76 | 4.4407** | 2.05 | -0.1378 | -0.60 | -2.6070 | -1.59 | -0.0289 | -0.08 |

## Table 2.12 - *Continued*

| Futures Contracts | Shock to Term Spread | | Unexpected Inflation | | Change in Expected Inflation | | Shock to Default Spread | | Unexpected Change Industrial Production | | Standard & Poor's Return | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio | Coefficient | t-ratio |
| **Panel C: Financial** | | | | | | | | | | | | |
| NYSE | 0.0174 | 1.26 | 0.5755 | 1.05 | -0.2307 | -0.87 | 0.0148 | 0.56 | 0.0837 | 0.44 | 1.0343* | 22.74 |
| SP500 | 0.0124 | 1.05 | -0.1459 | -0.31 | -0.0927 | -0.41 | 0.0099 | 0.44 | 0.1219 | 0.75 | 1.0245* | 25.75 |
| Treasury Bill | 0.0124 | 1.55 | -0.4963 | -1.55 | -0.0568 | -0.38 | 0.0656* | 4.20 | 0.0870 | 0.78 | 0.0270 | 1.08 |
| Treasury Note | -0 0172 | -0.54 | -0.1944 | -0.15 | -0.4949 | -0.83 | 0.3253* | 5.27 | 0.0212 | 0.05 | 0.174*** | 1.73 |
| Treasury Bond | -0.0601 | -1.35 | -0.3357 | -0.19 | -1.507** | -1.80 | 0.4194* | 4.84 | 0.0572 | 0.09 | 0.2957** | 2.10 |
| Deutsch Mark | -0.0637 | -1.15 | 1.3427 | 0.60 | 0.1920 | 0.19 | 0.2371** | 2.18 | 0.9198 | 1.19 | -0.1637 | -0.98 |
| Japanese Yen | -0.0528 | -0.98 | 1.1167 | 0.51 | 0.3156 | 0.32 | 0.0886 | 0.83 | -0.3176 | -0.42 | 0.0827 | 0.52 |
| Swiss Franc | -0.0369 | -0.63 | 0.9912 | 0.42 | 0.3298 | 0.31 | 0.2177*** | 1.88 | -0.0428 | -0.05 | -0.1514 | -0.87 |
| UK Pound | -0.0400 | -0.71 | 1.8054 | 0.79 | 0.8563 | 0.83 | 0.0937 | 0.84 | 0.5709 | 0.72 | -0.2036 | -1.21 |

* denotes significant at 1 percent,
** denotes significant at 5 percent,
*** denotes significant at 10 percent

sectional restrictions hold for any of the four models. Therefore the pervasive sources of risk explain the variation in the expected returns of all the futures contracts considered in this study. This in turn lends support to the hypothesis that the estimated models accurately describe the behaviour of futures prices.

Before any inference regarding the validity of the estimated model can be drawn, we also need to test the robustness of our findings to some specific hypotheses. In this respect we turn our attention to some diagnostic tests that look at the properties of the estimated residuals and also provide some additional information about the fit of the model.

To obtain valid inferences from the CAPM and the multifactor models in terms of which sources of risk command a risk premium in futures markets, we need to have some faith in the estimated parameters and in their standard errors. Namely we need to know whether the model is correctly specified. Although they are often ignored, these misspecification tests are of primary importance since they determine whether the estimated parameters meet the basic requirement of being efficient. The estimators derived in tables 2.5, 2.6, 2.9, 2.10, 2.11, and 2.12 are based on some basic assumptions regarding the time series properties of the residuals. In particular, it is commonly assumed that $E(\varepsilon\varepsilon') = \sigma^2 I$, where $\varepsilon$ is the residual from equations (2.6) and (2.15), E is the expectation operator, $\sigma^2$ is the variance operator, and I is a T*T identity matrix. This means that the residuals are serially uncorrelated and do not suffer from heteroscedasticity. In the case however where $E(\varepsilon\varepsilon') = \Omega \neq \sigma^2 I$, the estimators will still be unbiased but no longer efficient; namely, they may not have the lowest variance. This renders the estimated t-statistics incorrect. In such circumstances inferences regarding the pricing of a factor or the significance of a beta coefficient become insubstantial. Therefore, if we are to draw any valid conclusion regarding the significance of the estimated parameters and the applicability, or otherwise, of the normal backwardation theory, caution should be made that the residuals do not suffer from serial correlation and heteroscedasticity.

For each of the 26 equations, we test for the presence of twelve order serial correlation in the residuals and for changes in the residuals variance. The test for serial correlation consists in regressing the estimated residuals on a constant, the fitted returns, and the lagged residuals (equation (2.21)). Under the null hypothesis of no serial correlation, the coefficients on the lagged residuals are jointly equal to zero. This Lagrange Multiplier test is distributed as $\chi^2$ with twelve degrees of freedom and the calculated value equals $TR^2$ (where T represents the number of observations and $R^2$ is the goodness-of-fit statistic of the regression). The test for heteroscedasticity is implemented by regressing the variance of the residuals (measured as the residuals squared) on a constant and the squared fitted returns (equation (2.22)). Under the null hypothesis of homoscedastic residuals, the coefficient on the fitted returns is equal to zero. This test is distributed as $\chi^2$ with one degree of freedom and the calculated value equals $TR^2$. Hence the following equations are estimated

$$\hat{\varepsilon}_t = \alpha_0 + \sum_{j=1}^{12} \alpha_j \hat{\varepsilon}_{t-j} + \beta \hat{R}_t + u_t \tag{2.21}$$

$$\hat{\varepsilon}_t^2 = \alpha + \beta \hat{R}_t^2 + u_t \tag{2.22}$$

$\hat{\varepsilon}_t$ are the fitted residuals from equation (2.6) for the CAPM, the five factor model, and the model with the residual market factor and the residuals from equation (2.15) for the specification with the market portfolio, $\hat{\varepsilon}_t^2$ is the variance of the fitted residuals, $\hat{R}_t$ represents the asset's fitted returns, $\alpha$ and $\beta$ are the parameters to be estimated, and $u_t$ is a white-noise residual.

The results reported in table 2.13 suggest that the residuals from the CAPM and APT models meet the standard requirements of being homoscedastic. For the CAPM, the specifications with the residual market factor, and the multifactor model with the Standard & Poor's index, the residuals fail to have a constant variance in only three cases. For the five factor model, the rejection of homoscedastic residuals occurs in six cases at the 5 percent level. The residuals do not seem either to evolve according to an autoregressive process of order 12. No more than six residuals suffer from serial correlation at the 1 percent significance level. On average the residuals seem therefore to behave fairly well and the systems of non-linear equations appear to be reasonably well specified. Hence our previous inferences regarding the pricing of a specific risk factor or the significance of a beta coefficient seem valid. None of the specifications seem to fare better than the other ones in terms of misspecification. Hence it seems hard to rely on these tests to choose the most reliable specification of the risk-return relationship in futures markets.

To assess the ability of the models to explain actual futures returns and find out which of the competing specifications the data actually favour, we plot the futures mean (displayed in table 2.1) and expected returns, where the expected returns are computed as the cross-product of the risk premia vector and the sensitivity matrix from each model. The results are reported in figures 2.2, 2.3, 2.4, and 2.5. Since the market risk premium in table 2.6 and most of the beta coefficients in table 2.5 are insignificant, it is not surprising to see that the cross-product B$\lambda$ for the CAPM is in most cases an extremely poor proxy for average returns. Only when actual returns are close to zero, are expected returns a reasonably good estimate of average returns. For the three APT specifications, expected returns seem to be a better proxy for actual average returns in the five factor model. The graphs also indicate that the specification with the market portfolio seems to fare worse than the model with the residual market factor.

To formally assess the ability of the models to explain the cross section of futures returns, we test the hypothesis that expectations are unbiased by regressing actual mean returns on expected returns. We also examine whether expected returns meet the requirements of being rational. This test is performed by regressing actual mean returns on a constant and expected returns. Hence, for the CAPM and for each specification of the APT, the following regressions are estimated

$$\overline{R}_i = \alpha_1 E\left(R_{ij}\right) + \varepsilon_i \tag{2.23}$$

$$\overline{R}_i = \alpha_0 + \alpha_1 E\left(R_{ij}\right) + \varepsilon_i \tag{2.24}$$

## Table 2.13: Misspecification Tests

$$\hat{\varepsilon}_t = \alpha_0 + \sum_{j=1}^{12} \alpha_j \hat{\varepsilon}_{t-j} + \beta \hat{R}_t + u_t$$

$$\hat{\varepsilon}_t^2 = \alpha + \beta \hat{R}_t^2 + u_t$$

| Futures Contract | CAPM | | Five Factor Model | | Residual Market Model | | Standard & Poor's Model | |
|---|---|---|---|---|---|---|---|---|
| | S.C.[1] | Heterosc.[2] | S.C. | Heterosc. | S.C. | Heterosc. | S.C. | Heterosc. |
| **Panel A: Agricultural Commodities** | | | | | | | | |
| Cocoa | 19.2561 | 0.1182 | 20.2801 | 0.1037 | 20.1170 | 0.2333 | 20.4470 | 0.0928 |
| Coffee | 8.1656 | 0.0729 | 7.7355 | 1.0346 | 7.8206 | 1.4207 | 11.4528 | 0.6359 |
| Corn | 9.1392 | 0.0183 | 5.6862 | 0.0963 | 5.9387 | 0.0000 | 10.6687 | 0.2036 |
| Cotton | 10.7417 | 0.2050 | 8.8121 | 0.8377 | 9.9638 | 0.8518 | 8.6194 | 0.3186 |
| Oats | 7.4195 | 0.0168 | 6.4463 | 8.6960** | 6.2664 | 12.0498** | 9.7940 | 0.2795 |
| Soybeans | 12.2330 | 0.4548 | 12.9954 | 8.4474** | 11.5123 | 2.7448 | 9.7316 | 0.5784 |
| Soybean Meal | 15.0612 | 0.4479 | 14.5455 | 10.6933** | 12.8293 | 0.8353 | 13.0684 | 0.0321 |
| Soybean Oil | 9.8786 | 0.1190 | 10.3374 | 8.3986** | 9.6750 | 3.2143 | 9.7873 | 4.6696* |
| Sugar | 27.2741** | 0.8541 | 24.1866* | 0.5009 | 24.0451* | 0.3293 | 24.1281* | 0.2166 |
| Wheat | 16.7634 | 0.3629 | 16.6620 | 6.3128* | 17.7811 | 5.2613* | 25.2803* | 0.6928 |
| Lean Hogs | 46.8998** | 0.1656 | 44.0588** | 0.0003 | 45.2677** | 0.0587 | 44.3447** | 0.5737 |
| Lumber | 23.7128* | 1.3559 | 22.5395* | 0.5144 | 23.3998* | 1.6070 | 29.0879** | 0.1488 |
| Pork Bellies | 20.2081 | 0.4131 | 20.0907 | 0.0477 | 20.1536 | 0.0516 | 26.6095** | 0.0135 |

## Table 2.13 - *Continued*

| Futures Contract | CAPM | | Five Factor Model | | Residual Market Model | | Standard & Poor's Model | |
|---|---|---|---|---|---|---|---|---|
| | S.C.[1] | Heterosc.[2] | S.C. | Heterosc. | S.C. | Heterosc. | S.C. | Heterosc. |
| **Panel B: Metal and Oil Commodities** | | | | | | | | |
| Gold | 26.5045** | 1.8899 | 20.8235 | 2.8491 | 22.4729* | 0.8819 | 20.8619 | 2.1127 |
| Heating Oil | 25.1879* | 0.2994 | 23.9574* | 0.0100 | 23.4962* | 0.0537 | 23.8891* | 0.0378 |
| Silver | 23.0597* | 0.0075 | 16.4322 | 3.7801 | 16.7781 | 2.9953 | 20.6593 | 0.7268 |
| Platinum | 17.8110 | 0.4526 | 19.9689 | 2.7433 | 20.4382 | 3.0405 | 20.9186 | 2.2035 |
| **Panel C: Financial** | | | | | | | | |
| NYSE | 47.2174** | 0.2159 | 16.5319 | 1.2626 | 58.7601** | 0.0136 | 74.2689** | 2.9024 |
| SP500 | 74.0110** | 0.3355 | 15.1276 | 0.8539 | 88.8550** | 1.4149 | 97.1975** | 9.3837** |
| Treasury-Bill | 15.6421 | 20.9936** | 31.4151** | 11.9801** | 30.0485** | 11.6208** | 31.3353** | 11.7680** |
| Treasury-Note | 11.7545 | 53.1004** | 5.0106 | 0.0237 | 7.3423 | 0.1086 | 7.4264 | 0.0678 |
| Treasury-Bond | 9.4309 | 56.8132** | 2.6637 | 0.0517 | 6.2185 | 0.0082 | 6.9684 | 0.1651 |
| Deutsch Mark | 8.5741 | 0.5781 | 5.2026 | 0.3278 | 5.8950 | 0.4138 | 7.7435 | 0.0522 |
| Japanese Yen | 13.9723 | 0.1551 | 13.9307 | 0.3927 | 13.3525 | 0.2060 | 15.9959 | 0.4677 |
| Swiss Franc | 13.6537 | 0.1469 | 10.2890 | 1.0048 | 11.5180 | 0.0549 | 11.7970 | 0.2404 |
| UK Pound | 7.5286 | 0.0734 | 8.4713 | 3.7352 | 8.2236 | 3.5107 | 11.4927 | 0.1804 |

[1] Test of up to twelve order serial correlation distributed as $\chi^2(12)$ with a critical value of 21.03 at 5 percent and 26.22 at 1 percent,

[2] Test for the presence of heteroscedasticity distributed as $\chi^2(1)$ with a critical value of 3.84 at 5 percent and 6.63 at 1 percent,

* denotes significant at 5 percent,

** denotes significant at 1 percent.

Figure 2.2: Plot of Actual and Expected Returns:
Result from the CAPM

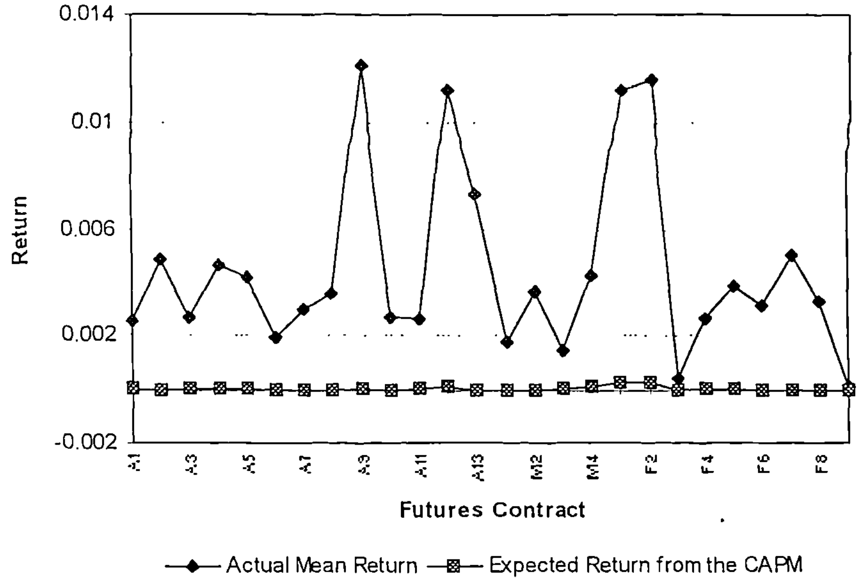
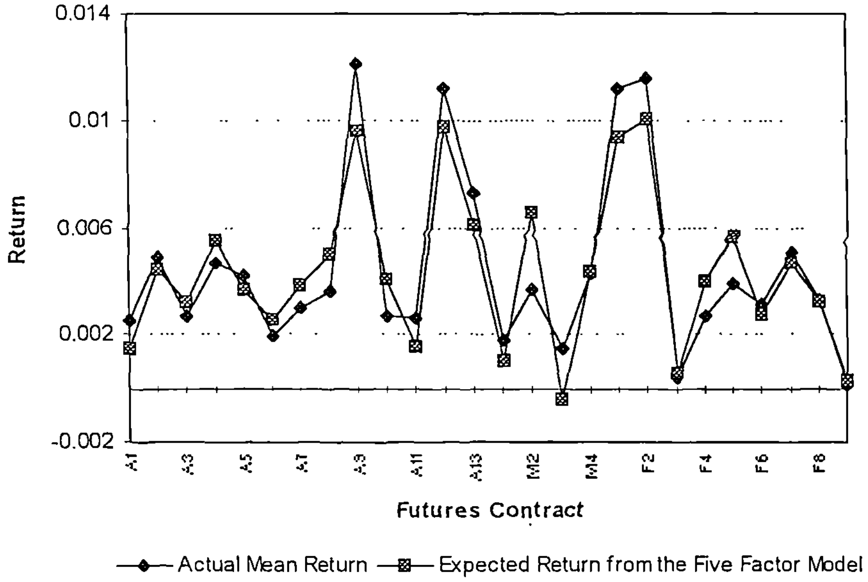


Figure 2.3: Plot of Actual and Expected Returns:
Result from the Five Factor Model



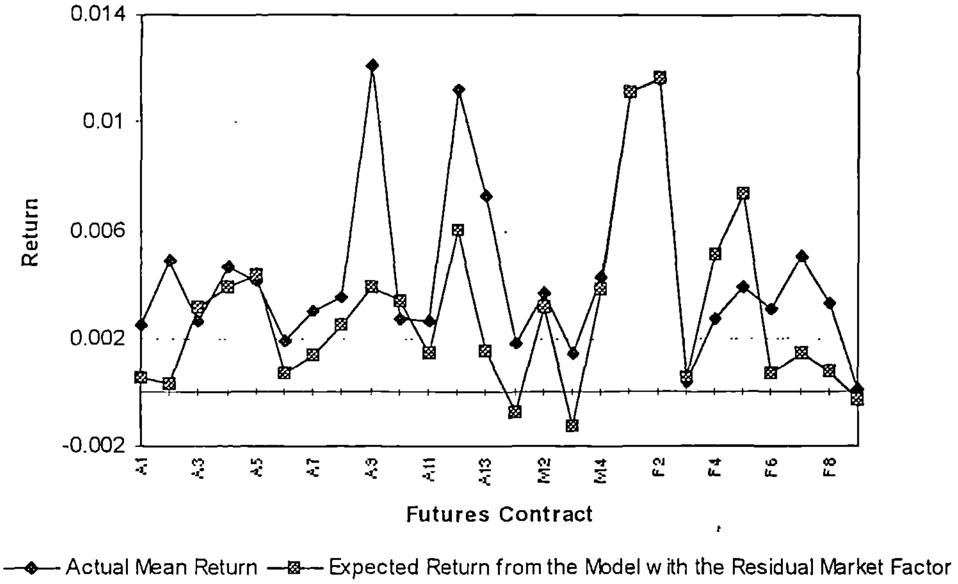


Figure 2.4: Plot of Actual and Expected Returns: Result from the Model with the Residual Market Factor

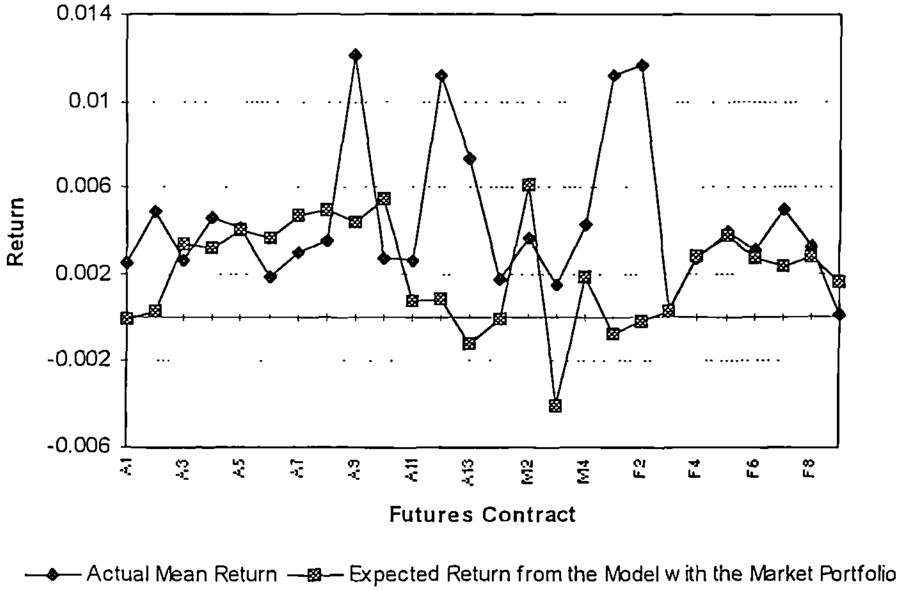


Figure 2.5: Plot of Actual and Expected Returns: Result from the Model with the Market Portfolio

$\overline{R}_i$ is the actual mean return on the i$^{th}$ futures contract, $E(R_{ij})$ is the expected return on the i$^{th}$ futures contract as measured from model j, $\varepsilon_i$ is a vector of residuals, $\alpha_0$ and $\alpha_1$ are the estimated coefficients. Under the null hypothesis that expectations are unbiased, $\alpha_1$ is equal to one in equation (2.23). Consistent with rational expectations, we also test the joint hypothesis that $\alpha_0$ equals zero and $\alpha_1$ equals one in equation (2.24). These Wald tests are distributed as $\chi^2$ with one and two degrees of freedom respectively. We further consider the intercept term in (2.24) as a measure of mispricing (see, for example, Mei (1993)) and the adjusted $R^2$ as a measure of the fit of the model. The results are reported in table 2.14 panels A and B. The t-tests for the null hypothesis that $\alpha_1$ equals one in (2.23) and the Wald tests in panel A suggest that expectations are unbiased for the three specifications of the APT but fail to be unbiased for the CAPM. The results from the rational expectation hypothesis suggest that the five factor model is the only specification that does a good job at tracking actual returns. For the three other representations indeed, expected returns fail to meet the criterion of being rational: the t-tests fail to support the null hypotheses embedded in equation (2.24) and the joint hypothesis of rational expectation is rejected for these models at the 1 percent level of statistical significance. The most striking feature of the regressions in table 2.14 panel B is the large proportion of cross sectional variation in expected returns explained by the five factor model. The adjusted $R^2$ of 85.8 percent is much larger than those of the three alternative specifications. The five factor model also presents the lowest estimated measure of mispricing in absolute terms (equal only to -0.02 percent)[12].

To find out which of the four specifications of the risk-return relationship the data favour, we further implement a direct comparison of the models that is in the spirit of Chen (1983). Namely, we estimate the following regression

$$\overline{R}_i = \alpha_0 + \alpha_1 E(R_{ik}) + \alpha_2 E(R_{il}) + \alpha_3 E(R_{im}) + \alpha_4 E(R_{in}) + \varepsilon_i \qquad (2.25)$$

---

[12] This result compares favourably with the estimate from the stock market (see Mei (1993)).

If the data favour model k over models l, m, and n, $\alpha_1$ should equal 1, while $\alpha_2$, $\alpha_3$, and $\alpha_4$ should equal 0 in (2.25). These restrictions can easily be tested using the Wald test that is distributed as $\chi^2$ with four degrees of freedom. This test is however rather inconclusive since the expected returns measured with the Chen, Roll, and Ross (1986) factors are considered three times in the right-hand-side of equation (2.25). Similarly, the inconclusiveness of the test stems from the fact that expected returns are measured from the CAPM and from the APT specification with the market portfolio. It follows that the expected returns on the right-hand-side of equation (2.25) are likely to be highly correlated. The high degree of multicollinearity between the regressors might produce inefficient estimates of the coefficients, biased standard errors, and hence unreliable estimates of the t-statistics. With this in mind, we hope nonetheless that the testing of the restrictions embedded in (2.25) will give us some insight as to which model the data actually favour. Table 2.14 panel C displays the results from this test and indicates that the data reject the joint hypotheses for the four models. Still the $\chi^2$ statistics indicate that the rejection is stronger for the CAPM, the models with the residual market factor and the market portfolio. Given besides that it fares at least as good as any other versions in terms of misspecification and with respect to the validity of the cross sectional non-linear restrictions, the five factor model is favoured as a description of futures returns.

## VIII. Implications in Terms of Normal Backwardation

In this section we make use of the CAPM and multifactor models previously estimated to analyse the issue of normal backwardation. Consistent with the Keynesian approach is the idea that the futures price exhibits an upward trend over the life of the contract to induce speculators to enter the demand side in futures markets. Since arbitrage ensures that the futures and spot prices converge at maturity, a positive and significant expected return indicates that the futures price before maturity is a downward biased estimate of the expected spot price and that the futures contract under investigation is risky. This in turn backs up the normal backwardation theory: long investors earn a premium proportional to the systematic risk of the futures contract for underwriting hedgers' risk of price

## Table 2.14: Goodness of Fit

*Panel A: Test of Unbiasedness:* $\overline{R}_i = \alpha_1 E(R_{ij}) + \varepsilon_i$

| Specification of the Risk-Return Relationship | $\alpha_1$ | Std-Error | t-ratio ($H_0$: $\alpha_1$=1) | Wald Test of the Restriction that $\alpha_1 = 1$ |
|---|---|---|---|---|
| CAPM | 47.9928* | 9.6187 | 4.89 | 23.87* |
| Five Factor Model | 1.0435 | 0.0475 | 0.92 | 0.84 |
| Multifactor Model with the Residual Market Factor | 1.0995 | 0.1313 | 0.76 | 0.57 |
| Multifactor Model with the Market Portfolio | 0.8613 | 0.3126 | -0.44 | 0.20 |

*Panel B: Rational Expectation Test:* $\overline{R}_i = \alpha_0 + \alpha_1 E(R_{ij}) + \varepsilon_i$

| Specification of the Risk-Return Relationship | $\alpha_0$ | SE | t-ratio ($H_0$: $\alpha_0 = 0$) | $\alpha_1$ | SE | t-ratio ($H_0$: $\alpha_1 = 1$) | Wald Test of $H_0$: $\alpha_0 = 0$ and $\alpha_1 = 1$ | Adjusted-$R^2$ |
|---|---|---|---|---|---|---|---|---|
| CAPM | 0.0034* | 0.0006 | 5.75 | 29.2961* | 7.1497 | 3.96 | 87.52* | 38.7% |
| Five Factor Model | -0.0002 | 0.0005 | -0.45 | 1.0759 | 0.0873 | 0.87 | 1.01 | 85.8% |
| Multifactor Model with the Residual Market Factor | 0.0023* | 0.0007 | 3.47 | 0.7476*** | 0.1493 | -1.69 | 12.84* | 49.1% |
| Multifactor Model with the Market Portfolio | 0.0048* | 0.0009 | 5.29 | -0.1514* | 0.2892 | -3.98 | 28.38* | 1.13% |

## Table 2.14 - *Continued*

*Panel C: Direct Comparison of the Four Specifications of the Risk-Return Relationship:*

$$\overline{R}_i = \alpha_0 + \alpha_1 E(R_{ik}) + \alpha_2 E(R_{il}) + \alpha_3 E(R_{im}) + \alpha_4 E(R_{in}) + \varepsilon_i$$

| Expected Returns Measured from | Estimate | Std-Error | t ratio $H_0$: $\alpha = 0$ | t ratio $H_0$: $\alpha = 1$ |
|---|---|---|---|---|
| Intercept Term | 0.0000 | 0.0003 | -0.02 | |
| CAPM | 22.8378 | 9.1179 | 2.50** | 2.40** |
| Five Factor Model | 1.3619 | 0.0975 | 13.96* | 3.71* |
| Multifactor Model with the Residual Market Factor | -0.6805 | 0.2343 | -2.90* | -7.17* |
| Multifactor Model with the Market Portfolio | -0.1332 | 0.1299 | -1.02 | -8.72* |

| Null Hypothesis | Wald Test of the Restrictions |
|---|---|
| $H_0$: $\alpha_1=1$, $\alpha_2=0$, $\alpha_3=0$, & $\alpha_4=0$ | 475.67* |
| $H_0$: $\alpha_1=0$, $\alpha_2=1$, $\alpha_3=0$, & $\alpha_4=0$ | 50.84* |
| $H_0$: $\alpha_1=0$, $\alpha_2=0$, $\alpha_3=1$, & $\alpha_4=0$ | 258.54* |
| $H_0$: $\alpha_1=0$, $\alpha_2=0$, $\alpha_3=0$, & $\alpha_4=1$ | 817.46* |

* denotes significant at 1 percent,
** denotes significant at 5 percent,
*** denotes significant at 10 percent.

fluctuation. The normal contango theory on the other hand asserts that the futures price has to fall over the life of the contract to entice speculators to open short futures positions. Therefore a negative and significant expected return suggests that a long position in the futures market offered a negative return proportional to the systematic risk of the futures contract. This implies that the futures price before maturity exceeds the expected spot price, a result consistent with the normal contango hypothesis. Finally an expected return that does not significantly differ from zero indicates that the futures price prior maturity is an unbiased estimate of the maturity spot price. In other words long and short hedgers transfer their risk to one another and there is no incentive for speculators to enter futures markets. To summarise our analysis a significant expected return is evidence in favour of the presence of a risk premium in futures markets. The sign of the expected return in turn tells us whether the premium supports the normal backwardation or the normal contango theory.

We use the risk premia vectors and sensitivities matrices estimated in tables 2.5 and 2.6 (for the CAPM) and in tables 2.9, 2.10, 2.11 and 2.12 (for the APT) to test the null hypothesis of zero systematic risk. The null hypothesis will be accepted whenever the cross product of the risk premia vector and the matrix of sensitivities is equal to zero. This can be achieved either when the beta coefficient does not significantly differ from zero, when the risk premium is insignificant, or when both conditions are met on the same time. In section VI we found that four factors (shocks to term and default spreads, unexpected inflation, and unexpected change in industrial production) are priced in futures markets and that eleven contracts exhibit significant sensitivities to these factors at the 10 percent level of statistical significance. Therefore eleven futures contracts can be considered as risky in the sense of the APT. While the expected returns on silver futures is negative, the expected return on the remaining ten contracts (soybean oil, gold, platinum, NYSE, S&P500, Treasury bill, Treasury bond, Treasury note, Deutsch Mark, and Swiss Franc) is positive.

One of the implications of the normal backwardation hypothesis, namely a rising price pattern, is supported for ten (principally financial and metal) out of 26 futures contracts.

The upward drift in futures prices identified for these futures indeed suggests that speculators are on average net long. The supply by short hedgers exceeds the demand by long hedgers, requiring the necessary intervention of long speculators to restore equilibrium. Similarly, the falling price pattern identified for silver futures lends support to the normal contango theory. The results indicate that speculators in this market are on average net short. The imbalance between long and short hedging is eliminated by short speculators who require a premium to bear that part of long hedgers' risk that is not covered at no cost by short hedgers. The evidence also suggest that the futures prices on the remaining 15 contracts exhibit no significant trend, suggesting that net hedging pressure in these markets equals zero. In this scenario, long and short hedgers transfer the risk of price fluctuations to one another at no cost, leaving no incentive to speculators to enter futures markets.[13]

The analysis of the normal backwardation theory in the context of the model with the residual market factor and with the market portfolio leads to similar conclusions. A careful look at tables 2.10, 2.11, and 2.12 indeed suggests that the hypothesis of unbiasedness is rejected in 10 cases for the model with the residual market factor and in 9 cases for the specification with the market portfolio. The alternative hypothesis sustained by the data for these contracts is the normal backwardation theory (except for silver that follows a contango). The CAPM results mentioned in section V suggest that, since the risk premium on the market portfolio is insignificant, the expected returns on the 26 futures contracts considered in this study are equal to zero. Hence futures prices exhibit no upward or downward trend. The tests undertaken in section VII however indicate that the CAPM results and the results from the multifactor models with the residual market factor and the market portfolio should be viewed with some suspicion. We believe thus that the five factor model is more likely to accurately address the issue of normal backwardation.

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[13] We collected settlement prices of the contract which is the nearest to maturity except in the maturity month, in which case we used the contract which is next nearest to maturity. Since we never used the settlement price at maturity, we do not claim that the evidence presented here support the hypothesis that the current futures price is a downward biased estimate of the spot price expected at maturity. We just conclude that ten (one) futures prices exhibit an upward (downward) trend which is consistent with the normal backwardation (contango) theory.

These results are to some extent consistent with the evidence presented in Kolb's (1992). Using a cross section of 23 commodities, four currencies, and three interest rates related futures contracts over a period of up to 32 years, he studies the actual behaviour of futures prices and tests three hypotheses consistent with the rising price pattern hypothesised by the theory of normal backwardation. He examines whether futures mean returns are positive, whether futures prices prior expiration tend to be below futures prices at expiration, and whether the premium required by speculators is a decreasing function of the time to maturity. He concludes that most futures contracts exhibit no risk premium. "Normal backwardation is not normal": only a few commodities contracts (feeder cattle, live beef, live hogs, and orange juice) support the rising trend in futures prices consistent with the Keynesian theory. The data provide scarce evidence for the normal contango theory too: only crude oil, heating oil, and lumber futures contracts present the downward drift in futures prices implied by a contango. Deaves and Krinsky (1995) use an extended sample to reinvestigate the issue of normal backwardation for the commodity futures that supported Keynes' hypothesis in Kolb (1992). The evidence suggest that it is even questionable that the futures that exhibit a risk premium in the sample studied by Kolb have significant expected return over a sample that ends in 1994.

Direct comparisons of Kolb and Deaves and Krinsky's results with ours are somehow difficult since most of the contracts that exhibit the characteristics of normal backwardation in Kolb are not included in this study. Likewise, according to our results, the stock index futures contracts consistently sustain the normal backwardation hypothesis. They were not considered in Kolb and Deaves and Krinsky. However our conclusions are to some extent in line with the evidence presented in both studies. While Kolb rejects Keynes' hypotheses for most agricultural commodity futures, we present evidence that only soybean oil futures exhibit a risk premium that is significant as implied by the normal backwardation and contango theories. Hence the conclusion that most agricultural futures contracts exhibit no risk premium seems to prevail, either because the supply and demand of futures contracts by equally risk adverse short and long hedgers are balanced, or because the risk associated with futures is mainly eliminated in a well-diversified portfolio and hence does not require any compensation. The results with respect to metal and financial futures are however somehow unexpected. While Kolb found that the futures price on metal and Treasury securities is an unbiased predictor of the spot price at maturity, we conclude that these contracts are risky. As such, they sustain the hypothesis that risk-adverse investors require a premium proportional to the systematic risk of the futures contract to underwrite hedgers' risk.

## IX. Conclusions

The issue of whether the risk-return relationship in futures markets conforms to the capital asset pricing model and to the arbitrage pricing theory constitutes a quite well-documented area of research in finance. Unfortunately most authors conduct their research in a time series framework and hence implicitly assume that the prices of risk across futures and equity markets are the same. Alternatively other authors use the Fama and McBeth methodology and hence relax the assumption underlying the time series tests. This approach however implicitly assumes that security returns follow a strict factor structure and also suffers from an error in variable problem that may lead to wrong inferences regarding the pricing of a specific risk factor or the significance of a beta coefficient. Our purpose in this chapter was to use two methodologies that tackle these two problems by jointly estimating the risk premia vector and the sensitivities of futures returns to the market portfolio and to the APT prespecified sources of risk. This enables us to draw some clear inferences regarding the presence of futures risk premia and the applicability, or otherwise, of the normal backwardation theory.

The results suggest that the risk-return relationship in futures markets does not conform to the CAPM model: the market risk premium associated with the Standard and Poor's composite index is insignificant and the estimated betas against this proxy are significant for only six out of the 26 futures contracts considered. As a further robustness check we test whether those preliminary poor results stemmed from a failure of the CAPM or from the inadequacy of the Standard & Poor's composite index to proxy the true market portfolio. Unfortunately our attempt to rescue the CAPM fails: a combination of 10 percent of the Dow-Jones cash commodity index and 90 percent of the Standard & Poor's index does not yield a significant price of market risk either. In the light of these evidence and given the poor performance of the CAPM at tracking actual returns, we conclude that the CAPM does not accurately describe the cross sectional variation in expected futures returns.

Taking special care that the derived factors meet the basic requirements of being truly unexpected, we then turn out attention to the estimation of the APT. Four factors associated with shocks to term and default spreads, unexpected inflation, and unexpected change in industrial production have statistically significant prices of risk. Eleven of the twenty-six contracts used are sensitive to the factors and thus command a risk premium. At least for these contracts (predominantly metal and financial), the theory of normal backwardation seems to apply. This suggests that the risk of price fluctuation for short hedgers is not completely hedged by long hedgers, requiring thus the intervention of speculators to re-establish equilibrium in financial and metal futures. For the remaining contracts, the evidence are consistent with the results presented in Kolb (1992): normal backwardation does not seem to prevail. The evidence that agricultural futures predominantly exhibit no risk premium indicate that the risk associated with agricultural futures is mainly diversifiable and hence is not compensated by any reward. Alternatively this could suggest that the supply of agricultural futures by short hedgers balances the demand by long hedgers, implying hence that there is no risk transfer between hedgers and speculators in agricultural futures markets.

We argue in this chapter that the conclusions regarding the pricing of systematic risk in the time series tests[14] crucially depend upon the assumption of an uniform factor structure across markets. The normal backwardation theory, as tested in these studies, will only be supported empirically if the prices of risk identified in the equity market coincide with the risk premia vector present in futures markets. Of course, unless a careful analysis of market integration is done, one cannot ascertain that such an assumption is valid. The

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[14] See, for example, Dusak (1973), Carter, Rausser, and Smith (1983), Baxter, Conine, and Tamarkin (1985), Chang, Chen, and Chen (1990) for the CAPM and Young (1991) and Chen, Cornett, and Nabar (1993) for the APT.

uniqueness of the risk premia vector across futures and spot markets, along with a careful analysis of the implications of market integration on the decision making process of investors, is the focus of the following chapter.

# Chapter III: Sources of Systematic Risk in Futures and Spot Markets: A Study of Market Integration

## I. Introduction

Funds managers interested in timing decisions and portfolio performance evaluation rely on traditional asset pricing models to adjust the quantity of risk of their portfolio and rank portfolios according to their level of systematic risk. Constant expected return asset pricing models posit that the quantity of risk of a portfolio equals the weighted average of the individual quantities of risk and that the Jensen's (1968) measure of abnormal performance detects the presence of mispriced securities and forms the basis of active investment strategies.

Such conclusions however rely on the additional hypothesis that the assets under investigation come from integrated markets; in the sense that the relationship between risk and return in these markets conforms to the same security market line (or hyperplane). In particular, it is assumed that the rewards per unit of risk are the same across markets. When assets come from segmented markets however, there might well be the case that the two markets follow different return generating processes; namely, the rewards per unit of systematic risk might differ.

In this chapter, we explain the implications of market integration on the decision making process of fund managers. More specifically, we demonstrate that, when assets come from segmented markets, fund managers interested in adjusting the quantity of risk of their portfolio and evaluating portfolio performance should look at the relative prices of risk in each market as well as the quantities of risk of the individual assets before making any buy or sell decision. In other words funds managers in the presence of market segmentation should carefully determine the implication that different prices of risk across markets might have on the desirability of their trade. For example, if they assume that markets are integrated, when in fact they are not, they might wrongly conclude that some securities are mispriced. They might also adjust the composition and the riskiness of their portfolio in ways that might not be profitable.

The issue of market integration is investigated with respect to the hypothesis that the prices of risk in futures markets coincide with the risk premia identified in the underlying commodity, currency, and equity markets. The choice of this cross section reflects the fact that, fund managers, instead of operating in the cash market, usually prefer investing in futures markets. First, short selling the cash asset might be restricted and this might render speculation worthwhile only to those that already carry the spot asset. Second, futures markets are more liquid and involve lower transaction costs than the underlying asset markets. Trading stock index futures to benefit from an anticipated rise or fall in the market is also much easier and cheaper than investing in a portfolio of stocks that closely mimics the underlying stock index. Finally the main advantage of using futures for speculation is that futures contracts are highly levered bets and, hence, only a small amount of capital has to be paid as margin requirements to take on a large long or short position. However, the advantages of trading in futures markets have to be weighted against the possible losses that might be incurred if decisions that wrongly rely on market integration are made. This calls for more evidence on the issue of market integration.

Our interest in studying the integration between futures and cash markets also stems from the fact that studies of the uniformity of the factor structure across futures and cash markets are limited to the integration between futures and equity markets. As such, they are of little interest to fund managers willing to trade commodities as well as equities and futures. Given besides the importance of the assumption of market integration for fund managers, it seems important to assess whether futures and other cash markets, such as commodity and foreign exchange markets, are integrated.

The contribution of this chapter is to explain the implications of market integration on the decision making process of fund managers and to provide a thorough analysis of the integration between futures markets and spot commodity, currency, and equity markets. To do so, we make use of a methodology that is in the spirit of Bessembinder (1992). We however extend his methodology to test the hypothesis that the prices of risk across different spot markets coincide with the risk premia identified in futures markets. While we fail to reject the hypothesis that the prices of risk identified in futures markets are equal to the factor risk premia for spot financial securities, the hypothesis that the prices of risk between the commodity and futures markets are equal is rejected at conventional levels of statistical significance. It follows that the spot markets for financial securities and the futures markets are integrated and that the futures and commodity spot markets are segmented. Such results are of primary importance to investors who use asset pricing models to adjust the risk-return trade-off of their portfolio and evaluate portfolio performance.

It might possibly be argued that, because of the absence of arbitrage opportunities between the futures and underlying assets, the factor structures across markets should coincide. The cost of carry model indeed implies that the futures and underlying prices move in tandem, are subject to the same pervasive sources of risk, respond to external economic news in like manner, and have therefore the same expected returns. In this scenario, one can expect to sustain the hypothesis of market integration. This however will only be the case if the basis, defined as the difference between the futures and spot prices, is deterministic. In the case however where the basis evolves stochastically, there might be some instability in the futures price that is not reflected in the spot price. This could for example happen because transaction costs, brokers' commissions, differences between lending and borrowing rates, short selling restrictions, non-synchronous trading between the futures and underlying asset markets, tax timing option ... hinder arbitrage and lead to segmentation. These transaction costs and trade restrictions might prevent some market participants from arbitraging away any apparent difference between the spot price and the cost of carry price. In such a case, the futures and spot prices might not be perfectly correlated, and the pervasive forces that drive changes in the spot price might differ from the factors that influence the pricing of futures contracts.

The rest of this chapter is organised as follows. Section II presents a brief review of the existing literature. Section III exposes the implications of market integration on the decision making process of fund managers. Section IV discusses the methodology used. Section V describes the data set. Section VI estimates the prices of risk associated with the market portfolio and the APT factors in the commodity, currency, and equity markets, thus providing some preliminary insights onto the issue of market integration. Section VII presents some more formal tests of the null hypothesis of market integration. Some concluding remarks are offered in section VIII.

## II. Market Integration: A Brief Review

Studies of the uniformity of the factor structure across futures and cash markets are scarce and limited to the integration between futures and equity markets. They do not address the issue of integration between futures and commodity spot markets and, as such, are of little interest to fund managers willing to trade commodities as well as equities and futures. The evidence mainly suggest that futures and equity markets are to some extend segmented. The general approach consists in testing the hypothesis that the relationship between risk and return in futures and equity markets conforms to the same security market line (or hyperplane). Hence, there should be a linear relationship between expected return and systematic risk in futures markets, the intercept of this relationship should equal zero[1], and the risk premia present in futures markets should coincide with the prices of risk identified in the equity market. It follows that, when markets are integrated, it should not be possible to construct portfolios of futures and stocks that perform better than stock only portfolios on a risk adjusted basis (see, for example, Bessembinder (1992, 1993) and Bessembinder and Chan (1992)).

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[1] The rate of return on a zero-beta futures contract should be zero because of the absence of capital investment in futures markets (see, for example, Dusak (1973)).

To investigate these issues, both constant and time-varying expected return asset pricing models have been used. Using the cross section regression $T^2$ test that measures the departure between realised mean returns and expected returns for both the traditional CAPM and the multifactor model, Bessembinder (1993) concludes that the restriction of a linear trade-off between risk and return, of a zero intercept term in futures markets, and of an uniform vector of factor risk premia across markets is rejected for both the CAPM and the multifactor model. This could result from the presence of some segmentation between the equity and futures markets, a failure of the underlying asset pricing model, some deficiency in measuring risk, or some combination of the three.

Investigating the uniformity of the risk structure in futures and equity markets and the proposition that futures markets do not require any initial investment, Bessembinder (1992) concludes that, when tested against an unspecified hypothesis, the hypothesis that futures and equity markets are integrated cannot be rejected at conventional level. However residual risk conditioned on net hedging appears to be priced in agricultural and foreign currency futures and does not seem to command a risk premium in financial and foreign currency futures markets. The presence of a risk premium conditional on net hedging in agricultural and foreign currency futures not only supports the normal backwardation theory but also suggests some degree of segmentation between the equity market on the one hand and the agricultural and foreign currency futures markets on the other hand. For these futures expected returns do not depend on systematic risk alone, there is an additional risk premium that is conditional upon net hedging pressure.

Given the growing interest in conditional asset pricing models in the stock markets, attempts have also been made to test market integration by testing whether the time-varying risk premia identified in futures markets coincide with the time-varying risk premia present in the equity market. The results once again suggest that there might be some degree of segmentation between the two markets. For example, using latent variable models, Bessembinder and Chan (1992) prove that the two latent variables present in futures markets differ from the two latent variables identified by Ferson (1990) in the equity market. It follows that futures and equity markets are to some extent segmented, either because the two markets are sensitive to different sources of risk, or because the two markets are subject to the same sources of risk but the risk premium associated with each factor varies across markets.[2] Finally, Antoniou, Malliaris, and Priestley (1997) study the time variation in the Standard & Poor's futures and spot returns. They estimate a conditional asset pricing model with time-varying risk and constant price of risk, where the dynamics of the conditional variance are a function of prespecified risk factors. They conclude that the prices of risk in the futures and spot markets differ, suggesting once again a lack of integration between the two markets.

The studies mentioned above test the hypothesis that the risk-return relationship in futures markets conforms to the security market line identified in the equity market. They do not address the issue of integration between other underlying assets and futures and, as such, are of little interest to fund managers willing to trade commodities and foreign currencies as well as equities and futures. Given the importance of the assumption of market integration for fund managers and the evidence that futures and equity markets might be segmented, it is of primary importance to assess whether futures and other cash markets, such as commodity and foreign exchange markets, are integrated. Along with the implications of market integration on the decision making process of fund managers, testing the uniformity of the factor structure across markets is our primary concern throughout this chapter.

## III. Implications of Market Integration on the Decision Making Process of Market Participants

It is commonly assumed that the prices of risk in futures markets coincide with the prices of risk identified in spot markets. Relaxing this assumption however has direct

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[2] Note however that, while latent variable models determine the number of time varying risk premia, they do not attach any economic interpretation to the risk the premia are supposed to be a compensation for. Therefore, notwithstanding the contribution of their research to the literature on market integration, the approach used by Bessembinder and Chan (1992) might be of little interest to market participants willing to hedge against or speculate on a specific source of uncertainty.

implications on the decision making process of investors who use constant expected return asset pricing models to time the market and evaluate portfolio performance. For example, assume an investor expects a bull (bear) market and wants to make his portfolio more aggressive (defensive) by increasing (decreasing) the risk of his portfolio. For simplicity, assume that the return generating process is a one-factor model where the quantity of risk is defined as B and the price of risk as $\lambda$. Three alternative strategies are offered to him. He can buy securities with high B in bull markets and sell them in bear markets; alternatively, he can keep the constitution of his risky portfolio constant, sell Treasury bills short in bull markets, and buy them back in bear markets; or, finally, he can trade futures contracts to manage the riskiness of his portfolio and thereby adjust the proportion of wealth invested in futures markets.

Futures are generally considered as the cheapest and fastest way of altering the effective quantity of risk of a cash assets portfolio. The investor just has to trade futures up to the point where the quantity of risk, B, of the portfolio equals the desired level. The number of futures required to change the B value of a portfolio from $B_1$ to $B_2$ equals $N_F = V_S/V_F(B_2 - B_1)$, where $V_S$ and $V_F$ are the value of the spot asset position and the value of one futures contract respectively and $B_1$ and $B_2$ are the initial and target quantities of risk of the portfolio. If $N_F$ is negative, a short sale is suitable; a positive $N_F$ suggests that a long futures position is appropriate.

To understand why market segmentation can alter the decision making process of investors while attempting to adjust the quantity of risk of their portfolio, let us first consider the case where the prices of risk are the same across markets. Let us then assume that we construct a portfolio that includes both spot assets and futures contracts. By definition, the expected return of this portfolio equals

$$E(R_P) = E(R_S) + HE(R_F) \qquad (3.1)$$

where $R_P$ represents the return on the portfolio, $R_S$ is the return on the spot asset, $R_F$ is the return on the futures contract, E(.) is the expectation operator, and H is the relative weight allocated to futures contracts in the portfolio expressed as a proportion of the total wealth of the portfolio. Assuming that assets and futures portfolios lie on the same security market line than assets only portfolios, the portfolio expected return can be expressed as

$$E(R_P) = \lambda_0 + B_P\lambda \tag{3.2}$$

while the expected returns on the cash asset and on the futures contract[3] respectively equal

$$E(R_S) = \lambda_0 + B_S\lambda \tag{3.3}$$

$$E(R_F) = B_F\lambda \tag{3.4}$$

$\lambda_0$ is the return on the risk-free asset, $B_i$ is the sensitivity of asset i to the risk factor, and $\lambda$ is the associated price per unit of risk. Substituting (3.2), (3.3), and (3.4) into (3.1) and dividing by $\lambda$ yield

$$B_P = B_S + HB_F$$

Hence the quantity of risk of a portfolio is a weighted average of the quantities of risk of the assets that comprise the portfolio, where the weights are given by the amount invested in each asset.

If we relax the assumption of market integration and implicitly assume that the rewards per unit of market risk differ across markets, equation (3.4) becomes

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[3] Because of the absence of initial investment in futures markets, investors do not receive any compensation for differed consumption. Therefore the return on a zero-beta futures should not significantly differ from zero (for a discussion on this issue, see, for example, Dusak (1973)).

$$E(R_F) = B_F \lambda^F \tag{3.5}$$

where $\lambda^F$ denotes the price per unit of market risk specific to the futures market. Substituting (3.2), (3.3), and (3.5) into (3.1) and dividing by $\lambda$ yields

$$B_P = B_S + HB_F \lambda^F \lambda^{-1} \tag{3.6}$$

The quantity of risk of the portfolio is still equal to a weighted average of the quantities of risk of the assets included in the portfolio but the weights now not only consider the amount invested in each asset but also the relative rewards per unit of market risk across markets. Hence, wrongly assuming that markets are integrated can lead to incorrect adjustments of the portfolio quantity of risk. This in turn might alter the riskiness of the portfolio in a way that may not be desirable. Under market segmentation the number of futures contracts that should be traded to adjust the portfolio quantity of risk from an initial value $B_1$ to a target value $B_2$ still equals $N_F = V_S / V_F (B_2 - B_1)$ but the definitions of $B_1$ and $B_2$ are given by equation (3.6).

This consideration notwithstanding, the gains from picking up mispriced stocks depends on the assumption of market integration too. Jensen (1968)'s alpha is traditionally used to measure the ability of fund managers to detect mispriced securities: if alpha is positive (negative), the security is underpriced (overpriced) and should be bought (sold). Likewise, a positive alpha suggests that the unit trust whose performance is being evaluated offers higher risk-adjusted returns than the market as a whole and that fund managers have done a good job at picking up mispriced securities. These considerations in turn should give us some incentive to invest in the unit trust under review. The Jensen's measure of abnormal performance however only accurately evaluates the performance of an unit trust when markets are integrated. If the factor structures differ across markets, an adjustment that considers the relative prices of risk across markets must be made before any inference regarding the performance of a managed portfolio can be drawn.

If the prices of risk associated with the factors or the reward per unit of market risk coincide across markets, the Jensen's measure of abnormal performance accurately detects abnormal returns and can induce us to invest in the unit trusts that outperform the market. Following Jensen (1968) for the traditional two-factor model and Connor and Korajczyk (1986) for the APT, we define Jensen's coefficient as the difference between the expected return on a managed portfolio and the expected return on a passive portfolio with the same amount of systematic risk. To understand how this definition arises, let us assume that returns are driven by the following linear multifactor model

$$r_{Pt} = E(r_P) + B_P F_t + \varepsilon_{Pt} \tag{3.7}$$

where $r_{Pt}$ is the return on the managed portfolio at time t, E(.) is the expectation operator, $B_P$ is either the quantity of risk from the two-factor linear model or the K-vector of sensitivities of the returns to the K-vector of factors $F_t$, and $\varepsilon_{Pt}$ is a white-noise error term. In the absence of arbitrage opportunities, the following risk-return relationship holds (see Ross (1976)):

$$E(r_P) = \lambda_0 + B_P \lambda \tag{3.8}$$

where $\lambda_0$ is the return on the risk-free asset and $\lambda$ is the price per unit of market risk or a K-vector of risk premia associated with the risk factors. Substituting equation (3.8) into equation (3.7) yields

$$R_{Pt} = B_P \lambda + B_P F_t + \varepsilon_{Pt}$$

where $R_{Pt}$ is the return on the managed portfolio in excess of the risk-free return. Then the abnormal excess return on the managed portfolio is given by

$$R_{Pt} = \alpha_P + B_P(\lambda + F_t) + \varepsilon_{Pt} \tag{3.9}$$

where $\alpha_P$ is an indicator of superior performance. A positive $\alpha_P$ suggests that the unit trust whose performance is evaluated offers a higher risk-adjusted return than the market as a whole and this conclusion should ultimately invite us to invest in the unit trust that manages the fund. Alternatively a finding of a negative $\alpha_P$ implies that the market as a whole performed better than the managed portfolio, suggesting hence a poor performance of the fund managers in picking up mispriced securities. Likewise, the Treynor (1965) 's reward to volatility ratio has been proposed as a measure of portfolio performance evaluation. This ratio, defined as $R_P/B_P$ , relates the average excess return on the managed portfolio to its systematic risk, as measured by the portfolio market beta. The performance of the fund is then evaluated with respect to the sign and the size of the reward to volatility measure. Higher values indicate better portfolio performance.

Obviously these considerations are of primary importance to investors since any unsatisfactory results should imply a change in investment policy. While Jensen's alpha and the reward to volatility ratio give correct portfolio performance evaluation under the assumption of market integration, an accurate measure of expected returns and hence of abnormal performance when markets are segmented requires to take into account the relative prices of risk across markets. To understand why, we consider a portfolio that consists of futures contracts and cash assets. The actual return on this portfolio equals

$$r_{Pt} = r_{St} + Hr_{Ft} + \varepsilon_{Pt} \tag{3.10}$$

where $r_{it}$ represents the time t actual return on either the portfolio, the cash asset, or the futures contract, and H is the proportion of wealth invested in futures markets as a percentage of the total wealth of the portfolio. Then, assuming that markets are segmented and that spot and futures returns follow the linear factor model (3.7) and the risk - expected return relationship (3.8), equation (3.10) becomes

$$r_{Pt} = \lambda_0 + B_S\lambda + B_SF_t + H\left(B_F\lambda^F + B_FF_t\right) + u_{St} + Hv_{Ft}$$

where $u_{St}$ and $v_{Ft}$ are white noise error terms specific to the spot asset and the futures contract respectively and the other parameters are as previously defined. The abnormal excess return on the managed portfolio can then be written as

$$R_{Pt} = \alpha_P + (B_S + HB_F)F_t + \left(B_S\lambda + HB_F\lambda^F\right) + \varepsilon_{Pt}$$

$$R_{Pt} = \alpha_P + B_P F_t + \left(B_S\lambda + HB_F\lambda^F\right) + \varepsilon_{Pt} \tag{3.11}$$

When the factor structure differs across markets, the accurate measure of abnormal performance is given by $\alpha_P$ in equation (3.11). While equation (3.9) identifies mispriced securities under the assumption of market integration, it will lead to incorrect estimates of $\alpha_P$ when the rewards per unit of systematic risk differ across markets. It becomes then obvious that assuming that markets are integrated, when in fact they are not, can lead to inaccurate investment decisions. Similar conclusions apply to Treynor 's reward to volatility measure. Portfolios rankings under the assumption of market integration are likely to differ from the rankings that relax this assumption. When the prices of risk are allowed to differ across markets, the reward to volatility ratio equals the excess return per unit of systematic risk, where systematic risk is defined as in (3.6).

Therefore a fund that seems to perform better than the market under the assumption of market integration might indeed exhibit lower risk-adjusted returns than the market portfolio once risk is accurately accounted for. In other words, while some funds might appear to overperform the market under the null hypothesis of market integration, a careful analysis of the risk return relationship in segmented markets might lead to the conclusion that expected returns are commensurate to the systematic risk of the portfolio or even that fund managers failed to pick up mispriced securities.

As mentioned in chapter II, a further incentive to look at the issue of market integration stems from the fact that many studies of the risk-return relationship in futures markets test the normal backwardation theory by simply estimating the sensitivity of the futures returns to the return on the market portfolio and to the extracted factors (see, for example, Dusak (1973), Carter, Rausser, and Smith (1983), Baxter, Conine, and Tamarkin (1985), Chang, Chen, and Chen (1990) for the CAPM and Young (1991) and Chen, Cornett, and Nabar (1993) for the APT). Since no attempt is made to estimate the price per unit of market risk or the vector of risk premia associated with the factors, it is implicitly assumed that the factor structure present in futures markets coincide with the one identified in the equity market. Since the prices of risk might well differ across markets, more evidence on the integration between futures and equity markets are needed before any conclusions can be drawn from these articles on the riskiness of futures contracts and on the validity, or otherwise, of the normal backwardation theory.

Finally a further incentive to look at market integration was offered by Bessembinder (1993). He argues that, when markets are segmented, it is possible, at least in principle, to construct portfolios that include futures contracts and spot assets that offer a higher risk-adjusted return than assets only portfolios. A finding of a different risk structure across markets should be appealing to fund managers that can ensure abnormal profits, just by combining futures and cash assets in their portfolios. The risk-adjusted return on these portfolios will be higher than the expected return that could have been earned on a portfolio formed with cash assets only. On the other hand, if the risk premia identified in futures markets coincide with the prices of risk present in cash markets, fund managers will only receive a return that is commensurate to the systematic risk of the portfolio and no abnormal profits will be made.

As Daigler (1993, page 415) mentions, the use of futures to adjust the quantity of risk of a portfolio "provides a lower cost alternative and a faster adjustment to achieve the stated goal than to attempt a similar strategy in the cash market". However the advantages of trading futures have to be weighted against the costs that might be incurred whenever a decision is made on the misleading assumption of market integration. Fund managers who open positions in the underlying markets will be able to fully benefit from the advantages of futures markets only if futures and cash markets are integrated. The quantity of risk of a portfolio of futures and spot assets will be the weighted average of the quantities of risk of the individual securities, Jensen's alpha will accurately detect mispriced securities and evaluate portfolio performance. In the presence of market segmentation however, before any active investment decisions can be made, adjustments must be implemented to consider the different prices of risk across markets. These considerations offer us further incentive to study the integration between cash and futures markets. The methodologies employed in this respect and some empirical evidence are explained in the following sections.

## IV. Methodology

To test the uniqueness of the factor structure across markets, we assume that returns follow the linear multifactor model

$$R_t = E(R) + BF_t + \varepsilon_t \qquad (3.12)$$

where $R_t$ is a N-vector of raw returns, E(.) is the expectation operator, B is the N*K-matrix of sensitivities of the returns to the K-vector of factors $F_t$ or the N-vector of beta coefficients in the context of the CAPM, and $\varepsilon_t$ is a N-vector of error terms. Given a set of simplifying assumptions and under the no-arbitrage condition (see Ross (1976)), the following risk-return relationship holds

$$E(R) = \lambda_0 + B\lambda \qquad (3.13)$$

where $\lambda_0$ is the return on the risk-free asset and $\lambda$ is a K-vector of risk premia associated with the risk factors or the price per unit of market risk.

The methodology employed to formally estimate the sensitivities B and the prices of risk $\lambda$ in equation (3.13) are the iterated non-linear seemingly unrelated regression technique (NLSUR) and the iterative non-linear three stage least squares technique (NL3SLS) presented in chapter II. These techniques are based on a set of non-linear regression equations which simultaneously estimate the risk premia vector and the sensitivity matrix, they further allow for the testing of Ross's (1976) crucial non-linear restrictions and consider the nature of the factor structure in tests of the APT using prespecified pervasive factors. Finally, the NL3SLS methodology offers the additional advantage of addressing the issue of the endogeneity of the market portfolio (see McElroy, Burmeister, and Wall (1985), McElroy and Burmeister (1988), and Burmeister and McElroy (1988)).

In terms of estimation, as long as NT>NK+K, where N is the number of equations, T the number of observations, and K the number of factors, the estimators for the system exist and the NLSUR and NL3SLS estimators are those that respectively solve the two following minimisation problems

$$\varepsilon'\left(\hat{\Sigma} \otimes I_T\right)\varepsilon$$

$$\varepsilon'\left[\hat{\Sigma} \otimes \left(Z(Z'Z)^{-1}Z'\right)\right]\varepsilon$$

where $\varepsilon$ is the vector of stacked residuals from equation (3.12), $\hat{\Sigma}$ is the residual covariance matrix, $I_T$ is an identity matrix, Z is a matrix of instruments, and $\otimes$ denotes a Kronecker product.

The NLSUR and the NL3SLS estimation methods are used to estimate the prices of risk and the sensitivities in the cash commodity, currency, and equity markets. Our purpose in so doing is to compare these results with the prices of risk estimated in chapter II for the futures markets and consequently to check whether the elements of $\lambda$ vary across markets. Although a finding of a similar factor structure across markets is encouraging in terms of market integration, more formal tests are needed if we are to draw some definite inference about market integration. It could indeed be the case that the futures and underlying asset markets are subject to the same sources of risk but, because of some market imperfections, the risk premium associated with each factor varies across markets. Hence any conclusions based solely on the previous tests could be misleading.

To formally test market integration, we undertake a test that is in the spirit of Bessembinder (1992). The following model is estimated

$$R_t = B\lambda + B\lambda^F d + BF_t + v_t \tag{3.14}$$

$R_t$ is a vector of returns, $\lambda^F$ is a K-vector of prices of risk specific to the futures market, d is a dummy variable equal to one for futures contracts and set to zero for spot assets, and the other parameters are as previously defined. In this framework the hypothesis of equal factor risk premia across markets can easily be tested. This hypothesis is evaluated by testing whether the estimates of $\lambda^F$ in equation (3.14) are equal to zero. While accepting the null hypothesis suggests that the prices of risk present in futures markets coincide with the prices of risk identified in spot markets, a finding of significant prices of risk in the futures market implies that the null hypothesis of market integration is rejected in favour of an unspecified alternative hypothesis that stipulates that the prices of risk between cash and futures markets differ. We do not investigate in this study the possible sources of rejection of the null hypothesis. As mentioned above, likely candidates are the presence of transaction costs and trade restrictions that might hinder arbitrage.

Accepting the null hypothesis of market integration implies that the factor structure identified in the cash equity, commodity, and currency markets does not significantly differ from the factor structure present in futures markets. Rejecting the null hypothesis however could imply that either the futures and commodity markets, or the futures and financial markets are segmented. In other words, if we are to reject the null hypothesis embedded in equation (3.14), we do not know why we are rejecting. Is it because the futures and cash commodity markets are segmented or does the rejection stand as a proof against the hypothesis of market integration between the spot market for financial securities and the futures market? To answer this question, we extend the methodology used by Bessembinder (1992) to include risk premia specific to the commodity spot market and the spot market for financial securities. In other words, the following system of pooled equations is estimated

$$
\begin{aligned}
RF_t &= B\lambda + BF_t + \varepsilon_t \\
RS_{Com,t} &= B\lambda + B\lambda^{Com} + BF_t + \upsilon_t \qquad (3.15) \\
RS_{Fin,t} &= B\lambda + B\lambda^{Fin} + BF_t + \omega_t
\end{aligned}
$$

where $RF_t$ is a vector of raw futures returns at time t, $RS_{Com,t}$ is a vector of spot commodity excess return, $RS_{Fin,t}$ is a vector of financial asset excess return, $\lambda^{Com}$ is the risk premium specific to the commodity spot market, $\lambda^{Fin}$ is the vector of prices of risk associated with the currency and equity markets. Once again, the proposition that the futures and commodity markets are integrated is tested with respect to the hypothesis that $\lambda^{Com}$ does not significantly differ from zero in system (3.15). Similarly, we test market integration between futures and financial spot securities by examining the significance of $\lambda^{Fin}$, the vector of prices of risk specific to the equity and currency spot markets.

## V. Data

In this chapter we use the same data set as in chapter II and extend it to include end-of-month spot prices on 13 agricultural commodities, 4 metal and oil commodities, 4 currencies, and 11 industry portfolios. A glossary of the assets used in this study is presented in table 3.1. The choice of this cross section was mainly dictated by the requirement that the cash asset be a reasonably good proxy for the underlying asset of the futures contract. It is often the case however that the cash assets considered in this study differ in terms of quality from the underlying asset specified in the futures contract. However, this is to be expected since futures contracts frequently amalgamate different underlying assets. For example, the underlying asset on the sugar futures contract traded on the Coffee, Sugar, and Cocoa Exchange includes cane sugar from 26 countries. Proxying the underlying asset would be an impossible task, especially since the percentage allocated to each country might vary across time. To make things easier, we use the world price of cane raw sugar as a proxy for the underlying asset.

## Table 3.1: Glossary of Futures Contracts and Spot Assets

| Futures Contracts | Spot Assets |
|---|---|
| **Panel A: Agricultural Commodities** | |
| Cocoa | Cocoa |
| Coffee | Brazilian Coffee |
| Corn | Corn (no. 2, yellow) |
| Cotton | Cotton |
| Oats | Oats (no. 2) |
| Soybeans | Soybeans (no. 1, yellow) |
| Soybean Meal | Soybean Meal |
| Soybean Oil | Soybean Oil |
| Sugar | Sugar (raw, world) |
| Wheat | Wheat (spring) |
| Lean Hogs | Hogs |
| Lumber | Lumber |
| Pork Bellies | Pork Bellies |
| **Panel B: Metal and Oil Commodities** | |
| Gold | Gold |
| Heating Oil | Fuel Oil |
| Silver | Silver |
| Platinum | Platinum |
| **Panel C: Financial Assets** | |
| NYSE | Equity Portfolio 1: Oil |
| SP500 | Equity Portfolio 2: Financial |
| Treasury-Bill | Equity Portfolio 3: Industrials |
| Treasury-Note | Equity Portfolio 4: Building and Construction |
| Treasury-Bond | Equity Portfolio 5: Transport |
| Deutsch Mark | Equity Portfolio 6: Utilities |
| Japanese Yen | Equity Portfolio 7: Textiles |
| Swiss Franc | Equity Portfolio 8: Services |
| UK Pound | Equity Portfolio 9: Leisure and Hotels |
| | Equity Portfolio 10: Food Producers |
| | Equity Portfolio 11: Tobacco |
| | Deutsch Mark |
| | Japanese Yen |
| | Swiss Franc |
| | UK Pound |

To test the integration between the futures and equity markets, we use the return on 11 industry portfolios. This choice was primarily governed by the fact that industry portfolio returns provide a wide spread between equity risk and return (see, for example, Ferson and Harvey (1991)). Finally, because of the unavailability of data for fixed-income securities, we could not study the integration between the futures and bond markets. The data are downloaded from Datastream International over the same sample than in the previous chapter (May 1982 - October 1996). Raw returns are computed as the percentage change in the spot price and the return on the one-month Treasury bill is used to calculate excess returns.

## VI. The Sources of Systematic Risk in Commodity, Currency, and Equity Markets

In this section we reproduce for the commodity, currency, and equity spot markets the results obtained in chapter II for the futures market. The purpose of this analysis is to get some insight as to whether the futures and underlying asset markets are integrated. As a weak test of market integration, we check whether the risk premia identified in futures markets (chapter II) coincide with the prices of risk present in the underlying cash markets. This introduces a joint hypothesis problem. Namely, the joint hypothesis states that markets are integrated and that the APT is a valid representation of the risk-return relationship in all asset markets. Hence any evidence against the null hypothesis can be regarded as a proof of market segmentation or can result from the use of a misspecified model of expected return, from our failure to accurately measure risk, or from a mixture of the two.

To ensure that estimation problems do not obscure our conclusions regarding the sources of priced risk in the underlying market, we follow an approach similar to the one used in the previous chapter and specify four different versions of the risk-return relationship in the underlying asset markets. The first model relates spot returns to a benchmark of the market portfolio that comprises 90 percent of the return on the Standard & Poor's composite index and 10 percent of the return on the Dow-Jones Commodity index. The three other specifications of the risk-return relationship are in the spirit of the APT models estimated in chapter II. They assume that the five Chen, Roll, and Ross (1986) factors, the residual market factor, and the return on the Standard & Poor's index are sources of systematic risk in commodity, currency, and equity markets. The systems of non-linear equations are estimated through NLSUR for the CAPM, the five factor model, and the model with the residual market factor and through NL3SLS for the APT model with the market portfolio.

The estimates of the prices of risk associated with the market portfolio and with the pervasive sources of uncertainty are reported in tables 3.2 and 3.3 respectively. In each table, panels A display the estimated factor risk premia in futures markets (as reported in tables 2.6 and 2.9) and the results from the commodity, currency, and equity spot markets are summarised in panels B. Panels C test the null hypothesis that the prices of risk in spot markets (panels B) can be restricted to be the same as the risk premia identified in futures markets (panels A). In this respect, the non-linear system of 32 spot returns is first estimated in unrestricted form and then estimated under the restriction that the prices of risk in spot markets are equal to the estimates displayed in panels A. These tests are distributed as $\chi^2$ with a number of degrees of freedom equal to the difference in the number of free parameters between the unrestricted and restricted models.

Looking first at the sources of systematic risk in the commodity, currency, and equity spot markets, it is interesting to notice that, in the context of the CAPM, the market portfolio is priced. The estimate of the price per unit of market risk however is negative, while the CAPM predicts that the relationship between risk and return is positive. The CAPM therefore does not seem to describe the trade-off between risk and return in commodity, currency, and equity markets. With respect to the five factor model, unexpected inflation, shocks to default spread, and the change in expected inflation are priced in the underlying asset markets. It is also clear from table 3.3 that the residual

## Table 3.2: Estimates of the Prices of Risk in Futures and Spot Markets ($\lambda^F$ and $\lambda^S$) and Test of the Null Hypothesis that $\lambda^F=\lambda^S$: CAPM Results

$$R_t = B_M \lambda_M + B_M R_{Mt} + \varepsilon_t$$

| | Estimate | Standard Error | t-ratio |
|---|---|---|---|
| **Panel A: Estimate of the Price per Unit of Market Risk in Futures Markets ($\lambda^F$)** | | | |
| Proxy of the Market Portfolio | 0.0002 | 0.0005 | 0.48 |
| **Panel B: Estimate of the Price per Unit of Market Risk in Spot Markets ($\lambda^S$)** | | | |
| Proxy of the Market Portfolio | -0.0045* | 0.0004 | -12.02 |
| **Panel C: Test of the Null Hypothesis that $\lambda^F = \lambda^S$** | | | |
| - Calculated Value[1] | 151 | | |
| - Critical Value (5 percent significance) | 3.84 | | |

* denotes significant at 1 percent.

[1] The calculated value is equal to the difference between the minimised values of the objective functions of the restricted and unrestricted models and is distributed as $\chi^2$ with a number of degrees of freedom equal to the difference in the number of free parameters between the two models.

## Table 3.3: Estimates of the Prices of Risk in Futures and Spot Markets ($\lambda^F$ and $\lambda^S$) and Test of the Null Hypothesis that $\lambda^F=\lambda^S$: APT Results

$$R_t = B\lambda + BF_t + \varepsilon_t$$

| Factors | Five Factor Model |  |  | Residual Market Factor |  |  | Market Portfolio |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  | Estimate | SE | t-ratio | Estimate | SE | t-ratio | Estimate | SE | t-ratio |
| **Panel A: Estimates of the Prices of Risk in Futures Markets ($\lambda^F$)** |  |  |  |  |  |  |  |  |  |
| Unexpected Term Structure | -0.0610*** | 0.0346 | -1.77 | -0.0177*** | 0.0101 | -1.75 | -0.0262*** | 0.0140 | -1.87 |
| Unexpected Inflation | -0.0017*** | 0.0009 | -1.84 | -0.0004 | 0.0003 | -1.49 | -0.0004 | 0.0004 | -1.10 |
| Change in Expected Inflation | 0.0031 | 0.0022 | 1.45 | 0.0005 | 0.0006 | 0.80 | 0.0011 | 0.0009 | 1.24 |
| Unexpected Default Spread | 0.0154*** | 0.0086 | 1.79 | 0.0088** | 0.0037 | 2.39 | 0.0087*** | 0.0048 | 1.81 |
| Unexpected Industrial Production | -0.0026*** | 0.0016 | -1.62 | -0.0010 | 0.0007 | -1.55 | -0.0008 | 0.0009 | -0.88 |
| Residual Market Factor |  |  |  | 0.0106* | 0.0012 | 8.55 |  |  |  |
| Return on the Market Portfolio |  |  |  |  |  |  | 0.0002 | 0.0008 | 0.20 |
| **Panel B: Estimates of the Prices of Risk in Spot Markets ($\lambda^S$)** |  |  |  |  |  |  |  |  |  |
| Unexpected Term Structure | 0.0133 | 0.0167 | 0.79 | -0.0110 | 0.0084 | -1.31 | -0.0194 | 0.0130 | -1.49 |
| Unexpected Inflation | -0.0021** | 0.0010 | -2.04 | 0.0007*** | 0.0004 | 1.92 | 0.0015** | 0.0007 | 2.12 |
| Change in Expected Inflation | -0.0022** | 0.0011 | -2.06 | -0.0006 | 0.0005 | -1.26 | -0.0004 | 0.0007 | -0.54 |
| Unexpected Default Spread | 0.0140*** | 0.0082 | 1.71 | -0.0001 | 0.0040 | -0.02 | -0.0024 | 0.0062 | -0.39 |
| Unexpected Industrial Production | 0.0012 | 0.0014 | 0.84 | -0.0008 | 0.0007 | -1.23 | -0.0003 | 0.0010 | -0.31 |
| Residual Market Factor |  |  |  | 0.0074* | 0.0013 | 5.54 |  |  |  |
| Return on the Market Portfolio |  |  |  |  |  |  | -0.0044* | 0.0007 | -6.11 |

Table 3.3 - *Continued*

|  | Five Factor Model | Residual Market Factor | Market Portfolio |
|---|---|---|---|
| Panel C: Test of the Null Hypothesis that $\lambda^F = \lambda^S$ |  |  |  |
| - Calculated Value[1] | 23* | 137* | 91.15* |
| - Critical Value (5 percent significance) | 11.07 | 12.59 | 12.59 |

* denotes significant at 1 percent,
** denotes significant at 5 percent,
*** denotes significant at 10 percent.

[1] The calculated values are equal to the difference between the minimised values of the objective functions of the restricted and unrestricted models and are distributed as $\chi^2$ with a number of degrees of freedom equal to the difference in the number of free parameters between the two models.

market factor command a risk premia.[4] Finally the results displayed in table 3.3 indicate that the inclusion of the five original factors to the CAPM does not render the market portfolio insignificant. Hence the market portfolio plays some role in accounting for the risk return relationship in commodity, currency, and equity markets. Surprisingly however the risk premium on the market portfolio appears to be negative.

We now compare the estimates of the prices of risk in commodity, currency, and equity markets (panels B) to the results obtained in panels A for the futures markets. Looking first at the results from the CAPM models, the estimates of the prices per unit of market risk differ across markets. While the market portfolio is priced in commodity, currency, and equity markets, the estimate of the market risk premium is insignificant in futures markets. The only consistent result across markets is the finding that the pricing of futures contracts and the pricing of the underlying assets do not conform to the CAPM. Turning our attention to the results from the multifactor models, it appears that the estimates of the prices of risk associated with the derived factors and the standard errors are of different amplitude across markets. The signs of the risk premia and the t-ratios also differ. For example, the variable associated with shocks to default spread is priced in all three versions of the risk-return relationship in futures markets, while it is priced at best marginally in spot markets. Similarly, the market portfolio does not play any role in explaining the cross section of futures returns, while it enters into the risk-return relationship in commodity, currency, and equity markets. The only finding that seems to be consistent across markets is the result that the residual market factor is priced and carries similar prices of risk in both markets.

The inequality of the risk premia vector implies the absence of an uniform trade-off between risk and expected returns across markets. The results displayed in tables 3.2 and 3.3 panels C clearly confirm this impression. Irrespectively of the specification of the risk-return relationship, the null hypothesis that the prices of risk in spot markets can be

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[4] Its inclusion into the five factor model renders the estimates of the prices of risk associated with the change in expected inflation and shocks to default spread insignificant. This is somehow striking since, by definition, the residual market factor is orthogonal to the original factors. As such, its inclusion should not alter the estimates, standard errors, and significance levels of the original risk premia.

restricted to be equal to the estimates from the futures markets is strongly rejected at the 5 percent level. Altogether these results indicate that the vector of prices of risk differs across markets: there does not seem to be an unique trade-off between risk and return. These tests therefore seem to suggest that the null hypothesis of market integration does not hold.

## VII. Direct Tests of Market Integration

On the basis of the results obtained so far, it appears that one of the conditions embedded in market integration, namely the uniformity of the risk premia vector across markets, is not supported by the data. The factor structure identified in futures markets does not coincide with the factor structure present in spot markets. The estimates of the prices of risk, their standard errors, and significance levels are not of similar sign and magnitude across markets. As a further robustness check, we implement some direct tests of the null hypothesis that futures and spot markets are integrated.

To formally address the issue of market integration, we estimate (3.14) through NLSUR for the CAPM, the five factor model, and the model with the residual market factor, and through NL3SLS for the model with the market portfolio. (3.14) is a pooled system of 26 futures raw returns and 32 spot excess returns that imposes the restrictions that the prices of risk are the same across equations. To test the uniformity of the factor structure across markets, we consider an additional risk premia vector $\lambda^F$ in the futures equations and test whether this vector significantly differs from zero. Once systematic risk has been accounted for through the vector of prices of risk common to the spot and futures markets ($\lambda$), the second vector, that is futures specific, should be insignificant under the null hypothesis of market integration. On the other hand, evidence that the latter vector is significant would suggest that the spot and futures markets are to some extent segmented.

Tables 3.4 and 3.5 report estimates of the risk premia vectors for the CAPM and the three APT specifications respectively. In panels A we present the estimates of $\lambda$ and the estimates of $\lambda^F$ are reported in panels B. It is apparent from panels A that the market portfolio as well as some of the derived factors enter the risk-return relationship in the spot and futures markets. The evidence in panels B suggest that the market portfolio and the factors command significant risk premia in futures markets too. Hence the null hypothesis of market integration is rejected.

To find out more about this rejection, we split the sample of spot assets into two subsamples. The first one includes agricultural and metal commodities and the second one considers financial assets such as currencies and equity portfolios. We then address the following question: does the rejection of market integration in the previous tests suggest that commodity and futures markets are segmented or does it stand as a proof against the null hypothesis of integration between the futures market and the spot market for financial securities? To answer this question, we estimate system (3.15). This system considers three vectors of prices of risk. The first vector is common to the futures and spot markets, the second one is specific to the spot market for agricultural and metal commodities, and the third set of risk premia is specific to the spot market for financial securities. Under the null of market integration, the prices of risk associated with the two latter vectors should be insignificant once systematic risk has been priced through the first set of risk premia.

The results are reported in table 3.6. Panel A displays the estimates of the prices of risk common to the futures and spot markets; panel B focuses on the risk premia estimated in commodity spot markets; and, finally, panel C summarises the results specific to the spot market for financial securities. The evidence presented in table 3.6 point out that the rejection of market integration in table 3.5 results from some kind of market imperfections between the agricultural and metal commodity market and the futures market. The results from the five factor model indicate that, even after controlling for risk through $\lambda$, unexpected inflation, shocks to default spread and to the change in industrial production are priced in the spot commodity market. Similar conclusions apply to the

## Table 3.4: Test of Market Integration:
## Estimates of the Prices per Unit of Market Risk in Futures, Commodities, Currencies, and Equities Markets

$$R_t = B\lambda_M + B\lambda_M^F d + BR_{Mt} + v_t$$

| | Estimate | Standard Error | t-ratio |
|---|---|---|---|
| **Panel A: Estimates of $\lambda_M$ in Spot and Futures Markets** | | | |
| Return on the Market Portfolio | -0.0037* | 0.0003 | -12.25 |
| **Panel B: Estimates of $\lambda_M^F$ in Futures Markets** | | | |
| Return on the Market Portfolio | 0.0043* | 0.0005 | 9.54 |

* denotes significant at 1 percent.

## Table 3.5: Test of Market Integration:
## Estimates of the Prices of Risk Associated with the APT Factors in Futures and Spot Markets

$$R_t = B\lambda + B\lambda^F d + BF_t + v_t$$

| Factor | Five Factor Model | | | Residual Market Model | | | Market Portfolio Model | | |
|---|---|---|---|---|---|---|---|---|---|
| | Estimate | SE | t-ratio | Estimate | SE | t-ratio | Estimate | SE | t-ratio |
| **Panel A: Estimates of $\lambda$ in Spot and Futures Markets** | | | | | | | | | |
| Shock to the Term Structure | -0.0093 | 0.0095 | -0.98 | -0.0111 | 0.0070 | -1.58 | -0.0200 | 0.0140 | -1.43 |
| Unexpected Inflation | -0.0012* | 0.0004 | -2.72 | 0.0000 | 0.0003 | 0.12 | 0.0017** | 0.0009 | 1.95 |
| Change in Expected Inflation | -0.0010*** | 0.0005 | -1.95 | -0.0006 | 0.0004 | -1.58 | -0.0004 | 0.0008 | -0.53 |
| Shock to Default Spread | 0.0050 | 0.0042 | 1.19 | 0.0012 | 0.0032 | 0.38 | -0.0043 | 0.0068 | -0.64 |
| Unexpected Industrial Production | -0.0005 | 0.0007 | -0.71 | -0.0006 | 0.0005 | -1.18 | -0.0001 | 0.0010 | -0.10 |
| Residual Market Factor | | | | 0.0061* | 0.0011 | 5.65 | | | |
| Return on the Market Portfolio | | | | | | | -0.0046* | 0.0008 | -5.72 |
| **Panel B: Estimates of $\lambda^F$ in Futures Markets** | | | | | | | | | |
| Shock to Term Structure | -0.0454*** | 0.0249 | -1.83 | -0.0239*** | 0.0129 | -1.86 | -0.0255 | 0.0234 | -1.09 |
| Unexpected Inflation | -0.0006 | 0.0008 | -0.75 | -0.0005 | 0.0004 | -1.25 | -0.0024** | 0.0010 | -2.32 |
| Change in Expected Inflation | 0.0034** | 0.0015 | 2.20 | 0.0023* | 0.0008 | 2.79 | 0.0028*** | 0.0015 | 1.90 |
| Shock to Default Spread | 0.0122*** | 0.0074 | 1.65 | 0.0130* | 0.0048 | 2.71 | 0.0169*** | 0.0087 | 1.95 |
| Unexpected Industrial Production | -0.0022*** | 0.0013 | -1.64 | -0.0007 | 0.0008 | -0.82 | -0.0008 | 0.0014 | -0.57 |
| Residual Market Factor | | | | 0.0058* | 0.0016 | 3.65 | | | |
| Return on the Market Portfolio | | | | | | | 0.0048* | 0.0013 | 3.66 |

* denotes significant at 1 percent,
** denotes significant at 5 percent.
*** denotes significant at 10 percent.

## Table 3.6: Test of Market Integration between Futures and Commodity Markets, and between Futures and Financial Markets

$$RF_t = B\lambda + BF_t + \varepsilon_t$$

$$RS_{Com,t} = B\lambda + B\lambda^{Com} + BF_t + \upsilon_t$$

$$RS_{Fin,t} = B\lambda + B\lambda^{Fin} + BF_t + \omega_t$$

| | Five Factor Model | | | Residual Market Model | | | Market Portfolio Model | | |
|---|---|---|---|---|---|---|---|---|---|
| Factor | Estimate | SE | t-ratio | Estimate | SE | t-ratio | Estimate | SE | t-ratio |
| **Panel A: Estimates of $\lambda$ in Spot and Futures Markets** | | | | | | | | | |
| Shock to the Term Structure | -0.0744*** | 0.0458 | -1.62 | -0.0248** | 0.0120 | -2.07 | -0.0371** | 0.0179 | -2.07 |
| Unexpected Inflation | -0.0018*** | 0.0011 | -1.64 | -0.0006*** | 0.0003 | -1.82 | -0.0006 | 0.0005 | -1.41 |
| Change in Expected Inflation | 0.0039 | 0.0029 | 1.38 | 0.0010 | 0.0007 | 1.35 | 0.0019*** | 0.0012 | 1.63 |
| Shock to Default Spread | 0.0157 | 0.0100 | 1.57 | 0.0101** | 0.0041 | 2.43 | 0.0109*** | 0.0057 | 1.93 |
| Unexpected Industrial Production | -0.0030 | 0.0020 | -1.51 | -0.0011 | 0.0007 | -1.53 | -0.0009 | 0.0010 | -0.92 |
| Residual Market Factor | | | | 0.0110* | 0.0014 | 7.73 | | | |
| Return on the Market Portfolio | | | | | | | 0.0002 | 0.0010 | 0.22 |
| **Panel B: Estimates of $\lambda^{Com}$ in Commodity Spot Market** | | | | | | | | | |
| Shock to Term Structure | 0.0760 | 0.0483 | 1.57 | 0.0251*** | 0.0156 | 1.61 | 0.0343 | 0.0218 | 1.57 |
| Unexpected Inflation | 0.0020*** | 0.0012 | 1.63 | 0.0008 | 0.0005 | 1.52 | 0.0009 | 0.0006 | 1.50 |
| Change in Expected Inflation | -0.0047 | 0.0030 | -1.58 | -0.0016*** | 0.0010 | -1.63 | -0.0024*** | 0.0014 | -1.76 |
| Shock to Default Spread | -0.0198*** | 0.0118 | -1.68 | -0.0151** | 0.0072 | -2.09 | -0.0162** | 0.0077 | -2.11 |
| Unexpected Industrial Production | 0.0037*** | 0.0023 | 1.63 | 0.0021*** | 0.0012 | 1.85 | 0.0020 | 0.0013 | 1.54 |
| Residual Market Factor | | | | -0.0055 | 0.0093 | -0.59 | | | |
| Return on the Market Portfolio | | | | | | | -0.0088 | 0.0068 | -1.30 |

## Table 3.6 - *Continued*

| Factor | Five Factor Model |  |  | Residual Market Model |  |  | Market Portfolio Model |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  | Estimate | SE | t-ratio | Estimate | SE | t-ratio | Estimate | SE | t-ratio |
| **Panel C: Estimates of $\lambda^{Fin}$ in Spot Market for Financial Securities** |  |  |  |  |  |  |  |  |  |
| Shock to Term Structure | -0.0809 | 0.2493 | -0.32 | -0.1212 | 0.3205 | -0.38 | -0.0321 | 0.1749 | -0.18 |
| Unexpected Inflation | 0.0055 | 0.0078 | 0.70 | 0.0074 | 0.0172 | 0.43 | 0.0109 | 0.0257 | 0.42 |
| Change in Expected Inflation | -0.0022 | 0.0068 | -0.32 | 0.0030 | 0.0129 | 0.23 | 0.0029 | 0.0150 | 0.19 |
| Shock to Default Spread | -0.0729 | 0.1098 | -0.66 | -0.0751 | 0.1661 | -0.45 | -0.0440 | 0.1008 | -0.44 |
| Unexpected Industrial Production | -0.0113 | 0.0243 | -0.47 | -0.0157 | 0.0393 | -0.40 | -0.0087 | 0.0239 | -0.37 |
| Residual Market Factor |  |  |  | 0.0130 | 0.0466 | 0.28 |  |  |  |
| Return on the Market Portfolio |  |  |  |  |  |  | -0.0026 | 0.0074 | -0.35 |

* denotes significant at 1 percent,
** denotes significant at 5 percent.
*** denotes significant at 10 percent.

models with the residual market factor and to the model with the return on the Standard & Poor's index. On the other hand, the evidence in panel C suggest that the spot market for financial assets and the futures markets are integrated: the t-ratios for the prices of risk in the equity and currency markets do not significantly differ from zero.

Our results are consistent with the evidence presented in Bessembinder (1992). He restricts his analysis to equity and futures markets and finds that, when tested against an unspecified hypothesis, the null hypothesis of market integration cannot be rejected. In this study, we not only confirm his results but also extend his conclusions to foreign exchange markets. The rejection of the integration between the futures market and the underlying asset market might result from the presence of trade restrictions and transaction costs between the commodity spot market and the futures markets. However further research in the area of market micro structure is required before one can ascertain that such imperfections explain the presence of market segmentation.

## VIII. Conclusions

Given the importance of the assumption of market integration for fund managers and the fact that research focused only on the integration between futures and equity markets, the contribution of this chapter was to provide a thorough analysis of the integration between futures markets and spot commodity, currency, and equity markets. Market integration is tested with respect to the hypothesis that assets returns in different markets follow the same factor structure. Hence the reward per unit of systematic risk should be the same across markets.

Irrespectively of the specification of the risk-return relationship, the factors that command a significant risk premium in futures markets differ from the factors that are priced in the underlying asset markets. This gives us some first insight onto the issue of market integration and suggests that the rewards per unit of systematic risk differ across markets. We then implemented some direct tests of the null hypothesis that the factor risk premia are identical across markets. For the CAPM and for any of the three specifications of the APT, the hypothesis that the prices of systematic risk in futures markets are equal to those in the underlying asset markets is rejected. Further evidence indicate that this rejection reflects the presence of market segmentation between commodity and futures markets. While the null hypothesis that the prices of risk associated with the APT factors in futures markets are equal to the factor risk premia for financial securities cannot be rejected, the hypothesis that the prices of risk between the commodity spot market and the futures markets are equal is rejected at conventional levels of statistical significance.

It is therefore possible to construct portfolios of commodities and futures contracts that offer a higher risk-adjusted expected returns than commodity only portfolios. On the other hand, one cannot earn any return in excess of the level predicted by traditional asset pricing models by diversifying an equity and currency only portfolio with futures contracts. The results also imply that a finding of a statistically significant sensitivity of futures returns to the factors that have been proved to be priced in equity and foreign exchange markets implies the presence of a risk premium in futures markets. However, if one is to consider only the prices of risk identified in commodity markets to draw inferences regarding the presence of a risk premium in futures markets, wrong inferences may be made since the prices of risk in both markets differ.

Most importantly, our research has direct implications for fund managers who trade in commodity and futures markets. Because of the presence of market imperfections between both markets, such fund managers need to consider the relative prices of systematic risk in both markets before making any buy or sell decisions to readjust the quantity of risk of their portfolio or to take advantage of any apparent mispricing. Fund managers who only operate in equity and foreign currency spot markets and in futures markets however can reliably estimate the quantity of risk of their portfolio as the weighted average of the quantities of risk of the assets included in the portfolio and can use the traditional measures of abnormal return as a way to evaluate portfolio performance and detect mispriced securities.

Alternatively the evidence presented in this chapter could reflect the theoretical and empirical limitations of our knowledge on asset pricing. The tests implemented here indeed rely on the joint hypothesis that the asset pricing model is valid and correctly implemented and that markets are integrated. Therefore, while the evidence are consistent with the presence of market segmentation, one cannot rule out alternative explanations, such as a failure of the constant expected return asset pricing theory or/and an incorrect estimation of the models. We believe however that the methodologies employed to derive the unexpected components in the factors and to estimate the sensitivities and the prices of risk associated with these factors mitigate the risk of inaccurately estimating the risk-return relationship. We took indeed special care that the generated factors are truly unanticipated and we jointly estimated the prices of risk and the sensitivities to shocks in the factors, thereby eliminating the error in variable problem present in the two-step methodology and therefore the risk of wrongly pricing a factor. We besides estimated alternative specifications of the risk-return relationship and found that the results are robust to the different specifications. Therefore we believe that the evidence are not too clouded by estimation problems.

# Chapter IV: Economic Significance of the Predictable Movements in Futures Returns

## I. Introduction

It is commonly accepted that returns are predictable. The source of predictability however has been the subject of extensive debate over the last two decades. The proponents of the efficient market hypothesis (hereafter, EMH) argue that the predictability of stock and bond returns reflects rational variation in required returns that mirrors the change in the consumption-investment opportunity set over time (Fama and French (1989), Ferson and Korajczyk (1995)). The opponents of the EMH however state that irrational waves of optimism and pessimism deter assets' prices from their fundamental value. Hence the predictability of stock and bond returns signals the presence of bubbles and stands as a proof of market inefficiency (Poterba and Summer (1988)).[1]

Most of the literature examines the predictability of equity and bond returns (see, for example, Campbell (1987), Fama and French (1989), Evans (1994), Ferson and Korajczyk (1995)). Very little attention however has been devoted to the issue of whether the predictability of futures returns is due to weak-form market inefficiency or to rational variation in the preferences of economic agents for consumption and investment. The purpose of the three following chapters is to study the time variation in expected futures returns and to investigate the issue of market efficiency with respect to three different hypotheses. In this chapter, we test the hypothesis that a simple trading rule based on available information does not generate any return on a risk and transaction cost

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[1] See Fama (1991) for a review.

adjusted basis. In the following chapter, we analyse whether the variation in expected returns is common across futures and is related to the business cycle. Finally, as a further robustness check, the last chapter investigates whether the pattern of forecastability is consistent with time-varying expected return asset pricing models. If markets set futures prices rationally, we expect to sustain these hypotheses. On the other hand, if the trading strategy hereafter implemented generates abnormal return after adjusting for transaction costs; if, besides, the time variation in expected futures returns is unrelated to business conditions and is not captured by conditional expected return asset pricing models, we will conclude that the predictable movements in futures returns result from weak-form market inefficiency.

As mentioned above, the focus of this chapter is to test market efficiency with respect to the hypothesis that no positive risk adjusted returns can be earned by actively trading futures contracts after accounting for transaction costs. Hence, if the predictable movements in futures returns reflect rational changes in required returns, the trading rule hereafter implemented should not be profitable. As a result, models that assume conditional expected returns should be favoured to traditional models of constant expected returns as a way to proxy for risk and evaluate portfolio performance. On the other hand, if the trading rule is profitable, the predictable movements in futures returns will reflect asset market predictability which is due to weak form market inefficiency.

This issue is of primary importance to market participants that rely on the quoted futures prices to hedge, speculate, or arbitrage away risk-free profits. This consideration notwithstanding our interest in the ability of trading rules to generate abnormal returns also stems from the fact that much of the evidence have focused on broad equity market indices (see, for example, Keim and Stambaugh (1986), Campbell (1987), Jegadeesh (1990), or, more recently, Ilmanen (1995)). We believe however that the trading rules these authors derive are hardly tractable since they are based upon portfolios of stocks and hence implies numerous monthly transactions before the strategy is implemented. Since, as opposed to portfolios of stocks, futures contracts are tradable securities, the *ex-*

*ante* trading rules we derive represent practical investment strategies (see, for example, Buckle, Clare, and Thomas (1994) and Clare and Miffre (1995)).

Our main conclusions suggest that a trading rule exploiting past information cannot be used consistently to generate positive returns once adjustments for time-varying risk and transaction costs are taken into account. The predictable movements in futures returns most likely therefore reflect the rational variation in the preferences of economic agents across time. The rest of the chapter is organised as follows. Section II describes the methodology. Section III explains how to construct mimicking portfolios. Section IV presents the data set. Section V documents the ability of the *ex-ante* variables to predict futures returns, estimates the performance of a trading rule based on out-of-sample forecasts returns, and studies the economic significance of the observed predictability. Some concluding remarks are offered in section VI.

## II. Methodology

To investigate the issue of predictability, we regress futures returns on the information variables lagged once and test the null hypothesis that expected returns are constant.[2] The following regression is estimated

$$R_t = \alpha_0 + \alpha Z_{t-1} + \varepsilon_t \tag{4.1}$$

where $R_t$ is the realised futures return, $Z_{t-1}$ is the set of state variables used by investors to form expectations of the futures price one period ahead, $\varepsilon_t$ is a vector of error terms, and $\alpha_0$ and $\alpha$ are the estimated parameters. The null hypothesis that the regressors can be jointly excluded from equation (4.1) is tested at the individual futures level, for each group of futures (agricultural, metal and oil, and financial), and for the whole cross section of futures. Since the omission of some *ex-ante* variables from the actual

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[2] For evidence from the futures markets, see, for example, Bessembinder and Chan (1992).

information set used by investors could result in serial correlation and heteroscedasticity in the regression errors (and, hence, in inefficient least squares estimates and biased t-statistics), the standard errors in equation (4.1) are adjusted for serial correlation and heteroscedasticity using Newey and West (1987) correction.

The purpose of this chapter is to test whether some risk and transaction cost adjusted profits can be earned by actively trading futures. The trading strategy we adopt takes on the following form (see Buckle, Clare, and Thomas (1994) and Clare and Miffre (1995)): if the time t forecast return on the futures contract is greater than the return on the one-month Treasury-bill, the investor buys the futures contract; if the absolute forecast return is less than the return on the Treasury-bill, the investor purchases the Treasury-bill; finally, if the forecast return is less than the return on the Treasury bill and the absolute value of the forecast exceeds the return on cash, the investor sells the futures contract. Following Ilmanen (1995), the time t forecast returns are estimated using the *ex-ante* models over the period June 1982 to t-1 through OLS, the sample is then increased by one observation at a time, and the models are reestimated over the new sample to produce new estimates of the coefficients and hence new estimates of the forecast returns. Since five years of data are required to estimate the first *ex-ante* models, the rolling one-step ahead forecast returns are estimated over the period June 1987 to October 1996 for each futures contract.

We then investigate the performance of the trading rule. First we compare the yearly mean and standard deviation of returns for each trading rule to the yearly mean and standard deviation of the returns on a buy and hold strategy that consists in being long in the futures contract over the period June 1987 to October 1996. Second, we assess the presence and significance of abnormal return in the context of a multifactor model with constant betas and estimate the following time series regression

$$R_t = \alpha + \beta f_t + \varepsilon_t \tag{4.2}$$

$R_t$ is defined as follows: when the strategy consists in investing in the Treasury bill market, it is equal to the excess return on the one-month Treasury bill (hence zero) to reflect the financial costs of purchasing the cash instrument. As a consequence of the absence of initial investment in futures markets, $R_t$ represents the realised raw return in the futures market, when the trading rule recommends to invest in futures markets. $f_t$ is the K-vector of macroeconomic and financial shocks derived in chapter II, $\varepsilon_t$ is a white-noise error term, and $\alpha$ and $\beta$ are the estimated parameters. Following Jensen (1968, for the CAPM), Connor and Korajczyk (1986, for the APT), and Jegadeesh (1990), we interpret $\alpha$ in (4.2) as a measure of abnormal performance and therefore as a measure of the profitability of the trading rule. Under the null hypothesis of market efficiency, the investment strategy does not generate any abnormal return; hence, $\alpha = 0$.[3]

Since low (high) beta securities offer an average return that is higher (lower) than the level predicted by the CAPM (see, for example, Black, Jensen, and Scholes (1972)), we believe that using the market model to evaluate abnormal performance in (4.2) might lead us to the misleading conclusion that markets are inefficient. We might wrongly conclude that the trading rules that are less (more) risky than the market as a whole offered a positive (negative) abnormal return. This however does not stands as a proof against the null hypothesis of no abnormal return. It rather reflects some benchmark problems while estimating the market model (see Roll (1977)).[4] The test we undertake uses the Chen, Roll, and Ross (1986) factors as risk proxies and is therefore not conditioned on the mean-variance efficiency of the benchmark of the market portfolio. Given besides the failure of the CAPM to describe the trade-off between risk and expected return in futures markets (see chapter II), we use some measures of macroeconomic and financial activity to estimate the systematic risk of the trading rule and evaluate abnormal performance.

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[3] Estimating (4.2) generates a joint hypothesis problem. It is jointly assumed that the trading rule does not generate any abnormal return and that the multifactor model (4.2) is correctly specified. As a test of the robustness of the conclusion to the specification of the risk-return relationship, we estimate hereafter a multifactor model that allows for time variation in risk.

[4] Unambiguous conclusions regarding the presence of abnormal returns in the context of the market model can only be obtained if the benchmark portfolio used in the test is mean variance efficient.

A fundamental assumption underlying equation (4.2) is stationarity of the regression relationships - differential return (intercept) and systematic risks (slopes) - over the entire period. If betas are time-varying, while equation (4.2) assumes they are constant, the estimates of alpha in (4.2) could be biased (Jegadeesh (1990)). In the context of the CAPM, Chan (1988), for example, argues that when the covariance between the time-varying betas and the expected market return is positive, the direction of the bias in equation (4.2) will be towards the presence of significantly positive abnormal returns. Similarly, if the beta coefficients decrease when the expected market return increase, the estimates of alpha in (4.2) will be downward biased. Only if the covariance between the time-varying betas and the market expected return is equal to zero, will the OLS regression (4.2) accurately detect the presence of abnormal return. Hence, assuming constant betas could lead to incorrect rejection of the null hypothesis of no abnormal return.

To test this hypothesis, we estimate the presence and size of abnormal returns using a time-varying multifactor model that accounts for possible changes in systematic risk. In this respect, we specify a conditional APT model that allows for time variation in the covariances between the excess returns on the trading rule and the sources of systematic risk present in the market (see, for example, Harvey (1989, 1991)). If we further assume that the reward per unit of covariance risk are constant, the conditional expected excess return on the trading rule can be expressed as a linear combination of the conditional covariance between the excess return on the trading rule and the excess returns on the factor mimicking portfolios. Hence

$$E(R_t / Z_{t-1}) = \lambda \operatorname{cov}[R_t, F_t / Z_{t-1}] \tag{4.3}$$

$E(R_t / Z_{t-1})$ is the time t expected excess return on the trading rule conditioned on the information set Z available at time t-1, $F_t$ is the K-excess return on the factor mimicking portfolios, $\lambda$ is the K-vector of prices of covariance risk associated with the APT factors, and $\mathrm{cov}\left[R_t, F_t / Z_{t-1}\right]$ is the vector of conditional covariances between the trading rule return and the systematic risk factors.

We allow for time-varying risk by recognising that the conditional covariances in (4.3) are time-varying with the information set available at time t-1. To estimate the conditional covariances, we need to impose some additional structure into model (4.3). In particular, the conditional first moments need to be identified. To do so, we assume that investors assess a linear relationship between conditional expected returns and the instruments. Hence, the excess return on the trading rule and the excess return on any factor mimicking portfolio can be expressed as

$$u1_t = R_t - Z_{t-1}\delta \tag{4.4a}$$

$$u2_t = F_t - Z_{t-1}\gamma \tag{4.4b}$$

where $u1_t$ and $u2_t$ are error terms that are orthogonal to the L instruments $Z_{t-1}$, $\delta$ and $\gamma$ are the estimated coefficients, and the other parameters are as previously defined. Hence, the definition of the covariance, equations (4.3), (4.4a), and (4.4b) yield

$$E\left(R_t / Z_{t-1}\right) = \lambda E\left[u1_t u2_t / Z_{t-1}\right]$$

We define the forecast error $u3_t$ as

$$u3_t = R_t - \lambda u1_t u2_t \tag{4.4c}$$

Stacking together (4.4a), (4.4b), and (4.4c) into a system and recognising that $E\left[u2_t u1_t / Z_{t-1}\right] = E\left[u2_t R_t / Z_{t-1}\right]$[5] (see Harvey (1991, footnote 9)) yield

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[5] This follows from the fact that $E\left[u2_t u1_t / Z_{t-1}\right]$

$$= E\left[u2_t\left(R_t - Z_{t-1}\delta\right) / Z_{t-1}\right]$$
$$= E\left[u2_t R_t / Z_{t-1}\right] - E\left[u2_t Z_{t-1}\delta / Z_{t-1}\right]$$

$$u_t = \left(u2_t \quad u3_t\right) = \begin{pmatrix} (F_t - Z_{t-1}\gamma)' \\ (R_t - \lambda u2_t R_t)' \end{pmatrix}' \tag{4.4}$$

We add an asset specific intercept term to the conditional asset pricing equations (4.4) and test the hypothesis that the intercept is equal to zero. Hence the following model is estimated

$$u_t = \left(u2_t \quad u3_t\right) = \begin{pmatrix} (F_t - Z_{t-1}\gamma)' \\ \left(R_t - \left(\alpha + \lambda u2_t R_t\right)\right)' \end{pmatrix}' \tag{4.5}$$

and the hypothesis that the intercept term $\alpha$ equals zero is tested. Following Harvey (1989), we consider the estimates of the intercept terms as the conditional asset pricing counterpart of the Jensen (1968) and Connor and Korajczyk (1986) alphas. Under the null hypothesis of market efficiency, the intercept term should equal zero irrespectively of the asset considered.

## III. Constructing Mimicking Portfolios

Since system (4.5) considers the excess returns on mimicking portfolios as one of the exogenous variables, the issue of mimicking portfolio formation needs to be addressed if one is to estimate conditional models with time-varying risk. The traditional approach to constructing mimicking portfolios follows from Huberman, Kandel, and Stambaugh (1987) and was recently applied to the estimation of conditional asset pricing models by Ferson and Korajczyk (1995). When an economic factor is expressed in excess return form (such as default spread or the term structure of interest rates), the time series of excess returns is used as a proxy of the returns on the mimicking portfolios. For the

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$$= E\left[u2_t R_t / Z_{t-1}\right] - E\left[u2_t / Z_{t-1}\right] Z_{t-1}\delta$$
$$= E\left[u2_t R_t / Z_{t-1}\right]$$

since $E\left[u2_t / Z_{t-1}\right] = 0$.

remaining factors (namely, unexpected inflation, the change in expected inflation, and the unexpected change in industrial production), we follow the two-step methodology proposed by Lehmann and Modest (1988) and Ferson and Korajczyk (1995). First, the sensitivities of the N individual stocks to the K APT factors and the idiosyncratic variances are estimated over the sample June 1977 - June 1982 through OLS regressions of individual returns on the K unexpected components (as estimated in chapter II) and the L lagged instruments. This produces a N*K matrix of conditional betas B for the APT factors and a N*N diagonal matrix of conditional residual variances V. Second, we employ a method referred to as the "minimum idiosyncratic risk procedure" (Lehmann and Modest (1988)) to estimate the vector of N portfolios positions $\omega_j = (\omega_1, \ldots, \omega_N)_j$ that solves the following quadratic problem for the j^th^ mimicking portfolio

$$\text{minimise } \omega_j{}' V \omega_j$$

subject to the constraints that

$$\omega_j{}' B_{[j]}{}' = \underline{0}$$

$$\omega_j{}' \underline{1} = 1$$

$B_{[j]}$ is a N*(K-1) matrix that excludes the j^th^ row from B, $\underline{0}$ is a K-1 vector of zeros, $\underline{1}$ is a N vector of ones, and $\omega_j$ is the N vector of security weights that is to be estimated. The second step is modelled as a quadratic program in which the decision variables are the proportions to invest in each of the possible securities. It consists in minimising a non-linear function (the squares of the proportions invested in each securities) subject to linear constraints. These restrictions impose the portfolio weights to sum up to one and to be orthogonal to the betas of the factors not being mimicked (the portfolio weights on the j^th^ factor are indeed unrestricted). The resulting vector $\omega_j$ is combined to the vector of individual stock returns to estimate the return on the j mimicking portfolio. The sample is then increased by one observation at a time to produce new estimates of B and V and hence new estimates of $\omega_j$. This procedure yields a time series of 173 mimicking portfolio returns for each of the factors that are not expressed in excess return form.[6]

## IV. Data

Along with the time series of futures returns and the Chen, Roll, and Ross (1986) derived factors used in the previous chapters, the data set we use in this chapter comprises six additional time series that are expected to measure the information set available to investors at time t-1. In addition to lagged stock and commodity returns, the information variables include the lagged dividend yield on the Standard and Poor's composite index, the lagged spread between the yields on 10-year Treasury bond and the lag on the three-month Treasury bill, the lagged spread between the yields on Moody's Aaa-rated bonds and 10-year Treasury bond, and the lagged realised return on a three-month Treasury bill. The rationale for including these variables into the data set stems from the fact that they have been shown to be an indicator of the current and future health of the economy (Fama and French (1989) and Chen (1991)). Also consistent with rational pricing in an efficient market is the idea that the *ex-ante* variables proxy for a change in the systematic risk of the asset and/or for a change in the risk premia present in all asset markets (see, for example, Evans (1994) and Ferson and Korajczyk (1995)). As such, they are expected to predict returns and to be a good proxy for change in expected futures returns.

The individual firms we include in our sample to construct mimicking portfolios consist of the Standard and Poor's 500 companies that have been continuously listed over the period June 1977 to October 1996. We exclude securities that have missing values because of the inability of SAS-IML to handle, for example, multiplication of such matrices. This consideration restricts our sample to 375 companies. We believe however

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[6] System (4.5) is estimated over the period June 1987 to October 1996. Hence a time series of 113 mimicking portfolio excess returns is only needed. The conditional asset pricing models estimated in chapter VI however cover the longer period June 1982 to October 1996. Consequently the mimicking portfolios are estimated over this longer sample.

that the resulting cross section is large enough for the orthogonal portfolios to contain negligible idiosyncratic risk.

It has been argued that, if the information variables track variation in expected returns, high first-order autocorrelations and low higher order autocorrelations in the *ex-ante* variables reveal the presence of persistence and mean reversion in expected returns. To test this hypothesis, we look at the twelve first order serial correlation in the end-of-month information variables. The results are reported in table 4.1. Consistent with previous empirical studies (see, for example, Fama and French (1988b, 1989)), the first order autocorrelation coefficients are by far the most significant for dividend yield, Treasury-bill, term and default spreads and the autocorrelations decay quickly across longer lags. On the other hand, the autocorrelation coefficients for the returns on the Standard & Poor's composite index and the Dow-Jones commodity index are insignificant, suggesting that futures returns cannot be predicted on the basis of past stock and commodity returns alone.

Table 4.2 displays the correlation matrix for the information variables. While default and term spreads, stock and commodity returns are weakly, if at all, correlated with the other information variables, the correlation between dividend yield and the return on the three-month Treasury bill is equal to 0.8 and the correlation between term spread and the Treasury-bill return exceeds 0.5 in absolute value. This could introduce a multicollinearity problem that might produce inefficient estimates of the coefficients, biased standard errors, and hence unreliable estimates of the t-ratios. To estimate the sensitivity of our results to the multicollinearity problem mentioned above, we adopt the two following approaches. First we test whether the return on the Treasury bill is redundant by estimating regression (4.1) with and without the Treasury-bill variable and compare the standard errors and t-ratios of both models. If the t-ratios are significant irrespectively of the inclusion of the Treasury-bill, multicollinearity should not be a problem. Second we examine the one-step ahead predictions of the models. If multicollinearity is a serious problem, the predictions from the model that suffers from multicollinearity should be worse than the predictions from the model that does not consider the Treasury-bill as an

# Table 4.1: Autocorrelation in the *Ex-Ante* Information Variables

|  | Dividend Yield (DY) |  | Term Structure (TS) |  | Default Spread (DS) |  | Treasury-Bill (TB) |  | S&P Return (SP) |  | Dow-Jones Return (DJ) |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio |
| Constant | 0.0327 | 0.52 | 0.197** | 2.55 | 0.1248* | 3.82 | 0.0901 | 1.52 | 0.0155* | 3.31 | 0.0001 | 0.04 |
| Lag 1 | 0.9646* | 11.75 | 1.2287* | 14.89 | 1.0935* | 13.31 | 1.5681* | 19.20 | -0.0076 | -0.09 | -0.1000 | -1.21 |
| Lag 2 | 0.0099 | 0.09 | -0.451* | -3.44 | -0.4144* | -3.40 | -0.7431* | -4.97 | -0.0453 | -0.56 | 0.0988 | 1.19 |
| Lag 3 | -0.0324 | -0.29 | 0.238*** | 1.74 | 0.2556** | 2.03 | 0.1968 | 1.24 | -0.0906 | -1.12 | 0.0509 | 0.61 |
| Lag 4 | -0.1015 | -0.90 | -0.1301 | -0.94 | -0.0482 | -0.38 | -0.0897 | -0.56 | -0.1533*** | -1.89 | -0.0574 | -0.71 |
| Lag 5 | 0.219*** | 1.96 | 0.0880 | 0.64 | -0.22*** | 1.74 | 0.2572 | 1.62 | 0.0769 | 0.95 | -0.1280 | -1.61 |
| Lag 6 | -0.0695 | -0.62 | -0.1242 | -0.92 | 0.1242 | 0.98 | -0.2324 | -1.46 | -0.0671 | -0.83 | 0.0136 | 0.17 |
| Lag 7 | 0.0319 | 0.29 | 0.239*** | 1.79 | 0.1205 | 0.96 | 0.0554 | 0.36 | 0.0333 | 0.41 | 0.0656 | 0.83 |
| Lag 8 | -0.186*** | -1.72 | -0.1086 | -0.82 | -0.1518 | -1.24 | -0.0602 | -0.39 | -0.1453*** | -1.83 | -0.0707 | -0.90 |
| Lag 9 | 0.1431 | 1.32 | -0.0024 | -0.02 | -0.0723 | -0.60 | 0.1715 | 1.15 | -0.0476 | -0.60 | -0.1309*** | -1.67 |
| Lag 10 | 0.0873 | 0.82 | -0.0760 | -0.71 | 0.0861 | 0.72 | -0.334* | -2.61 | 0.0536 | 0.69 | 0.0293 | 0.37 |
| Lag 11 | -0.1218 | -1.17 | 0.1153 | 1.11 | 0.0206 | 0.18 | 0.2648* | 2.67 | 0.0141 | 0.18 | 0.0610 | 0.78 |
| Lag 12 | 0.0409 | 0.56 | -0.0997 | -1.41 | 0.0219 | 0.29 | -0.0707 | -1.27 | -0.1397*** | -1.80 | 0.0325 | 0.42 |

* denotes significant at 1 percent,
** denotes significant at 5 percent,
*** denotes significant at 10 percent.

### Table 4.2: Contemporaneous Correlation Matrix of the *Ex-Ante* Variables

| | **Dividend Yield** | **Term Spread** | **Default Spread** | **Treasury-Bill Return** | **S&P Return** | **Dow-Jones Return** |
|---|---|---|---|---|---|---|
| **Dividend Yield** | 1 | | | | | |
| **Term Spread** | -0.10 | 1 | | | | |
| **Default Spread** | 0.56 | -0.15 | 1 | | | |
| **Treasury-Bill Return** | 0.80 | -0.52 | 0.34 | 1 | | |
| **S&P Return** | -0.03 | -0.14 | 0.13 | 0.02 | 1 | |
| **Dow-Jones Return** | -0.01 | 0.10 | 0.03 | -0.09 | -0.06 | 1 |

information variable. On the basis of these tests, we shall be able to choose the model that best predicts futures returns.

## IV. Empirical Results

This section aims at proving that futures returns can be predicted on the basis of information available at time t-1. With the *ex-ante* models at hand, our purpose hereafter is to test whether any economically and statistically significant abnormal return can be earned by actively trading futures. It is hoped that such an investigation will be useful at addressing the issue of market efficiency.

### 1. Evidence of Predictable Movements in Futures Returns

Table 4.3 reports coefficient estimates of regressions of futures returns on the information variables lagged once (equation (4.1)) and presents tests of the null hypothesis that expected returns are constant. These tests are conducted at the individual asset level, for groups of futures, and for the whole cross section of futures contracts. We first assume that the return on the Treasury bill is part of the information set used by investors to form expectations of the futures price one period ahead. We then exclude the Treasury bill variable from the information set, thereby addressing the problem of multicollinearity.

The results indicate that futures returns are predictable using information available at time t-1. The $\chi^2$ statistic that tests the hypothesis that the slope coefficients on the state variables are jointly zero across the 26 futures indeed suggests rejection of the null hypothesis of constant expected returns at the 1 percent level of statistical significance (p-value of 0.0008). The results for financial and metal futures are particularly striking. The $\chi^2$ statistics for these groups of futures indicate that the *ex-ante* variables forecast futures returns at least at the 10 percent level (p-values of 0.068 and 0.00006 for metal and financial futures respectively). The evidence however for agricultural futures are less remarkable. Although some of the $\chi^2$ statistics suggest that expected returns are not constant (soybeans, soybean oil, and soybean meal futures), the evidence mainly indicate that the information variables do not forecast the 10 remaining agricultural futures returns. Not surprisingly therefore, the joint test fails to reject the joint hypothesis that the variation in agricultural futures returns is unpredictable using information available at time t-1 (p-value of 0.645). Consistent with the analysis performed above, the proportion of the variation in futures returns that is explained by variation in expected returns is fairly small for agricultural futures and much larger for metal and financial futures. The R-squared typically range from a minimum of 1.1 percent for cotton to a maximum of 10.7 percent for the NYSE futures contract.

Bessembinder and Chan (1992) were the first to investigate the presence of time-varying risk premia in futures markets. They show that, over the period January 1975 to December 1989, dividend yield, the return on the three-month Treasury bill, and default spread track variation in expected currency, commodity, and metal futures returns: they reject the null hypothesis of constant expected returns for nine out of twelve futures at the 10 percent level. Although by large similar, the results we report in this section offer a weaker support to the hypothesis of time-varying expected futures returns. We indeed tend to accept the null hypothesis of constant expected returns more often than Bessembinder and Chan.

In table 4.4 we drop the Treasury bill variable. The resulting $\chi^2$ statistics confirm our first impression regarding the predictability of futures returns. The result across the whole set of futures suggests that futures returns can be forecast (p-value of 0.0014). While agricultural futures are mainly unpredictable (p-value of 0.52), the evidence for metal and financial futures indicate the presence of variation through time in expected returns (p-values of 0.066 and 0.0003 respectively). When the Treasury bill is not part of the information set, the lagged variables explain up to 9.1 percent of the variation in futures returns.

We then address the problem of multicollinearity that might result from the high correlation between the *ex-ante* variables. In this respect, a sensitivity analysis is

## Table 4.3: Predictable Movements in Futures Returns
## When the Return on the Treasury-bill is Considered as One of the Information Variables (a)

$$R_t = \alpha_0 + \alpha Z_{t-1} + \varepsilon_t$$

| Futures | Intercept | | DY(-1) | | TS(-1) | | DS(-1) | | TB(-1) | | SP(-1) | | DJ(-1) | | $R^2$ | $\chi^2$ (b) | p-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coeff | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | | | |
| **Panel A: Commodities** | | | | | | | | | | | | | | | | | |
| Cocoa | -0.0086 | -0.31 | 0.0023 | 0.24 | -0.0004 | -0.06 | 0.0320 | 1.22 | -0.0028 | -0.62 | -0.1144 | -0.86 | -0.1845 | -1.04 | 0.016 | 3.93 | 0.560 |
| Coffee | -0.0163 | -0.53 | 0.0121 | 0.53 | 0.0100 | 0.90 | -0.0305 | -0.70 | -0.0033 | -0.40 | -0.0821 | -0.56 | 0.1149 | 0.39 | 0.022 | 4.15 | 0.528 |
| Corn | 0.0019 | 0.05 | -0.0079 | -0.36 | 0.0024 | 0.35 | 0.0353 | 1.17 | -0.0006 | -0.09 | 0.0252 | 0.24 | 0.0946 | 0.51 | 0.015 | 4.61 | 0.465 |
| Cotton | 0.0391 | 1.42 | 0.0178 | 1.11 | -0.0098 | -1.21 | -0.0126 | -0.61 | -0.0100 | -1.42 | -0.0894 | -0.87 | -0.0571 | -0.24 | 0.011 | 4.43 | 0.489 |
| Oats | -0.0030 | -0.08 | -0.0121 | -0.57 | 0.0099 | 1.33 | 0.0225 | 0.74 | 0.0018 | 0.25 | -0.1810 | -1.48 | 0.0746 | 0.20 | 0.015 | 6.34 | 0.275 |
| Soybeans | -0.0150 | -0.53 | -0.0240 | -1.57 | 0.0112 | 1.63 | 0.0566** | 2.05 | 0.0054 | 0.86 | -0.183** | -1.99 | -0.29*** | -1.82 | 0.073 | 13.90 | 0.016 |
| Soybean Meal | 0.0036 | 0.11 | -0.0146 | -0.80 | 0.0083 | 1.10 | 0.0264 | 0.80 | 0.0023 | 0.32 | -0.280** | -2.29 | -0.3153 | -1.56 | 0.064 | 11.17 | 0.048 |
| Soybean Oil | -0.0495 | -1.36 | -0.04*** | -1.96 | 0.020** | 2.23 | 0.0768** | 2.09 | 0.0135 | 1.57 | -0.1601 | -1.36 | -0.1869 | -1.01 | 0.058 | 12.74 | 0.026 |
| Sugar | 0.0161 | 0.24 | 0.0458 | 1.25 | -0.0033 | -0.18 | -0.0636 | -0.78 | -0.0172 | -1.11 | 0.1235 | 0.38 | -0.4650 | -1.50 | 0.021 | 4.38 | 0.497 |
| Wheat | -0.0100 | -0.37 | -0.0047 | -0.30 | 0.0075 | 1.25 | 0.0036 | 0.14 | 0.0015 | 0.26 | -0.0339 | -0.38 | -0.1480 | -0.64 | 0.012 | 2.58 | 0.765 |
| Lean Hogs | 0.04*** | 1.66 | -0.0067 | -0.34 | -0.0085 | -0.95 | -0.0005 | -0.02 | 0.0007 | 0.09 | -0.2369 | -1.59 | 0.2234 | 1.05 | 0.029 | 6.85 | 0.232 |
| Lumber | 0.0460 | 1.28 | 0.0115 | 0.61 | -0.0094 | -1.00 | 0.0348 | 0.97 | -0.0126 | -1.32 | 0.1570 | 0.87 | -0.3699 | -1.33 | 0.039 | 6.87 | 0.230 |
| Pork Bellies | 0.0866 | 1.65 | -0.0026 | -0.11 | -0.0191 | -1.46 | 0.0224 | 0.52 | -0.0064 | -0.71 | 0.0358 | 0.15 | -0.65*** | -1.95 | 0.035 | 5.98 | 0.308 |
| **All agricultural ($\chi$2(78))** | | | | | | | | | | | | | | | | **72.80** | **0.645** |
| **Panel B: Metal and Oil** | | | | | | | | | | | | | | | | | |
| Gold | -0.0017 | -0.08 | 0.0018 | 0.23 | -0.0036 | -1.01 | 0.0373** | 2.00 | -0.0032 | -1.12 | -0.13*** | -1.70 | -0.342* | -2.87 | 0.093 | 16.16 | 0.006 |
| Heating Oil | 0.0541 | 1.49 | -0.0293 | -1.30 | -0.0044 | -0.39 | 0.0208 | 0.48 | 0.0080 | 1.13 | -0.3615 | -1.45 | -0.1030 | -0.46 | 0.033 | 5.59 | 0.348 |
| Silver | -0.0047 | -0.22 | 0.0194 | 1.15 | -0.0087 | -1.57 | 0.0628* | 3.51 | -0.01** | -2.31 | 0.0009 | 0.01 | -0.517* | -3.55 | 0.100 | 32.03 | <0.001 |
| Platinum | -0.0060 | -0.26 | 0.0146 | 0.97 | -0.0056 | -0.82 | 0.0436 | 1.46 | -0.0091 | -1.64 | -0.1508 | -0.75 | -0.2730 | -1.16 | 0.049 | 8.33 | 0.139 |
| **All Metals ($\chi^2$(24))** | | | | | | | | | | | | | | | | **35.02** | **0.068** |

## Table 4.3 - *Continued*

| Futures | Intercept | | DY(-1) | | TS(-1) | | DS(-1) | | TB(-1) | | SP(-1) | | DJ(-1) | | $R^2$ | $\chi^2$ (b) | p-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | | | |
| **Panel C: Financial** | | | | | | | | | | | | | | | | | |
| NYSE | 0.0208 | 1.03 | 0.0358* | 2.70 | -0.015** | -2.25 | -0.0212 | -1.25 | -0.01** | -2.57 | 0.0192 | 0.15 | 0.22*** | 1.81 | 0.107 | 14.86 | 0.011 |
| SP500 | 0.0241 | 1.22 | 0.035** | 2.64 | -0.015** | -2.30 | -0.0234 | -1.40 | -0.01** | -2.51 | 0.0131 | 0.10 | 0.23*** | 1.97 | 0.106 | 14.88 | 0.011 |
| Treasury-Bill | -0.0027 | -0.87 | 0.0016 | 1.45 | -0.0008 | -1.51 | 0.0007 | 0.26 | -0.0001 | -0.34 | -0.0053 | -0.58 | -0.0071 | -0.64 | 0.079 | 5.23 | 0.388 |
| Treasury-Note | -0.0113 | -0.95 | 0.015** | 2.64 | -0.0029 | -1.13 | -0.02*** | -1.72 | -0.0032 | -1.37 | -0.0357 | -0.88 | 0.0288 | 0.58 | 0.082 | 10.40 | 0.065 |
| Treasury-Bond | -0.0108 | -0.65 | 0.023** | 2.54 | -0.0044 | -1.09 | -0.029** | -2.14 | -0.0051 | -1.43 | -0.0243 | -0.44 | 0.0325 | 0.45 | 0.073 | 9.77 | 0.082 |
| Deutsch Mark | 0.0166 | 1.28 | 0.0029 | 0.36 | -0.0017 | -0.48 | -0.0109 | -0.74 | -0.0015 | -0.47 | -0.15*** | -1.94 | -0.0438 | -0.43 | 0.041 | 6.57 | 0.255 |
| Japanese Yen | -0.0107 | -0.67 | 0.0032 | 0.38 | 0.0044 | 1.20 | 0.0007 | 0.04 | -0.0009 | -0.32 | -0.0427 | -0.45 | 0.0896 | 0.89 | 0.037 | 6.94 | 0.225 |
| Swiss Franc | 0.0149 | 1.07 | -0.0022 | -0.24 | -0.0003 | -0.07 | -0.0025 | -0.15 | <0.0001 | 0.01 | -0.1268 | -1.41 | -0.0224 | -0.23 | 0.023 | 3.12 | 0.682 |
| UK Pound | 0.0123 | 0.79 | -0.0102 | -1.46 | 0.0022 | 0.56 | -0.0012 | -0.09 | 0.0032 | 0.91 | -0.1229 | -1.56 | -0.0793 | -0.95 | 0.040 | 10.63 | 0.059 |
| **All Financial ($\chi^2(54)$)** | | | | | | | | | | | | | | | | **103.4** | **0.00006** |
| **All Futures ($\chi^2(156)$)** | | | | | | | | | | | | | | | | **217.8** | **0.0008** |

(a) The standard errors are adjusted for serial correlation and heteroscedasticity using Newey and West (1987) correction.

(b) $\chi^2$ is a heteroscedasticity and serial correlation consistent test of the null hypothesis that the expected futures returns are constant, p-value is the probability of rejecting the null hypothesis when it is true. Unless specified otherwise, the tests are distributed as $\chi^2$ with 5 degrees of freedom.

Unless specified otherwise, the tests are distributed as $\chi^2$ with 5 degrees of freedom.

* denotes significant at 1 percent,

** denotes significant at 5 percent,

*** denotes significant at 10 percent.

## Table 4.4: Predictable Movements in Futures Returns When the Return on the Treasury-bill is Not Considered as One of the Information Variables (a)

$$R_t = \alpha_0 + \alpha Z_{t-1} + \varepsilon_t$$

| Futures | Intercept | | DY(-1) | | TS(-1) | | DS(-1) | | SP(-1) | | DJ(-1) | | $R^2$ | $\chi^2(b)$ | p-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | | | |
| **Panel A: Commodities** | | | | | | | | | | | | | | | |
| Cocoa | -0.0146 | -0.74 | -0.0039*** | -1.68 | 0.0021 | 0.34 | 0.037*** | 1.93 | -0.1160 | -0.86 | -0.1786 | -1.02 | 0.015 | 3.24 | 0.664 |
| Coffee | -0.0233 | -0.85 | 0.0048 | 0.42 | 0.0129 | 1.31 | -0.0246 | -0.62 | -0.0838 | -0.57 | 0.1218 | 0.41 | 0.022 | 4.12 | 0.532 |
| Corn | 0.0006 | 0.01 | -0.0092 | -0.89 | 0.0029 | 0.54 | 0.0363 | 1.37 | 0.0249 | 0.24 | 0.0958 | 0.51 | 0.015 | 4.50 | 0.480 |
| Cotton | 0.0180 | 0.72 | -0.0040 | -0.53 | -0.0010 | -0.20 | 0.0049 | 0.22 | -0.0947 | -0.95 | -0.0364 | -0.15 | 0.003 | 1.49 | 0.914 |
| Oats | 0.0008 | 0.02 | -0.0083 | -0.75 | 0.0084 | 1.22 | 0.0194 | 0.73 | -0.1801 | -1.50 | 0.0710 | 0.19 | 0.015 | 6.22 | 0.286 |
| Soybeans | -0.0035 | -0.15 | -0.0121 | -1.75 | 0.006*** | 1.74 | 0.0471** | 2.06 | -0.179** | -2.01 | -0.304*** | -1.87 | 0.069 | 13.26 | 0.021 |
| Soybean Meal | 0.0086 | 0.30 | -0.0095 | -1.05 | 0.0063 | 1.58 | 0.0223 | 0.80 | -0.279** | -2.31 | -0.3201 | -1.56 | 0.064 | 10.86 | 0.054 |
| Soybean Oil | -0.0209 | -0.77 | -0.0094 | -1.02 | 0.008*** | 1.73 | 0.053*** | 1.72 | -0.1529 | -1.29 | -0.2151 | -1.16 | 0.040 | 10.52 | 0.062 |
| Sugar | -0.0202 | -0.44 | 0.0082 | 0.48 | 0.0119 | 1.37 | -0.0334 | -0.50 | 0.1143 | 0.36 | -0.4291 | -1.40 | 0.015 | 2.85 | 0.723 |
| Wheat | -0.0068 | -0.26 | -0.0014 | -0.19 | 0.0061 | 1.20 | 0.0009 | 0.04 | -0.0331 | -0.37 | -0.1512 | -0.65 | 0.012 | 2.21 | 0.819 |
| Lean Hogs | 0.0462*** | 1.87 | -0.0052 | -0.69 | -0.009*** | -1.66 | -0.0017 | -0.06 | -0.2365 | -1.60 | 0.2220 | 1.08 | 0.030 | 6.81 | 0.235 |
| Lumber | 0.0194 | 0.78 | -0.0160 | -1.47 | 0.0017 | 0.23 | 0.057*** | 1.60 | 0.1502 | 0.83 | -0.3437 | -1.24 | 0.030 | 5.14 | 0.399 |
| Pork Bellies | 0.0730 | 1.52 | -0.0167 | -1.44 | -0.0134 | -1.25 | 0.0337 | 0:91 | 0.0324 | 0.14 | -0.643*** | -1.95 | 0.034 | 5.86 | 0.320 |
| **All agricultural ($\chi^2(65)$)** | | | | | | | | | | | | | | **63.63** | **0.520** |
| **Panel B: Metal and Oil** | | | | | | | | | | | | | | | |
| Gold | -0.0084 | -0.41 | -0.0052 | -1.03 | -0.0007 | -0.28 | 0.0428** | 2.39 | -0.13*** | -1.74 | -0.3355* | -2.81 | 0.091 | 13.32 | 0.021 |
| Heating Oil | 0.0711** | 2.19 | -0.0117 | -1.38 | -0.0115 | -1.61 | 0.0067 | 0.18 | -0.3572 | -1.46 | -0.1198 | -0.54 | 0.031 | 4.62 | 0.465 |
| Silver | -0.0336 | -1.18 | -0.0106 | -1.36 | 0.0034 | 1.20 | 0.0869* | 4.28 | -0.0065 | -0.08 | -0.4890* | -3.51 | 0.084 | 21.32 | 0.001 |
| Platinum | -0.0252 | -1.18 | -0.0053 | -0.70 | 0.0025 | 0.71 | 0.0596** | 2.15 | -0.1556 | -0.77 | -0 2540 | -1.07 | 0.041 | 5.25 | 0.387 |
| **All Metals ($\chi^2(20)$)** | | | | | | | | | | | | | | **30.25** | **0.066** |

## Table 4.4 - *Continued*

| Futures | Intercept | | DY(-1) | | TS(-1) | | DS(-1) | | SP(-1) | | DJ(-1) | | $R^2$ | $\chi^2$ (b) | p-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | | | |
| **Panel C: Financial** | | | | | | | | | | | | | | | |
| NYSE | -0.0071 | -0.41 | 0.0069 | 1.58 | -0.0032 | -1.08 | 0.0021 | 0.17 | 0.0121 | 0.10 | 0.2422** | 2.04 | 0.052 | 11.65 | 0.040 |
| SP500 | -0.0033 | -0.19 | 0.0068 | 1.61 | -0.0037 | -1.25 | -0.0005 | -0.04 | 0.0061 | 0.05 | 0.2613** | 2.18 | 0.053 | 12.17 | 0.032 |
| Treasury-Bill | -0.0030 | -1.01 | 0.0013 | 1.62 | -0.001*** | -1.91 | 0.0009 | 0.35 | -0.0054 | -0.59 | -0.0068 | -0.61 | 0.079 | 5.13 | 0.400 |
| Treasury-Note | -0.0180 | -1.50 | 0.0085** | 2.37 | -0.0001 | -0.07 | -0.0105 | -1.01 | -0.0375 | -0.93 | 0.0355 | 0.74 | 0.044 | 7.82 | 0.166 |
| Treasury-Bond | -0.0215 | -1.27 | 0.0117** | 2.21 | 0.0001 | 0.03 | -0.0201 | -1.31 | -0.0270 | -0.49 | 0.0430 | 0.62 | 0.061 | 6.84 | 0.233 |
| Deutsch Mark | 0.0135 | 1.19 | -0.0004 | -0.09 | -0.0003 | -0.13 | -0.0082 | -0.59 | -0.15*** | -1.96 | -0.0406 | -0.39 | 0.041 | 5.76 | 0.330 |
| Japanese Yen | -0.0126 | -0.83 | 0.0012 | 0.25 | 0.0052** | 2.03 | 0.0023 | 0.16 | -0.0432 | -0.46 | 0.0915 | 0.92 | 0.037 | 6.84 | 0.232 |
| Swiss Franc | 0.0150 | 1.19 | -0.0021 | -0.45 | -0.0003 | -0.10 | -0.0025 | -0.17 | -0.1268 | -1.42 | -0.0225 | -0.23 | 0.023 | 3.06 | 0.691 |
| UK Pound | 0 0192 | 1.64 | -0.0031 | -0.70 | -0.0007 | -0.22 | -0.0069 | -0.54 | -0.1212 | -1.52 | -0.0860 | -1.02 | 0.035 | 9.31 | 0.097 |
| **All Financial ($\chi^2(45)$)** | | | | | | | | | | | | | | **85.11** | **0.0003** |
| **All Futures ($\chi^2(130)$)** | | | | | | | | | | | | | | **183.1** | **0.0014** |

(a) The standard errors are adjusted for serial correlation and heteroscedasticity using Newey and West (1987) correction.

(b) $\chi^2$ is a heteroscedasticity and serial correlation consistent test of the null hypothesis that the expected futures returns are constant, p-value is the probability of rejecting the null hypothesis when it is true. Unless specified otherwise, the tests are distributed as $\chi^2$ with 5 degrees of freedom.

Unless specified otherwise, the tests are distributed as $\chi^2$ with 5 degrees of freedom.

* denotes significant at 1 percent,

** denotes significant at 5 percent,

*** denotes significant at 10 percent.

performed on the t-ratios to get some insight as to which model should be favoured as a description of the variation through time in expected futures returns. More futures returns in table 4.4 seem to be sensitive to the information variables than in table 4.3. It follows therefore that the standard errors might be more accurately estimated when the Treasury-bill variable is omitted. The sensitivity analysis performed above seems then to indicate that the Treasury-bill should be omitted from the information set. Before any definite conclusion can be drawn onto the issue of multicollinearity, we first examine the predictive power of both models. If the predictions are better when only a subset of information variables is used, the return on the Treasury-bill should not be considered as part of the information set.

## 2. Forecast Accuracy

The rest of the chapter aims at testing whether the observed predictability suggests evidence against the weak form of the efficient market hypothesis or reflects the presence of time variation in expected returns. In this respect we estimate one-step ahead forecast returns for each of the 26 futures contracts here considered, test the out-of-sample forecasting properties of the *ex-ante* models, and derive a simple trading rule that aims at testing the EMH.

We first estimate the one-step ahead forecast returns and look at the statistical properties of the dynamic forecasts. In this respect we undertake three sets of tests that attempt to analyse the accuracy of the forecasts. First, if forecast returns are accurate predictors of actual returns, the forecast errors should be white noise; namely, should meet the requirements of being serially uncorrelated and homoscedastic processes. The second forecast accuracy test looks at whether forecast returns meet the requirements of being rational estimates of actual returns. In this respect we estimate the following model

$$R_t = \alpha_0 + \alpha_1 E(R_t / Z_{t-1}) + \varepsilon_t \tag{4.6}$$

where $R_t$ is the actual futures return at time t, $E(R_t / Z_{t-1})$ is the expected futures returns derived from the *ex-ante* models given the information set Z available at time t-1, $\varepsilon_t$ is a vector of error terms, and $\alpha_0$ and $\alpha_1$ are the parameters to estimate. Under the null hypothesis of rational expectations, $\alpha_0 = 0$ and $\alpha_1 = 1$ in (4.6). These restrictions are tested using the Wald test that is distributed as $\chi^2$ with 2 degrees of freedom. The final criterion we use to test forecast accuracy consists in looking at the proportion of the variance of actual returns explained by variation through time in expected returns. If the model does a good job at tracking actual returns, the proportions of the variance of returns explained by the *ex-ante* models should be high compared to the proportion of the variance of returns that is relegated to the residuals. To implement this test, we compute the following variance ratios

$$VR_1 = \frac{\sigma^2(E(R_t / Z_{t-1}))}{\sigma^2(R_t)}$$

$$VR_2 = \frac{\sigma^2(R_t - E(R_t / Z_{t-1}))}{\sigma^2(R_t)}$$

where $\sigma^2(.)$ is the variance operator and the other parameters are as previously defined. If the *ex-ante* models accurately predict returns, the variation through time in expected returns should be high and the variance of unexpected returns should be small. Hence, $VR_1$ should exceed $VR_2$.

Table 4.5 summarises the results from these tests. With respect to the hypothesis that the forecast errors are white noise, the data suggests that the forecasts are accurate. As should be expected if actual returns can no longer be predicted on the basis of any information available at time t-1 to t-12, the forecast errors marginally suffer from heteroscedasticity and are predominantly serially uncorrelated up to order twelve. Hence, at least as far as this test is concerned, the data seem to support the hypothesis that the lagged *ex-ante* variables do a good job at picking up the expected variation in futures returns. According to the second criterion however, the $\chi^2$ statistics displayed in table 4.5

suggest that the forecast returns fail to meet the requirements of being rational at the 1 percent significance level. The null hypotheses embedded in equation (4.6) is indeed rejected for 16 futures contracts respectively at the 1 percent significance level. Hence the result mainly suggests that the forecasts are not accurate.[7] The final test looks at the proportion of the variance in realised returns explained by the *ex-ante* model. The results suggest that most of the variation in realised returns cannot be predicted and is relegated to the residuals of the model. One way to account for this poor performance is to conclude that the forecasts are not accurate. Alternatively, this could suggest that most of the variation in futures returns is unpredictable, a result that is somehow expected if we are to recall the low R-squared obtained in table 4.3. In such a case, it is not surprising to obtain $VR_1$ ratios that are low compared to $VR_2$.

To address the problem of multicollinearity referred to above, we assume that the Treasury-bill variable is not part of the information set used by investors, estimate one-step ahead forecasts from the *ex-ante* models, and test forecast accuracy. If multicollinearity is a problem, the predictions should be better when the return on the Treasury-bill is omitted from the information set. Table 4.6 summarises the results from the forecast accuracy tests. With respect to the hypothesis that the forecast errors are white noise, the data suggest that the omission of the Treasury-bill return does not improve forecast accuracy. The forecast errors still marginally suffer from heteroscedasticity and serial correlation. Only 9 forecasts fail to meet the requirements of rational expectations at the 1 percent significance level. Hence the omission of the Treasury-bill has some impact of the accuracy of the forecasts. On the basis of this test, one can conclude that the high correlation between the state variables does introduce some problem of multicollinearity. Since, besides, the proportion of the variance of returns not explained by variation in expected returns is less in table 4.6 than in table 4.5, i.e., when only a subset of information variables is considered, we favour the model that

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[7] As a further robustness check, a specification of the *ex-ante* models that includes twelve lags in the information variables was estimated and the hypothesis that expectations are rational was tested. The resulting $\chi^2$ statistics suggest that the forecast returns still fail to meet the basic requirements of being rational. The rejection is indeed stronger when twelve lags are considered. Since the inclusion of twelve lags does not improve the accuracy of the forecasts, we believe that the original specification with only one lag better predicts futures returns.

## Table 4.5: Properties of the Dynamic Forecasts and Forecast Errors When the Treasury-Bill is Considered as One of the *Ex-Ante* Variables

| Futures Contract | Residuals | | Rational Expectation | | | Variance Ratios | |
|---|---|---|---|---|---|---|---|
| | S.C. (a) | Het. (a) | $\alpha_0$ (b) | $\alpha_1$ (b) | $\chi^2(2)$ | $VR_1$ (c) | $VR_2$ (c) |
| Panel A: Agricultural Commodities | | | | | | | |
| Cocoa | 19.001 | 3.203 | -0.0060 | -1.4344 | 18.61* | 0.0263 | 1.1017 |
| Coffee | 10.598 | 1.613 | 0.0042 | -0.3724 | 6.60 | 0.0255 | 1.0446 |
| Corn | 17.216 | 0.060 | 0.0061 | 0.0131 | 8.63 | 0.0784 | 1.0764 |
| Cotton | 19.598 | 1.050 | 0.0174 | -1.0367 | 13.61* | 0.0232 | 1.0714 |
| Oats | 15.587 | 0.623 | 0.0063 | 0.0251 | 8.59 | 0.0795 | 1.0756 |
| Soybeans | 15.926 | 0.577 | 0.0005 | 0.4515 | 6.74 | 0.1859 | 1.0180 |
| Soybean Meal | 19.703 | 1.583 | -0.0010 | 0.4796 | 6.60 | 0.1675 | 1.0068 |
| Soybean Oil | 22.841* | 0.006 | 0.0043 | 0.1179 | 11.65* | 0.1316 | 1.1006 |
| Sugar | 32.443* | 7.167* | 0.0177 | -0.3256 | 29.11* | 0.1304 | 1.2153 |
| Wheat | 27.035* | 0.052 | 0.0054 | -0.5750 | 6.72 | 0.0538 | 1.0600 |
| Lean Hogs | 32.640 | 2.275 | 0.0043 | -0.1269 | 7.78 | 0.0531 | 1.0666 |
| Lumber | 15.584 | 13.269* | 0.0132 | -0.0351 | 1.76 | 0.0149 | 1.0159 |
| Pork Bellies | 19.180 | 0.961 | 0.1080 | -0.0349 | 5.12 | 0.0425 | 1.0455 |
| Panel B: Metal and Oil Commodities | | | | | | | |
| Gold | 24.131 | 0.171 | -0.0018 | 0.4147 | 6.31 | 0.1396 | 1.0238 |
| Heating Oil | 24.703 | 2.784 | 0.0111 | -0.2662 | 9.22* | 0.0516 | 1.0791 |
| Silver | 21.784 | 0.606 | -0.0021 | 0.2651 | 10.01* | 0.1641 | 1.0771 |
| Platinum | 31.263* | 40.880* | -0.0009 | -0.1214 | 34.54* | 0.1902 | 1.2364 |
| Panel C: Financial | | | | | | | |
| NYSE | 13.128 | 3.107 | 0.0076 | 0.0739 | 9.74* | 0.1022 | 1.0871 |
| SP500 | 13.012 | 5.804 | 0.0084 | 0.0387 | 10.14* | 0.0986 | 1.0909 |
| Treasury-Bill | 29.673* | 35.339* | -0.0001 | -0.2227 | 32.21* | 0.1608 | 1.2324 |
| Treasury-Note | 18.273 | 11.592* | 0.0016 | 0.1301 | 17.17* | 0.1607 | 1.1189 |
| Treasury-Bond | 18.317 | 17.802* | 0.0024 | 0.1093 | 16.12* | 0.1558 | 1.1217 |
| Deutsch Mark | 16.466 | 0.104 | 0.0021 | 0.0061 | 12.82* | 0.0648 | 1.0640 |
| Japanese Yen | 20.921 | 1.644 | 0.0023 | 0.0383 | 12.77* | 0.0765 | 1.0706 |
| Swiss Franc | 20.826 | 2.404 | 0.0064 | -0.4429 | 14.44* | 0.0435 | 1.0820 |
| UK Pound | 17.428 | 7.030* | 0.0016 | -0.2179 | 10.04* | 0.0503 | 1.0722 |

(a) The test for serial correlation (S.C.) consists in regressing the estimated forecast errors on the forecast returns and the residuals lagged 12 times and is distributed as $\chi^2(12)$ with a calculated value of $TR^2$ (where T represents the number of observations and $R^2$ is the goodness-of-fit statistic of the regression). The test for heteroscedasticity (Het ) consists in regressing the variance of the residuals on the squared forecast returns and is distributed as $\chi^2(1)$ with a calculated value of $TR^2$.

(b) $\alpha_0$ and $\alpha_1$ are the coefficient estimates of a regression of actual futures returns on a constant and the one-step ahead forecast returns. Under rational expectations, $\alpha_0=0$ and $\alpha_1=1$.

(c) $VR_1 = \sigma^2(E(R_t \;\; Z_{t-1}))/\sigma^2(R_t)$, $VR_2 = \sigma^2(R_t - E(R_t \;\; Z_{t-1}))/\sigma^2(R_t)$.

* denotes significant at 1 percent.

## Table 4.6: Properties of the Dynamic Forecasts and Forecast Errors When the Treasury-Bill is Not Considered as One of the *Ex-Ante* Variables

| Futures Contract | Residuals | | Rational Expectation | | | Variance Ratios | |
|---|---|---|---|---|---|---|---|
| | S.C. (a) | Het. (a) | $\alpha_0$ (b) | $\alpha_1$ (b) | $\chi^2(2)$ | $VR_1$ (c) | $VR_2$ (c) |
| **Panel A: Commodities** | | | | | | | |
| Cocoa | 18.301 | 3.063 | -0.0057 | -1.4068 | 17.24* | 0.0250 | 1.0955 |
| Coffee | 10.233 | 1.569 | 0.0047 | -0.3509 | 6.10 | 0.0252 | 1.0428 |
| Corn | 16.564 | 0.117 | 0.0061 | 0.0448 | 7.75 | 0.0743 | 1.0676 |
| Cotton | 18.826 | 0.955 | 0.0105 | -0.6510 | 12.86* | 0.0363 | 1.0835 |
| Oats | 15.155 | 0.639 | 0.0065 | 0.0093 | 7.86 | 0.0716 | 1.0703 |
| Soybeans | 15.753 | 0.795 | 0.0002 | 0.4904 | 6.14 | 0.1929 | 1.0037 |
| Soybean Meal | 19.476 | 0.942 | -0.0004 | 0.4912 | 5.31 | 0.1498 | 1.0026 |
| Soybean Oil | 21.511 | 0.331 | 0.0023 | 0.4044 | 5.29 | 0.1309 | 1.0250 |
| Sugar | 27.938* | 7.270* | 0.0223 | -0.6438 | 21.19* | 0.0640 | 1.1465 |
| Wheat | 26.154 | 0.004 | 0.0052 | 0.0078 | 5.80 | 0.0526 | 1.0518 |
| Lean Hogs | 32.255* | 1.649 | 0.0034 | -0.0155 | 5.92 | 0.0490 | 1.0505 |
| Lumber | 14.782 | 11.844* | 0.0142 | -0.1512 | 1.54 | 0.0101 | 1.0131 |
| Pork Bellies | 19.005 | 0.908 | 0.0105 | 0.0053 | 4.67 | 0.0420 | 1.0415 |
| **Panel B: Metal and Oil** | | | | | | | |
| Gold | 24.784 | 0.016 | -0.0016 | 0.4965 | 4.28 | 0.1288 | 1.0009 |
| Heating Oil | 24.083 | 2.832 | 0.0126 | -0.3506 | 8.85 | 0.0431 | 1.0733 |
| Silver | 19.215 | 0.037 | -0.0012 | 0.2869 | 7.01 | 0.1214 | 1.0517 |
| Platinum | 25.575 | 29.391* | -0.0009 | -0.1712 | 14.36* | 0.1282 | 1.1721 |
| **Panel C: Financial** | | | | | | | |
| NYSE | 7.641 | 7.682* | 0.0096 | -0.2986 | 9.14 | 0.0432 | 1.0689 |
| SP500 | 8.250 | 7.265* | 0.0098 | -0.1889 | 8.71 | 0.0507 | 1.0698 |
| Treasury-Bill | 28.225* | 34.619* | -0.0001 | -0.1673 | 29.97* | 0.1683 | 1.2245 |
| Treasury-Note | 14.509 | 7.726* | 0.0020 | 0.2190 | 11.52* | 0.0807 | 1.0453 |
| Treasury-Bond | 14.874 | 14.709* | 0.0027 | 0.1638 | 10.92* | 0.0814 | 1.0547 |
| Deutsch Mark | 12.438 | 0.004 | -0.0006 | 0.3320 | 6.14 | 0.0398 | 1.0134 |
| Japanese Yen | 20.054 | 1.014 | 0.0024 | 0.0236 | 11.49* | 0.0718 | 1.0684 |
| Swiss Franc | 17.604 | 1.552 | 0.0045 | -0.2627 | 10.00* | 0.0355 | 1.0542 |
| UK Pound | 16.981 | 5.767 | 0.0015 | -0.2037 | 8.98 | 0.0455 | 1.0640 |

(a) The test for serial correlation (S.C.) consists in regressing the estimated forecast errors on the forecast returns and the residuals lagged 12 times and is distributed as $\chi^2(12)$ with a calculated value of $TR^2$ (where T represents the number of observations and $R^2$ is the goodness-of-fit statistic of the regression) The test for heteroscedasticity (Het.) consists in regressing the variance of the residuals on the squared forecast returns and is distributed as $\chi^2(1)$ with a calculated value of $TR^2$.

(b) $\alpha_0$ and $\alpha_1$ are the coefficient estimates of a regression of actual futures returns on a constant and the one-step ahead forecast returns. Under rational expectations, $\alpha_0=0$ and $\alpha_1=1$.

(c) $VR_1 = \sigma^2\left(E\left(R_t \quad Z_{t-1}\right)\right)/\sigma^2\left(R_t\right)$, $VR_2 = \sigma^2\left(R_t - E\left(R_t \quad Z_{t-1}\right)\right)/\sigma^2\left(R_t\right)$.

* denotes significant at 1 percent.

does not consider the Treasury-bill return as a description of the variation in expected futures returns.

### 3. Profitability of the Trading Rule

Having estimated *ex-ante* models for the 26 futures contracts and tested the accuracy of the one-step ahead forecasts, we now turn our attention to the issue of market efficiency. In this respect, we test whether the trading rule mentioned above generates abnormal profits.

To assess whether abnormal profits can be generated from the models in table 4.4, we first compare the yearly mean and standard deviation of returns for each trading rule to the yearly mean and standard deviation of returns on a buy and hold strategy that consists in being long in the futures market over the period June 1987 to October 1996. The yearly means and standard deviations of returns from the trading rule and the passive investment strategy are pictured in figures 4.1 and 4.2 respectively. A summary statistics of the results from the trading rules for the 26 futures contracts and the passive buy and hold strategies is also provided in table 4.7.

It is clear from figures 4.1 and 4.2 that the total risk associated with the trading rule is of similar amplitude as the total risk born when passively holding the futures contract. If the EMH holds, one should expect returns to be commensurate to the risk born. In other words, the return on the trading rule and on the passive investment strategy should be of similar amplitude. This is however not always the case. In 7 cases out of 26 (soybeans, soybean meal, soybean oil, gold, silver, platinum, and Treasury-bill), the return on the trading rule exceeds the return on the buy and hold strategy by at least 4 percent. Even more striking is the result for the trading strategy on silver futures contract, where the difference between the yearly mean return on the trading rule and the yearly mean return on the buy and hold strategy peaks at 9.81 percent. For the remaining contracts, following the trading rule yields a return that is either inferior or similar to the return on the alternative of passively holding the futures contract.

Table 4.7 also reports estimates of the measure of abnormal performance $\alpha$ for the multifactor model (4.2), along with the yearly abnormal returns, with and without transaction costs. The results are mainly consistent with the analysis performed above. The trading rules that offered a return in excess of the level of total risk usually exhibit positive and significant Jensen's alphas. In particular, the trading rule consistently generates positive and significant abnormal profits for the futures contracts on soybeans, soybean oil, and gold. The abnormal returns equal 11.51, 12.3, and 5.94 percents per year respectively, while the difference between the yearly mean return on the trading rule and the yearly mean return on the buy and hold strategy for similar level of total risk equal 8.9, 7.3, and 8.1 percents. Hence, at least as far as these futures contracts are concerned, the evidence seem to indicate that the futures markets under investigation are weak-form inefficient.

The evidence are not so clear-cut for the trading rule on lumber. The abnormal measure of performance in the context of the five factor model indeed indicates that the trading rule does not generate any statistically significant abnormal return. However the yearly abnormal return equals 13.11 percent and is therefore significant in economic terms. Similar conclusions apply to the trading rule on corn, soybean meal, wheat, lean hogs, pork bellies, and silver futures contract. The yearly abnormal returns, although statistically insignificant, appear fairly large (they exceed 5 percent per year). Hence it seems reasonable to say that the trading rule might also generate a return that is in excess of the level of the systematic risk of the portfolio for these futures contracts. On the other hand, the evidence for the 16 remaining, principally financial, contracts indicate that the measures of abnormal performance are either fairly small or even negative.

In an attempt to assess the impact of transaction costs on the profitability of the trading rule, we estimate the number of transactions that need to be implemented to perform the investment strategies. Across the 26 futures contracts, an average of 39 transactions out of 113 forecasts had to be implemented for each trading rule. This means that on average the portfolios need to be rebalanced approximately every three months. Note that there are some discrepancies across futures: while seven transactions only were required to

Figure 4.1: Plot of Yearly Mean Returns for the Trading Rule and the Buy and Hold Strategy

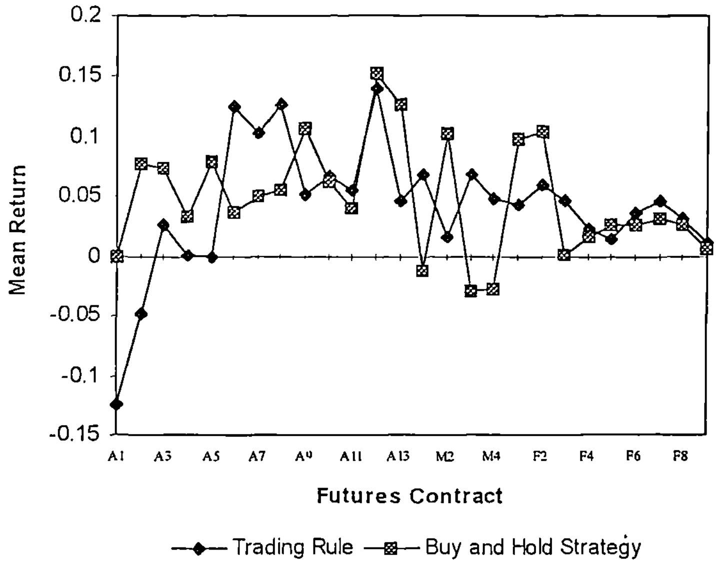
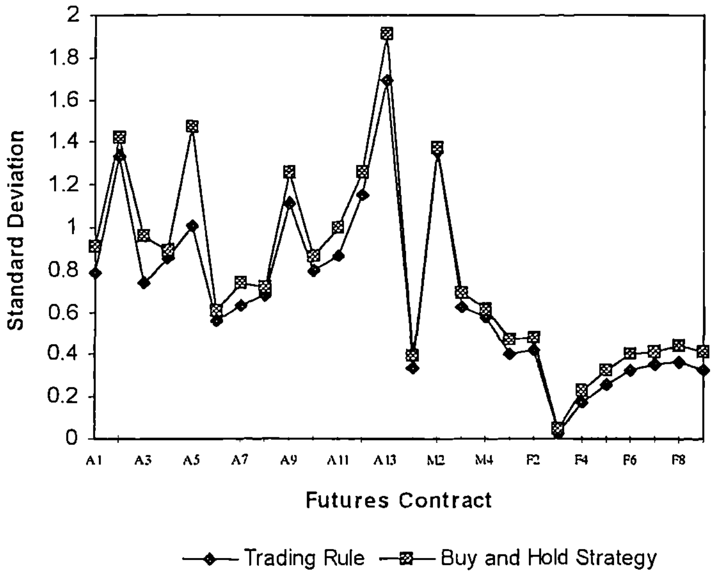


Figure 4.2: Plot of Yearly Standard Deviation of Returns for the Trading Rule and the Buy and Hold Strategy



## Table 4.7 : Abnormal Performance

| | Yearly Mean and SDev | | | | Multifactor Model | | Yearly | Abnormal |
|---|---|---|---|---|---|---|---|---|
| | Trading Rule | | Buy-Hold Strategy | | Jensen's α | t-ratio | Abnormal Return | Return Net of TCosts |
| | Mean | SDev | Mean | SDev | | | | |
| **Panel A: Agricultural Commodities** | | | | | | | | |
| Cocoa | -0.124 | 0.789 | -0.001 | 0.911 | -0.01** | -1.83 | -13.45% | -15.05% |
| Coffee | -0.049 | 1.332 | 0.077 | 1.426 | -0.006 | -0.54 | -6.87% | -8.30% |
| Corn | 0.026 | 0.741 | 0.074 | 0.962 | 0.006 | 0.79 | 7.19% | 6.95% |
| Cotton | 0.001 | 0.853 | 0.033 | 0.896 | -0.001 | -0.18 | -1.46% | -2.26% |
| Oats | <0.001 | 1.010 | 0.080 | 1.471 | -0.001 | -0.10 | -0.98% | -1.50% |
| Soybeans | 0.125 | 0.553 | 0.036 | 0.610 | 0.010* | 2.17 | 11.51% | 10.54% |
| Soybean Meal | 0.103 | 0.631 | 0.050 | 0.740 | 0.008 | 1.51 | 9.12% | 8.06% |
| Soybean Oil | 0.128 | 0.679 | 0.055 | 0.717 | 0.01** | 1.89 | 12.30% | 11.59% |
| Sugar | 0.052 | 1.117 | 0.107 | 1.263 | 0.004 | 0.41 | 4.25% | 2.98% |
| Wheat | 0.068 | 0.802 | 0.063 | 0.868 | 0.005 | 0.79 | 5.90% | 4.87% |
| Lean Hogs | 0.055 | 0.863 | 0.040 | 0.998 | 0.004 | 0.62 | 5.04% | 3.83% |
| Lumber | 0.140 | 1.158 | 0.153 | 1.259 | 0.011 | 1.19 | 13.11% | 11.87% |
| Pork Bellies | 0.047 | 1.692 | 0.127 | 1.915 | 0.005 | 0.36 | 5.75% | 4.97% |
| **Panel B: Metal and Oil Commodities** | | | | | | | | |
| Gold | 0.069 | 0.333 | -0.012 | 0.394 | 0.005** | 1.90 | 5.94% | 3.94% |
| Heating Oil | 0.016 | 1.357 | 0.102 | 1.372 | 0.001 | 0.09 | 1.18% | -0.04% |
| Silver | 0.069 | 0.628 | -0.029 | 0.692 | 0.005 | 0.96 | 5.77% | 4.22% |
| Platinum | 0.048 | 0.581 | -0.028 | 0.616 | 0.003 | 0.62 | 3.44% | 1.97% |
| **Panel C: Financial** | | | | | | | | |
| NYSE | 0.043 | 0.407 | 0.099 | 0.470 | 0.002 | 0.62 | 2.38% | 0.37% |
| SP500 | 0.060 | 0.423 | 0.106 | 0.482 | 0.004 | 1.12 | 4.49% | 2.55% |
| Treasury-Bill | 0.048 | 0.031 | 0.001 | 0.049 | <0.001 | -0.50 | -0.10% | -0.36% |
| Treasury-Note | 0.023 | 0.173 | 0.016 | 0.228 | <0.001 | -0.35 | -0.53% | -1.55% |
| Treasury-Bond | 0.015 | 0.261 | 0.026 | 0.327 | -0.001 | -0.31 | -0.73% | -2.02% |
| Deutsch Mark | 0.037 | 0.329 | 0.026 | 0.400 | 0.002 | 0.82 | 2.57% | 1.40% |
| Japanese Yen | 0.047 | 0.357 | 0.032 | 0.414 | 0.002 | 0.83 | 2.75% | 2.38% |
| Swiss Franc | 0.032 | 0.368 | 0.027 | 0.438 | 0.002 | 0.62 | 2.15% | 1.03% |
| UK Pound | 0.011 | 0.325 | 0.007 | 0.413 | -0.001 | -0.36 | -1.10% | -2.88% |

* denotes significant at 5 percent.
** denotes significant at 10 percent.

implement the trading rule for the Treasury-bill futures contract,[8] the trading rule on the gold futures contract required 72 rebalancings of the portfolio. We assume a two-way transaction cost of 0.15 percent in the futures market and a round trip transaction cost of 0.5 percent in the treasury bill market.[9] If we further suppose that the strategy recommends to invest in futures markets in 50 percent of the cases, the total cost of revising the strategy over the period June 1987 to October 1996 amounts to an average of 11.22 percent of the aggregate value of the position in the futures or Treasury-bill market. Hence, the yearly abnormal returns displayed in table 4.7 have to be reduced by an average of 1.19 percent to obtain the yearly abnormal returns net of transaction costs.

The last column of table 4.7 displays the yearly abnormal returns net of transaction costs. In the cases of the three contracts that clearly exhibit abnormal returns (soybeans, soybean oil, and gold), the actual transaction costs equal 0.97, 0.72, and 2.0 percents per year respectively. The risk and transaction cost-adjusted abnormal returns exceed 10 percent per year for the futures on soybeans and soybean oil. They remain therefore economically significant, even after accounting for transaction costs. On the other hand, little abnormal returns can be earned on the trading rule for gold on a risk and transaction costs adjusted basis. The measure of abnormal performance net of transaction costs for gold is indeed less than 4 percent.

In sum, as far as the futures on soybeans and soybean oil are concerned, a fund manager pursuing our active investment strategy could perform on a risk-adjusted and transaction-cost adjusted basis better than a fund manager pursuing a passive investment strategy that aims at tracking the market or taking a long position in the futures. With respect to the 24 remaining futures contracts, it appears that a trading rule exploiting past information cannot be used consistently to generate excess returns once adjustments for risk and

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[8] The trading rule recommends a long position in the one-month Treasury bill in 94 percent of the cases.

[9] Norman and Annandale (1991) actually estimate that the round-trip transaction costs for trading the FTSE-100 futures contract equal 0.116 percent. Since some futures might not be as liquid as the FTSE-100 futures contract, we consider a conservative 0.15 percent transaction cost in futures markets. Jegadeesh (1990) considers a two-way transaction costs of 0.5 percent for trading securities. We assume here that the transaction costs in the equity market approximately equal the transaction costs in the Treasury bill market.

transaction costs are taken into account. The evidence therefore indicates that futures markets are predominantly weak-form efficient: futures prices incorporate available information so quickly that it is not possible to "beat the market" by following a trading rule based on past information.

### 4. Alternative Explanation

The possibility however remains that the presence of abnormal returns for some futures contracts reflects some kind of misspecification in the multifactor model. If betas are time-varying, while we assume they are constant, the estimates of $\alpha$ in equation (4.2) might be biased. Hence, assuming constant betas could lead to incorrect rejection of the null hypothesis of no abnormal return.

Table 4.8 reports estimates of the size and significance of the trading rule abnormal returns after accounting for time-varying risk. With respect to the trading rules that exhibit abnormal performance in table 4.7 (soybeans and soybean oil), the results in table 4.8 indicate that, when risk is allowed to be time-varying, the returns are proportionate to the risk born. Hence, the estimates of the measures of abnormal performance in table 4.7 were biased which lead us to the misleading conclusion that the soybeans and soybean oil futures markets were weak-form inefficient. With regards to the other contracts, the trading rule does not seem to generate any abnormal return either. Note however that the large standard errors in table 4.8 make it difficult to reject the null hypothesis of no abnormal returns. This point aside there does not seem to be any abnormal return when risk changes are controlled for.

## VI. Conclusions

In this chapter we test the hypothesis that the predictable variation in futures returns is consistent with rational pricing in an efficient market. In this respect we derive a simple trading rule whose aim is to test the EMH. Since the trading rule implies investing in

## Table 4.8 : Abnormal Performance and Time-Varying Risk

$$u_t = \begin{pmatrix} u2_t & u3_t \end{pmatrix} = \begin{pmatrix} (F_t - Z_{t-1}\gamma)' \\ (R_t - (\alpha + \lambda u2_t R_t))' \end{pmatrix}'$$

| | Intercept | Standard Error | t-ratio |
|---|---|---|---|
| **Panel A: Agricultural Commodities** | | | |
| Cocoa | -0.0241 | 0.6708 | -0.04 |
| Coffee | -0.0298 | 0.4023 | -0.07 |
| Corn | -0.0108 | 0,2144 | -0.05 |
| Cotton | -0.0418 | 0.1950 | -0.21 |
| Oats | -0.0156 | 0.0338 | -0.46 |
| Soybeans | -0.0109 | 0.0810 | -0.13 |
| Soybean Meal | 0.0269 | 0.1038 | 0.26 |
| Soybean Oil | <0.0001 | 0.0340 | 0.00 |
| Sugar | 0.0569 | 0.1433 | 0.40 |
| Wheat | 0.0083 | 0.0255 | 0.32 |
| Lean Hogs | -0.1188 | 2.2133 | -0.05 |
| Lumber | 0.0208 | 0.0783 | 0.27 |
| Pork Bellies | -0.0349 | 0.1500 | -0.23 |
| **Panel B: Metal and Oil Commodities** | | | |
| Gold | -0.0010 | 0.0076 | -0.13 |
| Heating Oil | 0.0131 | 0.0742 | 0.18 |
| Silver | 0.0017 | 0.0117 | 0.15 |
| Platinum | -0.0789 | 0.6155 | -0.13 |
| **Panel C: Financial** | | | |
| NYSE | -0.0017 | 0.0460 | -0.04 |
| SP500 | 0.0018 | 0.0496 | 0.04 |
| Treasury-Bill | <0.0001 | <0.0001 | -0.17 |
| Treasury-Note | 0.0050 | 0.0237 | 0.21 |
| Treasury-Bond | 0.0135 | 0.0463 | 0.29 |
| Deutsch Mark | 0.0090 | 0.0196 | 0.46 |
| Japanese Yen | -0.0023 | 0.0116 | -0.19 |
| Swiss Franc | 0.0058 | 0.0092 | 0.63 |
| UK Pound | 0.0016 | 0.0063 | 0.25 |

tradable securities in the Treasury bill and futures markets, it offers the additional advantage of being a practical investment strategy.

Three criteria are used to investigate the performance of the trading rule. First we compare the mean and standard deviation of returns on the trading rule to the mean and standard deviation of returns on a passive investment strategy that consists in being long in the futures market. Second, we estimate the size and presence of abnormal returns in the context of a multifactor model with constant parameters. Third, we use a conditional multifactor model with time-varying risk to measure abnormal performance. While the two first criteria suggest that the soybeans and soybean oil futures markets are inefficient, the third test indicates that it was not possible to earn a time-varying risk adjusted return by actively trading futures contracts over the period June 1987 to October 1996. This result is consistent with the evidence from the stock market which suggest that trading rules based on available information fail to generate abnormal returns. We conclude therefore that the predictable movements in futures returns most likely reflect the rational variation in the preferences of economic agents across time.

In the following chapter we investigate the issue of market efficiency further by looking at whether the *ex-ante* variables have parallel effects across futures and are a proxy for the changes in the business cycle. This is to be expected if the predictable variation in futures returns mirrors the rational changes in investors' opportunity set over time.

# Chapter V: Economic Activity and Time Variation in Expected Futures Returns

## I. Introduction

The question we address in this chapter is similar to the issue we investigated in the previous chapter. Our interest is still to analyse whether the variation through time in expected returns documented in chapter IV reflects rational pricing in an efficient market or is the result of weak-form market inefficiency. Our perspective however differs. The issue is now investigated with respect to the hypotheses that the variation through time in expected returns is common across futures markets and is related to business conditions.

The first question we address looks at whether the forecasting variables have parallel effects across a wide cross section of futures. If the predictable movements in returns reflect the rational change in the consumption-investment opportunity set over time, the futures risk premia should move together (see, for example, Fama and French (1989)). The second issue we investigate focuses on the relationship between the time-varying futures risk premia and the business cycle. If markets price futures contracts rationally, it can be alleged that the information variables forecast futures returns because they are an indicator of the health of the economy. The general message is thus as follows: if the predictable movements in futures returns reflect changes in the business cycle and the *ex-ante* variables predict returns across a wide cross section of futures, this will be an indication that the predictability of returns is consistent with rational pricing in an efficient market. On the other hand, if the variation in expected returns is not common across futures and the *ex-ante* variables are not proxies for economic activity, there might be some concern onto the issue of market efficiency.

This chapter therefore models the link between the time-variation in expected futures returns and the economy. Our interest in this issue stems from the fact that, by studying the relationship between real activity and time-varying expected futures returns, we hope to get a better understanding of the way futures prices are set. Our concern in this question also comes from the fact that studies of the relationship between the predictable movements in returns and economic activity only focus on stocks and bonds returns. No attempt has ever been made so far to extend the link between the real economy and the time-varying expected returns identified in the stock and bond markets to any other markets. The contribution of this chapter is unique in this respect.

In relation to this, we address the following questions:

(1) Do the futures risk premia move in tandem? In particular, does the restriction of common variation in expected returns hold for a wide cross section of futures?
(2) Do the information variables predict futures returns because of their ability to proxy for the business cycle?
(3) Is the pattern of forecastability in futures markets consistent with the evidence from the stock and bond markets and with theoretical explanations of the trade-off between risk and expected returns?

As evidenced hereafter, this chapter raises some interesting questions that have not been evidenced in the literature on the predictability of stock and bond returns. In anticipation of our results, we demonstrate that, while the relationship between economic activity and the predictable movements in stock, bond, and metal futures returns is consistent with the evidence from the stock and bond markets and with extant economic theories, the evidence do not extend to other futures, such as currency and agricultural commodity futures. Instead of having a traditional countercyclical pattern, the expected returns on these futures follow the ups and downs of the business cycle. Some further theoretical work is needed to account for this “anomaly”.

The rest of the chapter is organised as follows. Section II briefly reviews the literature on the relationship between time-varying expected stock and bond returns and economic wealth. Section III presents some primary evidence of common variation in expected futures returns. Section IV studies the ability of the state variables to forecast economic activity. Section V splits the cross section into procyclical and countercyclical futures and investigates the common variation in expected returns within each group. Finally section VI concludes.

## II. Expected Stock and Bond Returns and Economy Health: A Review

If the predictability of returns mirrors the rational change in investors' opportunity set over time, the variation through time in expected returns should be common across markets. The evidence suggest that the idea that returns are predictable prevails across a wide cross section of assets. For example, dividend yield, commonly used to forecast stock excess returns, has forecast power in the bond market and variables issued from the bond market, such as the Treasury bill return, term and default spreads predict equity excess returns. Likewise, dividend yield, the Treasury bill return, and the spread between risky and riskless bond yields track variation in expected currency and commodity futures (Keim and Stambaugh (1986), Campbell (1987), Fama and French (1989), and Bessembinder and Chan (1992)). Hence, as implied by the EMH, the same set of information variables predicts returns across a wide cross section of assets.

Another way to account for the predictability of returns in terms of market efficiency is to analyse whether the variation in expected returns is related to business conditions (as measured by the rate of growth in GNP). It appears that dividend yield and default spread take on low values when business conditions are good and will continue to ameliorate in the next two quarters (see, for example, Fama and French (1989) or Chen (1991)). This suggests that dividend yield and default spread proxy for short-term variation in the business cycle. In contrast, the level in the one month Treasury-bill and the term structure of interest rates predict future economic health. More precisely, lower Treasury bill rates and a steeper slope of the yield curve indicate better business activity up to at least 4 quarters ahead (see, for example, Chen (1991) and Estrella and Hardouvelis (1991)). In short, the evidence presented in these studies suggest that lower than average dividend yield and default spread indicate short-term economic growth, while a lower than average Treasury bill rate and a higher than average term spread announce good economic prospects in the future. It follows therefore that there is a link between the predictive power of the state variables and economic activity.

Since they predict immediate and future economic activity, it can be argued that the state variables forecast stock and bond excess returns because of their ability to proxy for short and long-term changes in the business cycle. Testing this hypothesis, Chen (1991) shows that expected stocks returns decrease under the influence of dividend yield and default spread when short-term economic conditions are good and increase in the long run under the influence of Treasury bill and term spread when future economic prospects are good. Since besides stock returns are negatively related to current economic growth and positively related to expected future economic growth, dividend yield and default spread track variation in expected returns because they predict the current health of the economy. Similarly, the term structure of interest rates and the one-month Treasury bill predict stocks excess returns because they are indicators of the future health of the economy. In sum, the state variables predict stocks and bonds excess returns because of their ability to track short and long-term changes in the business cycle.

These evidence are consistent with extant economic theories. For example, the fact that expected returns move opposite to short-term business conditions is consistent with risk aversion and the general trade-off between risk and expected returns implicit in the literature on asset pricing: Since the risks the instruments are proxying for is higher during recessions and lower during periods of expansion, risk averse investors require higher returns when economic conditions are poor and lower returns when economic conditions are good.

As an alternative explanation, the negative association between short-term business conditions and expected market returns supports the predictions of the consumption smoothing theory: When the economy is strong and hence income is high, investors wish to smooth consumption into the future by saving more. Other things being equal, the resulting increase in the demand for savings pushes expected returns downward. Hence, when the macroeconomic environment is safer, investors require a lower return on their investment. Similarly, when business conditions are low, income is low and expected returns are high to deter economic agents from consumption and into investment. An increase in risk causes investors to try and avoid the risk by substituting out of risky assets and into current consumption, thereby driving the price of risky assets down and raising the required rate of return.

So far we demonstrated that economic theory predicts a negative relationship between short-term economic activity and expected returns. The evidence presented in Chen (1991) of a positive relationship between future economic conditions and expected returns is also consistent with the general equilibrium model of stock and bond prices derived by Abel (1988). Using a Lucas (1978) asset pricing framework and assuming that the mean and measure of volatility of dividends (or of industrial production) evolve stochastically over time, Abel derives an expression of the expected market premium $E_t\left(R_{t+1}^M - R_{t+1}^F\right)$ that depends upon (1) the expected value of future production (or dividends) $\mu_t$, (2) the volatility of future production $\upsilon_t$, and (3) the most recent level of industrial production $y_t$. Most specifically, with a logarithmic utility function,

$$E_t\left(R_{t-1}^M - R_{t+1}^F\right) = \beta^{-1}\left(\mu_t / y_t\right)\frac{\upsilon_t^2}{1+\upsilon_t^2}$$

where $\beta^{-1}$ is a discount factor (Abel (1988), equation (40)). Consistent with the evidence presented in Chen (1991), better future economic prospects (i.e., an increase in $\mu_t$) indicate higher expected market risk premium. Stated differently, since securities are claims against future output, an expected increase in the productivity of capital (namely, a positive technological shock $\mu_t$) is expected to raise future output and future operating profits, thereby stimulating investment and bidding up expected market returns.

Simultaneously, economic agents will be willing to substitute current for future consumption, thereby bidding up interest rates. Hence better future economic prospects signal higher expected stock and bond returns.

Since it is common to many assets, reflects the change in the business cycle, and is consistent with traditional asset pricing models, the predictable variation in stock and bond returns probably mirrors the rational change in the preferences of economic agents for consumption versus investment. While most of the literature examines the link between economic activity and the time-varying risk premia present in the stock and bond markets, the relationship between the predictable movements in futures returns and the change in business conditions has never been investigated. The purpose of this article is to test whether the evidence from the stock and bond markets can be extended to the futures markets. This should give us some valuable insight as to whether the variation in expected futures returns supports the EMH.

## III. Evidence of Common Variation in Expected Futures Returns: A First Look

In chapter IV we present convincing evidence that futures returns are predictable using information available at time t-1. In this purpose the following regression was estimated

$$R_{it} = \alpha_{i0} + \alpha_{ij} Z_{jt-1} + \varepsilon_{it} \tag{5.1}$$

where $R_{it}$ is the time t realised return on the $i^{th}$ futures contract, $Z_{jt-1}$ is the j *ex-ante* variable used by investors to form expectations of the futures price one period ahead, $\varepsilon_{it}$ is a vector of error terms, and $\alpha_{i0}$ and $\alpha_{ij}$ are the estimated parameters. To test the hypothesis that the variation in expected futures returns is common across assets, we now constraint the coefficients on the *ex-ante* variables in (5.1) to be the same across equations and test the hypothesis that the restrictions are valid. Hence the following model is estimated

$$R_{it} = \alpha_{i0} + \alpha_j Z_{jt-1} + \varepsilon_{it} \tag{5.2}$$

and the restrictions that $\alpha_{ij} = \alpha_j$ ($\forall i$, $i=1,\ldots,26$; $\forall j$, $j=1,\ldots,5$) is tested by comparing the difference in the likelihood ratios of the restricted and unrestricted models to a $\chi^2$ table with degrees of freedom equal to the difference in the number of parameters between the two models. The system of equations is estimated through SUR allowing hence for some across equation correlations in the residual covariance matrix.

The estimates of the parameters $\alpha_j$ from equation (5.2) are displayed in table 5.1. The estimate of the coefficient on default spread is significant at 10 percent. When common cross sectional variation is imposed, the other *ex-ante* variables do not seem to have any significant impact on expected returns. In the previous chapter, we took special care of addressing the problem of multicollinearity that might result from the high correlation between the Treasury-bill and the other *ex-ante* variables and concluded that the *ex-ante* model that excludes the Treasury-bill from the information set should be favoured as a description of the time variation in expected futures returns. We believe therefore that the insignificance (or the marginal significance) of the estimated coefficients in table 5.1 does not result from a problem of multicollinearity.

We finally test the hypothesis that the slope coefficients can be restricted to be the same across equations. This results in a $\chi^2$ calculated value of 162 with 125 degrees of freedom (p-value of 0.014). Hence the constraints are only accepted at the 1 percent level and are rejected at any other level of statistical significance. This suggests that the restricted model (5.2) might impose non valid restrictions on the *ex-ante* model (5.1). This result is not encouraging in terms of the EMH since it indicates that the information variables do not track changes in expected returns that are common to all the assets considered in this study. The futures risk premia do not seem to move together.

# Table 5.1: Common Variation in Expected Futures Returns

$$R_{it} = \alpha_{i0} + \alpha_j Z_{jt-1} + \varepsilon_{it}$$

| *Ex-Ante* Variable | Estimate | Standard Error | t-ratio |
|---|---|---|---|
| Dividend Yield | 0.0006 | 0.0004 | 1.31 |
| Default Spread | 0.0024* | 0.0014 | 1.73 |
| Return on the Standard & Poor's Composite Index | -0.0005 | 0.0072 | -0.06 |
| Term Spread | -0.0005 | 0.0003 | -1.56 |
| Return on the Dow-Jones Commodity Index | 0.0047 | 0.0109 | 0.43 |

* denotes significant at 10 percent.

## IV. The State Variables as Proxies for the Business Cycle

To understand more about this rejection, we turn our attention to the hypothesis that the predictable variation in futures returns reflects the change in the business cycle. In this purpose we first look at the hypothesis that the information variables are indicators of the health of the economy and use the yearly change in industrial production as a proxy for the business cycle[1]. In this respect, we plot the yearly change in industrial production against each of the *ex-ante* variables lagged once. Figures 5.1 to 5.5 offer a visual representation of the predictive power of the *ex-ante* variables over the yearly change in industrial production. We then measure the correlation between the lagged state variables and the yearly change in industrial production. As a more formal test of the relationship between economic activity and the information variables, table 5.2 finally reports estimates of univariate regressions of the yearly change in industrial production on the lagged *ex-ante* variables. The evidence presented in this section are consistent with the conclusions exposed in Fama and French (1989), Chen (1991), and Estrella and Hardouvelis (1991)).

The plots in figure 5.1 indicate that default spread takes its highest values during the 1982 recession and its lowest values during the period of economic growth that followed. Leaving aside the period January 1988 to September 1988, the spread between low and high grade bond yields generally increases when the economy is weak and decreases when the economy is strong. Figure 5.2 reports similar results for dividend yield. With relatively few exceptions (essentially over the periods January 1989 - August 1989 and June 1990 - June 1991), dividend yield exhibits a similar countercyclical pattern: an above average dividend yield indicates that the economic activity one period ahead will be below average. With one main outlier (that corresponds to the October 1987 crash), similar conclusions apply to the return on the Standard & Poor's composite index too (see figure 5.3). Consistent with the above, the yearly change in industrial production has

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[1] The choice of the monthly year-on-year change in industrial production as a measure of the business cycle was governed by the fact that, with longer lags, we might by-pass some business cycles; while, with shorter lags, we might end up picking up short-term variation in industrial production, instead of long-term economic health (see Chen (1991)).

a negative correlation with the lagged dividend yield, the lagged default spread, and the lagged return on the Standard & Poor's composite index. These correlations are respectively equal to -0.24, -0.34, and -0.19 over the period July 1982 to October 1996.

This pattern is consistent with the intuition that default spread, dividend yield, and the Standard & Poor's returns are proxies for the riskiness of the business cycle. In periods of economic uncertainty (i.e., when income is low), risk-averse investors require a relatively higher premium for holding risky assets. Other things being equal, the resulting decrease in the demand for risky assets bids up the yields on relatively risky bonds, the dividends on stocks, and the return on the market as a whole. Simultaneously, the relative increase in the demand for Treasury bonds pushes down the yield on government securities; leading to a widening of the spread between low and high grade bond yields. Likewise, when economic prospects are good (and income is high), investors are more willing to invest in risky assets. The resulting increase in the demand for risky assets explains why the spread between low and high grade bonds, dividend yield, and the return on the Standard & Poor's tend to decrease.

In contrast, figure 5.4 suggests that the term structure of interest rates closely mirrors the ups and downs of the business cycle. The correlation between the yearly change in industrial production and the lagged term spread, equal to 0.37, confirms this first impression. This suggests that the spread between the yields on long- and short-term government bonds rises during business expansions and falls during economic recessions. Finally there does not seem to be any consistent pattern between the Dow-Jones commodity returns and  the yearly change in industrial production in figure 5.5. The correlation between these two variables is also marginal (0.02).

Estrella and Hardouvelis (1991) illustrate why monetary policy can partly explain the positive association between the yearly change in industrial production and the term structure of interest rates. They argue that a monetary contraction lasting over a short period of time rises short-term interest rates, while leaving the level of long-term interest rates mostly unchanged. Simultaneously, the increase in short-term interest rates results in fewer investment opportunities and in lower economic activity. Hence a short-term monetary contraction can induce both a flattening of the yield curve and a period of recession. Likewise, real business cycle models posit a positive response of future economic activity to the term spread. The rationale behind this association is that future positive technology shocks increase future output and induce economic agents to postpone consumption into the future, thereby bidding up long-term interest rates. Simultaneously there is a negative association between short-term interest rates and future economic growth.[2] A positive future productivity shock therefore induces a widening of the spread between long- and short-term interest rates. Stated differently, in periods of expansion, the slope of the yield curve steepens (Chen (1991)).

As a sterner test of the hypothesis that the state variables predict economic activity, we finally estimate univariate regressions of the yearly change in industrial production on the *ex-ante* variables lagged once. Hence, for each of the information variable, the following regression is estimated

$$\Delta YIP_t = \alpha_0 + \alpha_1 Z_{t-1} + \varepsilon_t$$

where $\Delta YIP_t$ is the yearly change in industrial production, $Z_{t-1}$ is the state variable under consideration, $\varepsilon_t$ is an error term, and $\alpha_0$ and $\alpha_1$ are the estimated parameters. The coefficients of determination (R-squared) reported in table 5.2 provide an estimate of the proportion of future industrial production explained by each of the state variables. The t-tests of statistical significance indicate whether the estimates are reliable in forecasting future economic activity. The results, similar to Chen's (1991), confirm that the state variables (with the exception of the Dow-Jones commodity returns) have power to forecast economic activity one period ahead. As such, they are indicators of the health of the economy. The goodness of fit statistics are impressive for default and term spreads (11.79 and 13.36 percents respectively). The pattern of predictability is consistent with the idea that dividend yield, default spread, and the Standard & Poor's returns are

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[2] Lower short-term interest rates may indicate (1) lower expected inflation (Chen (1991)) and (2) higher level of investments (Estrella and Hardouvelis (1991)) which in turn could result in better future economic prospects.

Figure 5.1: Default Spread as a Proxy of the Business Cycle

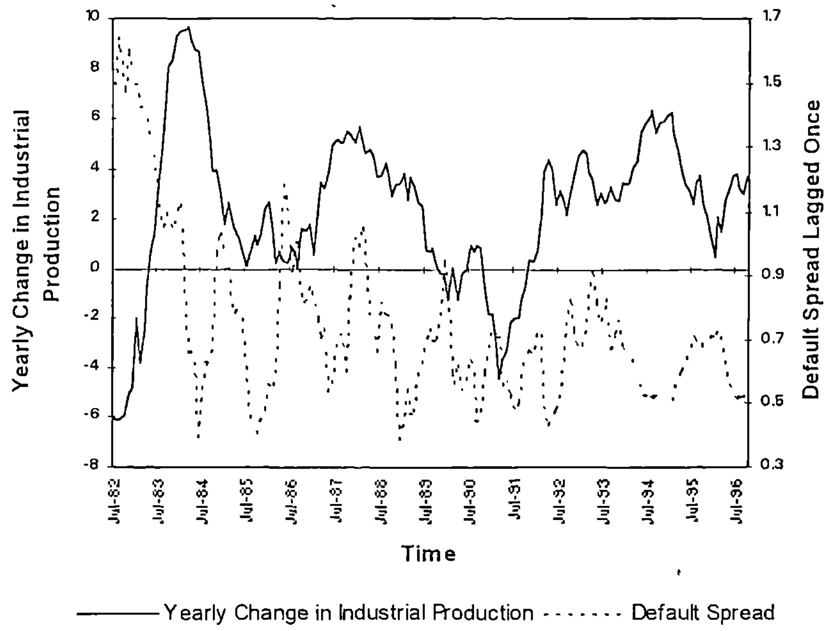


Figure 5.2: Dividend Yield as a Proxy of the Business Cycle

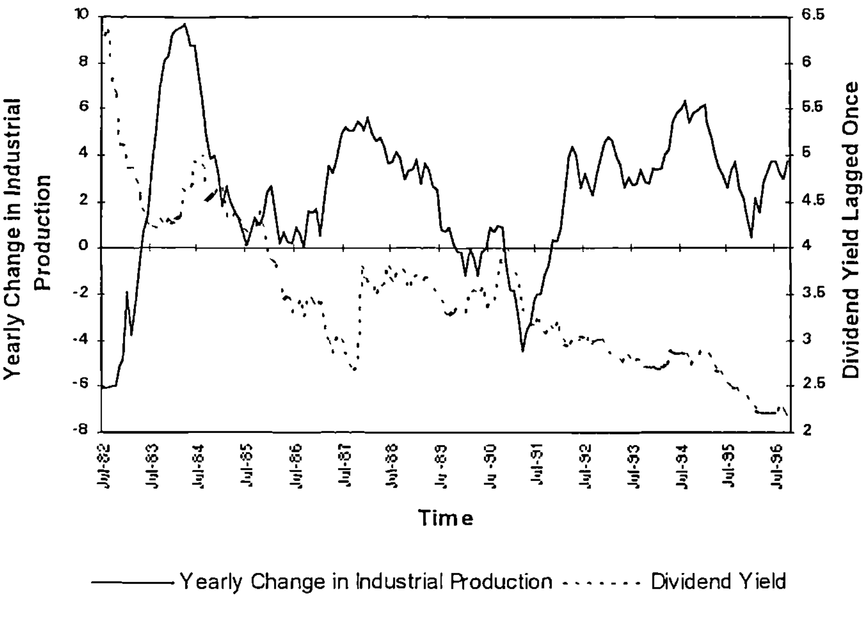


Figure 5.3: The Returns on the Standard and Poor's Composite Index as a Proxy of the Business Cycle

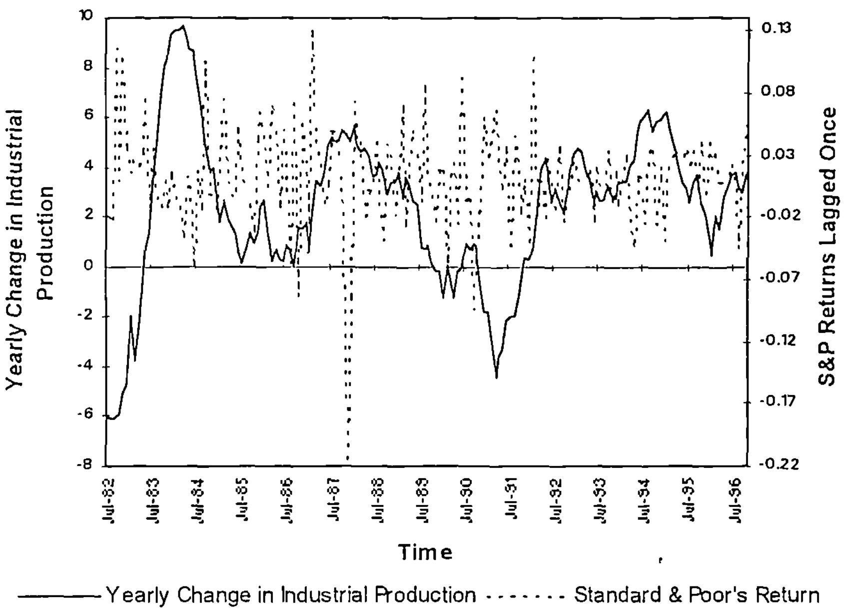


Figure 5.4: Term Structure as a Proxy of the Business Cycle

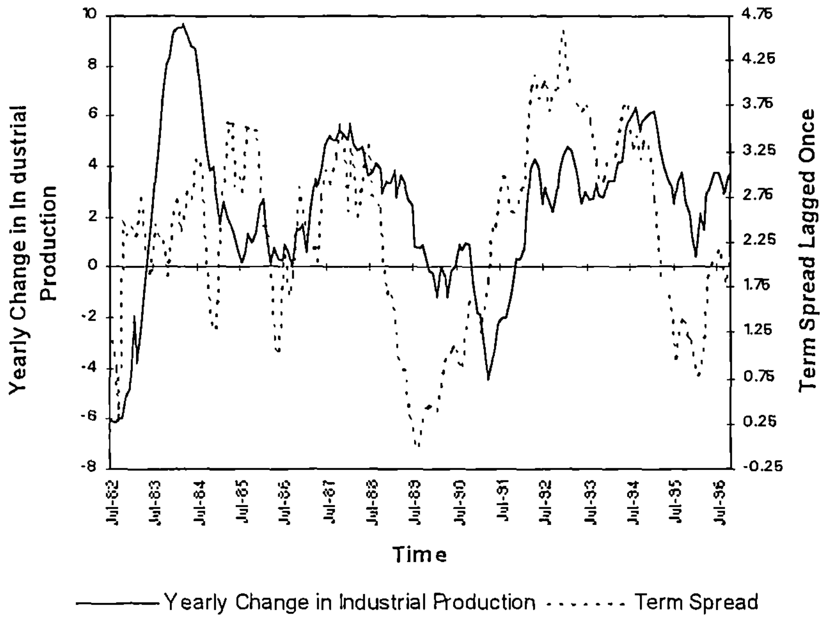
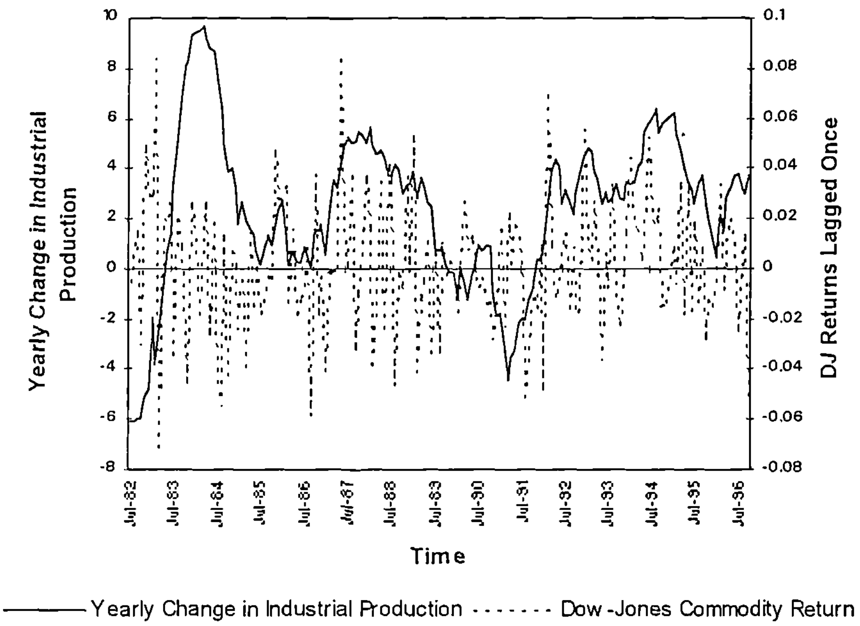


Figure 5.5: The Returns on the Dow-Jones Commodity Index as a Proxy of the Business Cycle



## Table 5.2: The State Variables as Proxies for the Business Cycle:

$$\Delta YIP_t = \alpha_0 + \alpha_1 Z_{t-1} + \varepsilon_t$$

| *Ex-Ante* Variable | Estimate | Standard Error | t-ratio | R-Squared (%) |
|---|---|---|---|---|
| Dividend Yield | -0.9218* | 0.2866 | -3.22 | 5.74. |
| Default Spread | -4.1095* | 0.8620 | -4.77 | 11.79 |
| Return on the Standard & Poor's Composite Index | -14.5189** | 5.6931 | -2.55 | 3.68 |
| Term Spread | 1.1045* | 0.2157 | 5.12 | 13.36 |
| Return on the Dow-Jones Commodity Index | 2.2282 | 8.9268 | 0.25 | 0.04 |

* denotes significant at 1 percent,
** denotes significant at 5 percent.

countercyclical; while the term structure of interest rates follows the ups and downs of the business cycle. In sum, a below average dividend yield, a below average default spread, a below average return on the Standard & Poor's, and an above average term spread indicate that the change in industrial production one period ahead is expected to be above average. On the other hand, the return on the Dow-Jones Commodity index does not seem to have any noticeable power to forecast future economic activity.

## V. Evidence of Common Variation in Expected Futures Returns: A Further Look

To summarise thus far, while the state variables forecast economic activity (table 5.2), they do not have any parallel effect across futures (table 5.1). Since expected futures returns fail to move together, one can reasonably question whether expected futures returns move opposite to short-term economic conditions as hypothesised by asset pricing models and real business cycle fans.

In this respect, we look at the relationship between economic conditions and expected futures returns (measured as the fitted values of a regression of futures returns on the state variables) and estimate the OLS regressions[3]

$$E\left(R_{it} / Z_{t-1}\right) = \alpha_0 + \alpha_1 \Delta YIP_t + \varepsilon_t \qquad (5.3)$$

$E\left(R_{it} / Z_{t-1}\right)$ is the expected return on the $i^{th}$ futures contract conditioned on the information set $Z_{t-1}$, $\Delta IP_t$ is the yearly change in industrial production, $\varepsilon_t$ is an error term, and $\alpha_0$ and $\alpha_i$ are the estimated parameters. Table 5.3 displays the OLS estimates of the sensitivities of expected futures returns to the yearly change in industrial production. These estimates are negative and statistically significant for stock index, interest rate, and

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[3] Estimating (5.3) through SUR would yield identical estimates of the parameters than OLS, even if the residuals are correlated across equations. This follows from the fact that (5.3) does not impose any restriction across equations and considers the same right-hand-side variable in every equation (see Burmeister and McElroy (1988)).

## Table 5.3: The Sensitivity of Expected Futures Returns to the Business Cycle

$$E\left(R_{it} / Z_{t-1}\right) = \alpha_{0} + \alpha_{1} \Delta YIP_{t} + \varepsilon_{t}$$

| Expected Return on | Estimate | Standard Error | t-ratio |
|---|---|---|---|
| **Panel A: Agricultural Commodities** | | | |
| Cocoa | -0.0003 | 0.0002 | -1.22 |
| Coffee | 0.0022* | 0.0004 | 5.98 |
| Corn | -0.0002 | 0.0002 | -0.75 |
| Cotton | 0.0002** | 0.0001 | 2.06 |
| Oats | 0.0014* | 0.0003 | 4.69 |
| Soybeans | 0.0006 | 0.0004 | 1.59 |
| Soybean Meal | 0.0014* | 0.0004 | 3.57 |
| Soybean Oil | 0.0004 | 0.0004 | 1.18 |
| Sugar | 0.0015* | 0.0004 | 3.52 |
| Wheat | 0.0009* | 0.0002 | 4.97 |
| Lean Hogs | -0.0001 | 0.0003 | -0.24 |
| Lumber | -0.0009** | 0.0004 | -2.02 |
| Pork Bellies | -0.0017* | 0.0006 | -2.83 |
| **Panel B: Metal and Oil Commodities** | | | |
| Gold | -0.0007* | 0.0003 | -2.26 |
| Heating Oil | <0.0001 | 0.0005 | 0.06 |
| Silver | -0.0015* | 0.0005 | -2.74 |
| Platinum | -0.0007*** | 0.0004 | -1.97 |
| **Panel C: Financial** | | | |
| NYSE | -0.0009* | 0.0002 | -3.96 |
| SP500 | -0.0008* | 0.0002 | -3.69 |
| Treasury-Bill | -0.0002* | <0.0001 | -5.14 |
| Treasury-Note | -0.0001 | 0.0002 | -0.91 |
| Treasury-Bond | -0.0001 | 0.0002 | -0.34 |
| Deutsch Mark | 0.0006* | 0.0002 | 3.65 |
| Japanese Yen | 0.0006* | 0.0002 | 3.96 |
| Swiss Franc | 0.0005* | 0.0001 | 3.64 |
| UK Pound | 0.0006* | 0.0002 | 3.84 |

* denotes significant at 1 percent.
** denotes significant at 5 percent.
*** denotes significant at 10 percent.

metal futures and mainly positive and significant for agricultural commodities and currency futures. Hence, during business troughs, the returns on stock index, interest rate, and metal futures are expected to rise, while the returns on commodities and currency futures are expected to fall:

The results for commodity and currency futures are inconsistent with extant economic theories that predict a negative relationship between short-term economic conditions and expected returns. For example, according to the general belief regarding the trade-off between risk and return, the poorer the economy, the higher expected returns. Hence expected returns should increase during recessions and decrease during periods of economic expansion. The consumption smoothing theory also predicts a negative association between expected returns and short-term economic activity. When business conditions are poor, income is low and economic agents tend to favour consumption over investment. The resulting decrease in the demand for risky assets drives the price of risky assets down and raises their required rate of return. Similarly, during business peaks, income is high and economic agents are willing to smooth consumption into the future. Other things being equal, the resulting increase in the demand for savings pushes expected returns downwards.

The results in table 5.3 however indicate that, while stock index, interest rate, and metal futures follow a clear countercyclical pattern, the returns on commodity and currency futures tend to follow the ups and downs of the business cycle. In figures 5.6 and 5.7, we plot the relationship between economic activity and the expected returns on two futures. The first one, the three-month Treasury bill futures, is clearly countercyclical, while the second one, the futures on coffee, exhibits a distinct procyclical pattern.[4] It is clear from these figures that, while the expected return on the Treasury-bill futures is negatively correlated with economic performance (correlation coefficient of -0.37), the expected return on coffee futures follows the business cycle (correlation coefficient of 0.42).

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[4] The choice of these two contracts was dictated by the fact that the sensitivities of expected returns to the yearly change in industrial production (in table 5.3) be significant at the 1 percent level.

Figure 5.6: Expected Return on the Treasury Bill Futures and the Business Cycle: Result from the Countercyclical Group

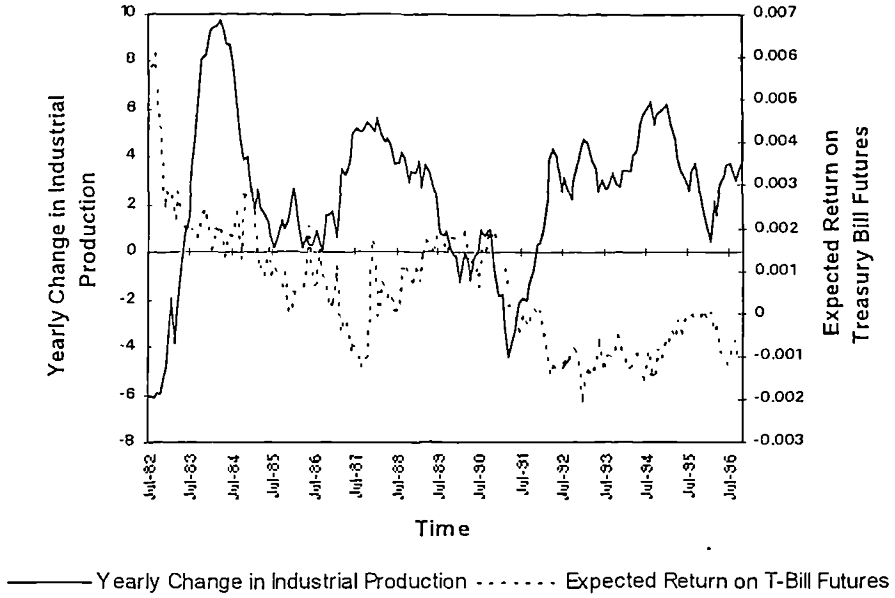
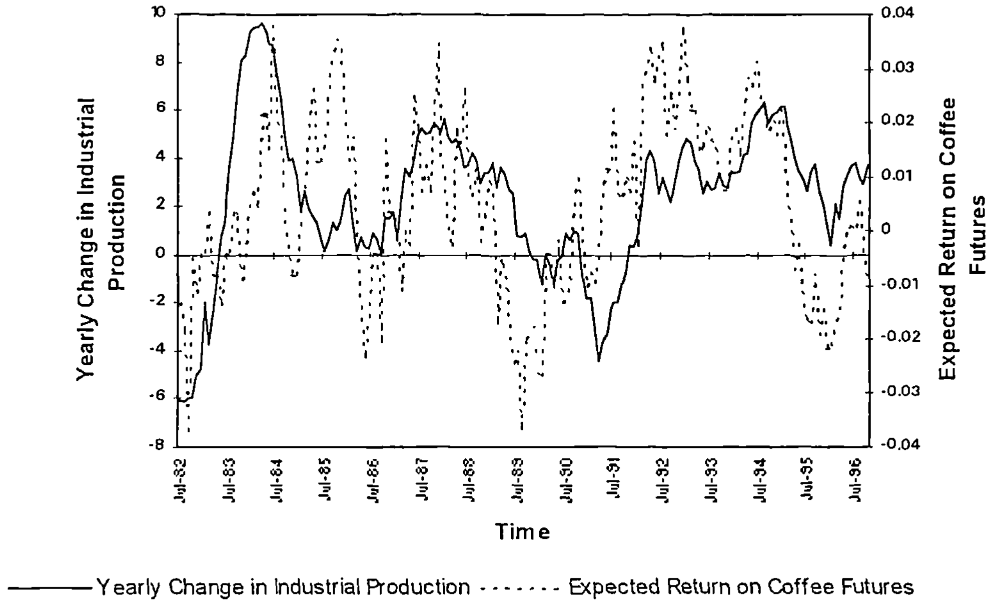


Figure 5.7: Expected Return on Coffee Futures and the Business Cycle: Result from the Procyclical Group



On the basis of these results, one can reasonably postulate that the rejection of the cross sectional restrictions in table 5.1 reflects the fact that some futures are procyclical. As such, their return is expected to decrease in periods of economic uncertainty and increase during business peaks. To investigate this assumption further, we split the sample of futures contracts into two subsamples. The first one includes countercyclical futures and the second one considers procyclical futures. The decision to include a futures in either group is dictated by the sign of the coefficients in table 5.3. Therefore a futures contract is included in the procyclical (countercyclical) sample if its expected return follows (is inversely related to) the business cycle.

We then look at the mean correlation in expected returns across groups and within a group. The mean correlations within groups equal 0.15 and 0.43 for the countercyclical and procyclical groups respectively. The mean correlation across group is negative and equal to -0.03. There are therefore some convincing evidence that expected returns move together within a group (the presence of comovements in expected returns is particularly striking for the procyclical group). On the other hand, there does not seem to be any covariation in expected returns across groups. A finding of a negative mean correlation across groups is consistent with the hypothesis that the expected return on countercyclical futures increases during business contractions; namely, when the expected return on procyclical futures decreases. However, since the estimate is small in absolute terms, we believe that some further tests are needed before any definite conclusions regarding the relationship between expected returns and economic activity can be drawn.

As a further robustness check, we estimate univariate regressions of each group of futures returns on the *ex-ante* variables and impose common variation in expected returns across equations. For each group of futures, the estimates of the parameters $\alpha_j$ from equation (5.2) are displayed in table 5.4. Panel A focuses on the countercyclical futures and panel B summarises the results for the procyclical futures. For comparison purpose with the results from the equity market, we also estimate univariate regressions of the return on the Standard & Poor's composite index on the state variables. The results are displayed in panel C.

## Table 5.4: Common Variation in Expected Futures Returns: Results for the Two Subsamples and for the Standard & Poor's Composite Index

$$R_{it} = \alpha_{i0} + \alpha_j Z_{jt-1} + \varepsilon_{it}$$

| Coefficient on $Z_{jt-1}$ | Estimate | Standard Error | t-ratio |
|---|---|---|---|
| **Panel A: Countercyclical Futures** | | | |
| Dividend Yield | 0.0012* | 0.0004 | 3.13 |
| Default Spread | 0.0053* | 0.0016 | 3.27 |
| Return on the Standard & Poor's Composite Index | 0.0039 | 0.0076 | 0.51 |
| Term Spread | -0.0009* | 0.0003 | -2.8 |
| Return on the Dow-Jones Commodity Index | -0.0088 | 0.0137 | -0.64 |
| **Panel B: Procyclical Futures** | | | |
| Dividend Yield | -0.0018 | 0.0021 | -0.88 |
| Default Spread | -0.0036 | 0.0065 | -0.55 |
| Return on the Standard & Poor's Composite Index | -0.1003** | 0.0405 | -2.48 |
| Term Spread | 0.0038** | 0.0016 | 2.34 |
| Return on the Dow-Jones Commodity Index | -0.0259 | 0.0634 | -0.41 |
| **Panel C: Standard & Poor's Composite Index** | | | |
| Dividend Yield | 0.0077** | 0.0039 | 2.01 |
| Default Spread | 0.0170 | 0.0120 | 1.41 |
| Return on the Standard & Poor's Composite Index | -0.0089 | 0.0766 | -0.12 |
| Term Spread | -0.0040 | 0.0030 | -1.32 |
| Return on the Dow-Jones Commodity Index | 0.2082*** | 0.1168 | 1.78 |

* denotes significant at 1 percent.
** denotes significant at 5 percent,
*** denotes significant at 10 percent.

The results summarised in table 5.4 panel A suggest that the sensitivities of countercyclical futures to dividend yield and default spread is positive, while the estimate of $\alpha_j$ for the term structure of interest rates is negative. The returns on the Standard & Poor's and the returns on the Dow-Jones commodity index only have a marginal impact (if any) on expected returns. Hence investors require higher returns on countercyclical futures when dividend yield and default spread take on high values and when term spread takes on low values; namely during economic recession.[5] Similarly, below average dividend yield and default spread signal above average economic prospects and below average expected futures returns. Hence, the results for the group of countercyclical futures are consistent with the idea that expected returns are high during business troughs and low during business peaks. Such a pattern is consistent with the consumption smoothing theory and the idea that the risk the state variables proxy for increases during business troughs and decreases during business peaks. Table 5.4 panel C investigates the link between economic activity and expected stock returns. Although statistically less strong, the results indicate that the relationship between business conditions and expected returns in the equity market is consistent with the results for countercyclical futures. Like in panel A, stock returns indeed are expected to increase during business troughs under the influence of dividend yield, and, to a lesser extent, default spread and the term structure of interest rates.

Table 5.4 panel B summarises the results for the group of procyclical futures. The results are consistent with the hypothesis that the instruments predict futures returns because they are an indicator of economic activity. The point estimates suggest that expected returns increase during business peaks under the influence of the term structure of interest rates and the return on the Standard & Poor's index. Despite insignificant coefficient estimates, dividend yield and default spread push expected returns upwards during expansion too. Such a pattern is inconsistent with extant economic theory but is to be expected for securities whose expected returns follow the business cycle.

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[5] The estimates of the sensitivities of the yearly change in industrial production to the *ex-ante* variables in table 5.2 suggest that, while dividend yield, default spread, and the return on the Standard & Poor's index take on high values during business troughs, the term variable falls when economic conditions are expected to be poor.

For each group, we finally estimate multivariate regressions of futures returns on the *ex-ante* variables and test the joint hypothesis that the coefficients on the *ex-ante* variables can be restricted to be the same across equations within a group. These tests are distributed as $\chi^2$ with 60 degrees of freedom for each group. The resulting $\chi^2$ calculated values of 72 for the countercyclical futures and 52 for the procyclical futures (or corresponding p-values of 0.14 and 0.76) suggest failure to reject the null hypothesis of common variation in expected returns within a group. Hence, once one accounts for the sensitivity of expected returns to the business cycle, the restrictions that the state variables describe the cross sectional behaviour of all futures returns within each group are easily accepted at any conventional level of statistical significance. The futures risk premia move in tandem within each group.

To summarise the results presented thus far, the evidence indicate that the rejection of the hypothesis that the variation in expected returns are common across futures results from the fact that some futures are procyclical. The evidence then suggest that the instruments forecast futures returns because they are a proxy for the business cycle. As expected, a higher term spread, a lower return on the Standard & Poor's index, and, to a lower extent, lower dividend yield and default spread during economic peaks push expected returns upwards for procyclical securities. Similarly, as anticipated, the expected returns on countercyclical futures decrease during business peaks under the influence of dividend yield, default and term spreads. Hence the expected returns of countercyclical futures move opposite to business conditions, while the expected returns of procyclical futures mimic the business cycle. This reconciles our results with the general belief that the forecast power of the state variables over futures returns is consistent with their ability to forecast economic activity.

## VI. Conclusions

In this chapter we pursued the question of market efficiency further. The issue was investigated with respect to two hypotheses. The first one looks at whether the variation in expected returns is common across futures. The second one examines the relationship between economic activity and the time-varying risk premia present in futures markets. These issues seem interesting for two reasons. First, since the purpose of the previous chapter was also to test market efficiency, it is hoped that the present analysis will help us reinforce our evidence in favour of the EMH. Second, since studies of the link between the economy and time-varying expected returns focus on equity returns, it seems important to check whether the evidence from the stock market can be extended to the futures markets. Such a result is to be expected if markets are efficient.

Three conclusions emerge from our analysis. First, when the whole cross section of futures contracts is considered, the futures risk premia do not seem to move together. However, once one accounts for the sensitivity of expected returns to the business cycle, there are some convincing evidence of common variation in expected returns within a group. Second, we find that the predictive power of the state variables over the countercyclical group is consistent with the evidence from the equity market and with what economic theory predicts. In short, during recessions expected returns increase to reflect the fact that the risk the instruments are proxies for is higher and to induce investors to differ consumption into the future. Finally, although the evidence for the procyclical securities sustain the hypothesis that the *ex-ante* variables predict futures returns because of their ability to proxy for the business cycle, the pattern of predictability however is at odds with the predictions of economic theory. Their expected returns on procyclical futures indeed increase during business peaks and decrease when the economy is weak. This last evidence calls for some economic rationale to account for what we can only call so far an "anomaly".

Where do these evidence leave us in terms of market efficiency? On the one hand, we find that the state variables forecast futures returns via their ability to forecast business conditions. Hence the information variables can be considered as proxies for the riskiness of the business cycle. This is encouraging in terms of the EMH since it suggests that the predictable movements in futures returns reflect the change in the consumption-investment opportunity set of agents over time. On the other hand, the cross sectional restrictions that the futures risk premia move in tandem is rejected for the whole cross section. While this evidence might suggest some kind of market inefficiency, we offer an alternative explanation consistent with the EMH. More precisely, we argue that the rejection of the cross sectional restrictions reflect the fact that, while some futures are countercyclical, the expected returns on other futures follow the ups and downs of the business cycle. When the cross section is partitioned into procyclical and countercyclical futures, the restrictions of common movements within a group are easily accepted. We believe therefore that the absence of common movements across the whole sample results more from the presence of procyclical futures in our cross section than from a failure of the EMH.

Finally our results have interesting implications for fund managers interested in security selection and timing decisions. The analysis performed above suggests that, while some futures contracts are countercyclical, other follow the ups and downs of the business cycle. This suggests that, during economic troughs, fund managers should favour countercyclical futures and sell procyclical futures short. Similarly, when the economy is expected to be strong, the reverse strategy (long position in procyclical futures and short position in countercyclical futures) should be profitable.

# Chapter VI: Predictable Futures Returns and Time-Varying Expected Return Asset Pricing Models

## I. Introduction

Since futures returns are predictable using a set of instruments available at time t-1, the purpose of the two previous chapters was to analyse whether the variation in expected futures returns reflects rational pricing in an efficient market or is the result of weak-form market inefficiency. The issue was investigated with respect to two hypotheses. First, we tested whether a trading rule based on available information generates abnormal returns. Second, we examined whether the predictability of futures returns is common across futures and is related to business conditions. Irrespectively of the hypothesis tested, the evidence suggested that futures markets are efficient.

The purpose of this chapter is to further study the variation through time in expected futures returns and to analyse whether the predictability of futures returns reflect rational change in required returns or market inefficiency. The issue is now investigated with respect to the hypothesis that conditional asset pricing models capture the predictability of futures returns. Using the variables that have been proved to forecast futures returns as instruments, we test whether time-varying expected return models account for the predictable variation in futures returns evidenced in chapter IV. If most of the time variation in futures returns is captured by conditional versions of the CAPM and the APT, the evidence will suggest that the predictable movements in futures returns reflect rational pricing in an efficient market. On the other hand, if the conditional asset pricing models hereafter estimated do a poor job at tracking the predictable movements in futures returns, the predictability identified in chapter IV could result from weak-form market inefficiency. This chapter can therefore be considered as a test of the robustness of the evidence presented in the previous chapters. Since the conclusions should be insensitive to the methodology used, we can reasonably expect to sustain the hypothesis that futures markets are efficient.

Most importantly, this study is the first attempt to formally link the variation through time in expected futures returns (tracked by information variables such as dividend yield, term and default spreads...) and the time-varying risk and risk premia associated with common economic factors (for instance, unexpected change in industrial production, unexpected inflation, shocks to the term structure of interest rates, default risk...). Unlike previous studies of conditional expected futures returns, we do not make any strong assumption regarding the source of predictability in futures markets and estimate conditional asset pricing models that allow for time variation in either the covariances, the prices of systematic risk, or all moments. We offer besides the first analysis of the proportion of the predictable variance of futures returns captured by conditional versions of asset pricing models and hence provide some clear inference with respect to the issue of market efficiency in futures markets. Finally, we study an unprecedently large cross section of futures contracts.

These considerations notwithstanding, understanding the implications of market efficiency is of primary interest to market participants who rely on the quoted futures prices to speculate, hedge, or take advantage of arbitrage opportunities. The issue of whether conditional asset pricing models capture the predictability of futures returns should also be appealing to fund managers who use models with time-varying expected returns to proxy for risk and evaluate portfolio performance. If the conditional versions of the CAPM and the APT are better proxies for risk than the traditional constant expected return versions, the Jensen's (1968) measure of abnormal performance will be more reliable when estimated in the context of conditional asset pricing models. The risk of wrongly detecting mispriced securities will thereby be reduced. Hence, while the traditional CAPM and APT might suggest the presence of abnormal returns, conditional asset pricing models might indicate that the fund under consideration offers a return that is commensurate to the risk born. Unless a careful comparison of the ability of both models to proxy for risk is done, one cannot reasonably infer that the fund is mispriced.[1]

As is often the case in tests of the EMH (see Fama (1991)), the tests implemented here rely on a joint hypothesis that stipulates that futures markets are efficient and that the conditional asset pricing models are correctly estimated and are valid representations of the time variation in futures returns. Any evidence against the null hypothesis can therefore be regarded as a proof against the EMH or can result from the use of a misspecified conditional asset pricing model, from our failure to accurately proxy for the variation through time in expected return, or from a mixture of the two. To ensure that estimation problems do not obscure our conclusions, we specify different versions of the conditional asset pricing models and study the ability of each representation to explain the predictable movements in futures returns.

In anticipation of our results, we find that the pattern of forecastability in futures markets is consistent with a conditional APT model with time-varying covariances and constant prices of covariance risk. A further test indicates that the model explains on average 85 percent of the predictability of futures returns. Hence the predictable movements in futures returns seem to mirror the rational change in the consumption-investment opportunity set over time.

The rest of the chapter is organised as follows. Section II presents a brief review of the existing literature. Section III introduces the methodology. Along with some preliminary results, the tests undertaken to check whether the conditional asset pricing models explain the variation in expected futures returns are introduced in section IV. Sections V and VI expose our main empirical results. More specifically, section V focuses on different versions of the conditional CAPM and section VI concentrates on the conditional APT. In section VII we analyse the implications of our findings in terms of market efficiency and estimate the proportion of the predictable variance of returns captured by the

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[1] For example, Chan (1988) shows that contrarian strategies do not perform better than the market, when risk is allowed to be time-varying.

conditional APT model with time varying covariances. Some concluding remarks are offered in section VIII.

## II. Conditional Asset Pricing and Futures Returns: *A Brief Review*

Over the past decade, the relationship between the predictable variation in stock and bond returns and the conditional cross section of expected return has been the subject of an increasing debate. The general message is that the movements in expected returns proxy for a shift in the pervasive risk of the asset and/or for a change in the prices of systematic risk required by investors. The evidence suggest that the variation in the prices of risk, combined with the dynamics of the betas, capture most of the predictable variance of stock and bond excess returns. Besides, while shifts in betas' account for some of the predictable movements in excess returns, the change in the prices of risk is the main source of predictability, leaving little variation to be explained in terms of market inefficiency (see, for example, Harvey (1989, 1991), Ferson and Harvey (1991), Evans (1994), and Ferson and Korajczyk (1995)).

Little attention however has been given to the issue of whether conditional asset pricing models are applicable to other markets. In particular, only a few studies estimate conditional asset pricing models in futures markets (McCurdy and Morgan (1991, 1992), Bessembinder and Chan (1992), and Antoniou, Malliaris, and Priestley (1997)). Other studies investigate whether the predictable movements in the basis are related to the risk premia present in the stock and bond markets (Bailey and Chan (1993)).

Attempts have first been made to extend the conditional version of the CAPM to the pricing of currency futures contracts. The evidence in McCurdy and Morgan (1991) suggest that a single factor CAPM with time-varying betas and time-varying market risk premium fails to price currency futures contracts. Similarly, McCurdy and Morgan (1992) prove that a specification of the CAPM that uses consumption and wealth as a proxy for the market portfolio does not fare better with the data. In both studies, the change in the price of covariance risk and the variation in the covariances between the currency futures returns and the benchmark do not explain all of the stochastic movements in currency futures returns[2]. The rejection of the conditional CAPM as a description of the variation through time in expected futures returns parallels the failure of the traditional CAPM to price futures contracts evidenced in chapter II (see also Bodie and Rosansky (1980), Park, Wei, and Frecka (1988), or Kolb (1996)).

Since a more dissaggregated structure of risk might better proxy for the stochastic movements in futures returns, attempts have been made recently to explain the time variation in futures returns through the use of conditional multifactor models emanating from the APT of Ross (1976). In these studies, some strong assumptions are made regarding the source of predictability and no attempt is made to relax these assumptions. For example, Bessembinder and Chan (1992) assume time-varying prices of risk and constant betas. They prove that the pattern of forecastability in commodity futures markets is consistent with a latent variable model with two time-varying risk premia.[3] On the other hand, Antoniou, Malliaris, and Priestley (1997) study the time variation in the Standard & Poor's futures and spot returns and estimate a conditional asset pricing model with time-varying risk and constant price of risk, where the dynamics of the conditional variance are a function of observed risk factors.

Finally another scope of research investigates the presence of time variation in the basis. The evidence suggest that the time-varying risk premia present in the commodity basis are related to the macroeconomic factors identified by Chen, Roll, and Ross (1986) in the equity market (Bailey and Chan (1993)). Further evidence indicate that the forecast power of the *ex-ante* variables over the basis reflects the presence of time-varying risk

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[2] A local interest rate differential and an ARCH-M term also have some power in explaining the conditional mean of currency futures returns.

[3] Notwithstanding the contribution of their research to the literature on conditional asset pricing, the methodology used by Bessembinder and Chan suffers from the drawback that no economic or financial meaning is attached to the time-varying risk premia. Therefore their paper might be of little interest to investors who want to speculate on or hedge against a specific source of uncertainty.

premia in commodity futures markets. Following the same approach, Baum and Barkoulas (1996) report similar results for the foreign currency futures basis, while Antoniou, Malliaris, and Priestley (1997) directly prove that a conditional model with time-varying risk and constant price of risk captures the dynamics in the Standard & Poor's basis.

These studies do not explicitly relate the time-varying risk premia identified in futures markets to the systematic change in risk and prices of risk associated with macroeconomic factors. They also make some strong assumptions regarding the source of predictability in futures markets. For example, Bessembinder and Chan assume that the dynamics of the prices of risk capture the time-varying risk premia present in futures markets, while Antoniou, Malliaris, and Priestley believe that the variation through time in the conditional variance is the only source of predictability in futures markets. Besides the studies mentioned above focus on a relatively narrow cross section of futures contracts[4] and do not explicitly address the issue of market efficiency. In this chapter, we estimate asset pricing models that allow for time variation in either the covariances, the prices of covariance risk, or all moments. We therefore do not make any definite assumption regarding the source of predictability in futures markets. Besides we analyse the behaviour of an unprecedently wide range of futures contracts and explicitly test whether the predictability of futures returns is consistent with rational pricing in an efficient market. Hence we believe that our research should be of some interest to market participants interested in conditional asset pricing and in market efficiency.

## III. Methodology

The evidence presented in chapter IV suggest that futures returns are varying with the level of the information set available to investors at time t-1. In an asset pricing

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[4] McCurdy and Morgan (1991, 1992) examine foreign currency futures, Bessembinder and Chan (1992) study commodity futures, Bailey and Chan (1993) analyse the behaviour of commodity bases, Baum and Barkoulas (1996) consider foreign currency bases. Antoniou, Malliaris, and Priestley (1997) look at stock index futures. No attempt is made to analyse the behaviour of a wider cross section of futures contracts.

framework, the predictability of returns implies some stochastic movements in the prices of covariance risk, the covariance between the asset returns and the systematic sources of risk, or in both parameters. Hence, in the case of a conditional multi factor model

$$E(R_t / \Omega_{t-1}) = \sum_{j=1}^{K} \frac{E\left[F_{jt} / \Omega_{t-1}\right]}{\mathrm{var}\left[F_{jt} / \Omega_{t-1}\right]} \mathrm{cov}\left[R_t, F_{jt} / \Omega_{t-1}\right] \tag{6.1}$$

$E(R_t / \Omega_{t-1})$ is the time t expected futures return conditioned on the information set $\Omega$ available at time t-1, $F_{jt}$ is the excess return on the $j^{th}$ mimicking portfolio or the excess return on the market portfolio. $E\left[F_{jt} / \Omega_{t-1}\right] / \mathrm{var}\left[F_{jt} / \Omega_{t-1}\right]$, the ratio of the conditionally expected excess return on the mimicking portfolio divided by the conditional variance of the portfolio excess return, is the price of covariance risk associated with factor j (j = 1, ..., K). It is the compensation received by investors for bearing one unit of factor j risk. $\mathrm{cov}\left[R_t, F_{jt} / \Omega_{t-1}\right]$, the conditional covariance between the asset return and the $j^{th}$ systematic risk factor, measures the sensitivity of the asset returns to the price per unit of covariance risk.

Depending on the assumptions made regarding the nature of the predictability, one can estimate different types of models: one can first test whether the pattern of forecastability is consistent with a model with time-varying covariances; one can then assume that only the prices of systematic risk are time-varying; finally, as suggested by equation (6.1), one can examine whether the variation in expected returns imply that all three moments (the means, the variances, and the covariances) vary with the available information set. Following much of the literature on conditional asset pricing,[5] we estimate models that attempt to explain the predictability of futures returns by allowing either the prices of systematic risk, the covariances, or all moments to vary with the level of the information variables.

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[5] See, for example, Harvey (1989, 1991), Ferson and Harvey (1993), and Ferson and Korajczyk (1995).

## 1. Conditional Asset Pricing Models with Time-Varying Covariances

Under the assumption of constant reward per unit of factor risk, equation (6.1) becomes

$$E(R_t / Z_{t-1}) = \lambda \operatorname{cov}[R_t, F_t / Z_{t-1}] \qquad (6.2)$$

where $\lambda$ is a K-vector of prices of covariance risk. Note that, because of the unobservability of the true information set $\Omega_{t-1}$, expectations are conditioned on $Z_{t-1}$, a set of instruments assumed to be a good proxy for the actual information set. If we further assume that investors assess a linear relationship between conditional expected returns and the instrumental variables, the return on any asset (or the return on any mimicking portfolio) can be expressed as

$$u1_t = R_t - Z_{t-1}\delta \qquad (6.3a)$$

$$u2_t = F_t - Z_{t-1}\gamma \qquad (6.3b)$$

where $u1_t$ and $u2_t$ are 1*N and 1*K vectors of errors that are orthogonal to the L instrumental variables $Z_{t-1}$, $R_t$ is a 1*N vector of assets, $F_t$ is a 1*K vector of mimicking portfolio excess returns, $\delta$ and $\gamma$ are L*N and L*K matrices of estimated coefficients. Therefore, the definition of the covariance, equations (6.2), (6.3a) and (6.3b) yield

$$E(R_t / Z_{t-1}) = \lambda E[(R_t - E(R_t / Z_{t-1}))(F_t - E(F_t / Z_{t-1})) / Z_{t-1}]$$

$$E(R_t / Z_{t-1}) = \lambda E[u1_t u2_t / Z_{t-1}]$$

We define the forecast error $u3_t$ as

$$u3_t = R_t - \lambda u1_t u2_t \qquad (6.3c)$$

Stacking together (6.3a), (6.3b), and (6.3c) into a system yields

$$u_t = (u1_t \quad u2_t \quad u3_t) = \begin{pmatrix} (R_t - Z_{t-1}\delta)' \\ (F_t - Z_{t-1}\gamma)' \\ (R_t - \lambda u1_t u2_t)' \end{pmatrix}' \tag{6.3}$$

Equation (6.3a) defines expected futures returns as the fitted values from a regression of actual returns on a constant and the lagged information variables. Equation (6.3b) is a system of K regressions of the excess returns on factor mimicking portfolios on the lagged instruments. Finally, equation (6.3c) defines the conditional prices of risk that are assumed to be fixed parameters.

We test the moment conditions that the residuals in (6.3) are orthogonal to the instruments. Namely, system (6.3) implies

$$E[u_t / Z_{t-1}] = E[u1_t / Z_{t-1}, u2_t / Z_{t-1}, u3_t / Z_{t-1}] = 0$$

With N futures contracts, K mimicking portfolios, and L instruments, there are 2N+K innovations, (2N+K)*L orthogonality conditions, and (N+K)*L+K parameters to estimate. Therefore, for K=N*L, the number of orthogonality conditions equals the number of free parameters and the system is perfectly identified; while, for N*L>K, the system is overidentified and the overidentifying restrictions that the vector of $u_t$ is orthogonal to the instruments can be tested using the minimised value of the GMM criterion function. Under the null hypothesis of orthogonality, this $\chi^2$ value is less than the $\chi^2$ critical value with N*L-K degrees of freedom and the model is well specified.

Following Harvey (1991, footnote 9), we simplify system (6.3) by recognising that $E[u2_t u1_t / Z_{t-1}] = E[u2_t R_t / Z_{t-1}]$. This enables us to reduce (6.3) to a system of N+K equations. The econometric model we estimate then becomes

$$u_t = \left(u2_t \quad u3_t\right) = \begin{pmatrix} (F_t - Z_{t-1}\gamma)' \\ (R_t - \lambda u2_t R_t)' \end{pmatrix} \tag{6.4}$$

There are (N+K)*L orthogonality conditions, K*(L+1) parameters to estimate, leaving N*L-K overidentifying restrictions. As Harvey (1991) notices, systems (6.3) and (6.4) have the same number of overidentifying restrictions; they are therefore asymptotically equivalent. However, system (6.4) reduces to N+K equations and is therefore much more easily and more quickly estimated.

System (6.4) is first estimated for groups of futures (agricultural, metal and oil, and financial) and for the whole cross section of contracts. Each time, the orthogonality restrictions are tested. Such a specification is properly defined since it restricts $\gamma$, the sensitivities of the excess returns on the mimicking portfolios to the instruments, to be the same across futures contracts and imposes the asset pricing restriction that the prices of covariance risk ($\lambda$) are the same across assets. We also estimate (6.4) at the individual asset level. Since all of the conditional asset pricing restrictions are then not imposed, caution should be the rule while failing to reject the orthogonality conditions for individual futures. Estimating system (6.4) at the individual futures level is however interesting since it might tell us why we are rejecting the hypothesis of orthogonality when the whole set of futures contracts is considered.

The conditional covariances between futures returns and the excess returns on the factor mimicking portfolios in system (6.4) are measured as the product of the unconditional futures returns and the residuals from a regression of the factor mimicking portfolio excess returns on the instruments. System (6.4) implicitly assumes that these conditional covariances are time-varying. To test this hypothesis, we follow Harvey (1989): we save the covariance terms $u2_{jt}R_t$ in (6.4), regress them on the set of lagged instruments, and test the hypothesis that the regressors can be jointly excluded from the regression. Under the null hypothesis of constant covariance, only the intercept term should significantly differ from zero. Therefore the following regression is estimated

$$u2_{jt}R_t = \alpha_0 + \alpha Z_{t-1} + \varepsilon_t \qquad (6.5)$$

and the hypothesis that $\alpha$ equals zero is tested using a $\chi^2$ test with L-1 degrees of freedom. $u2_{jt}R_t$ is the conditional covariance and is defined as the product of the asset returns and the j mimicking portfolio residuals. The omission from some elements of $\Omega_{t-1}$ in $Z_{t-1}$ might result in serial correlation and heteroscedasticity in the regression errors; and, hence in inefficient estimates and biased test statistics. The standard errors in (6.5) are therefore adjusted for serial correlation and heteroscedasticity using Newey and West (1987) correction.

System (6.4) also assumes constant prices of covariance risk. To test this hypothesis, we follow the approach proposed by Harvey (1989). For each mimicking portfolio excess return, we estimate the following system

$$\varepsilon_{jt} = \left(\varepsilon 2_{jt} \quad \varepsilon 3_{jt}\right) = \begin{pmatrix} \left(F_{jt} - Z_{t-1}\gamma_j\right)' \\ \left(F_{jt} - \lambda_j \varepsilon 2_{jt} \varepsilon 2_{jt}\right)' \end{pmatrix}' \qquad (6.6)$$

Under the null hypothesis of constant reward to covariance risk, the forecast errors in (6.6) should be orthogonal to the information set. If the model with constant prices of covariance risk is well specified, one can interpret the test of the overidentifying restrictions in (6.6) as a test of whether the prices of covariance risk are constant. Under the null hypothesis, the minimised value of the GMM criterion function is less than the critical value and is distributed as $\chi^2$ with L-1 degrees of freedom.[6]

## 2. Conditional Asset Pricing Models with Time-Varying Expected Returns

Under the assumption of constant sensitivities of the asset returns to the prices of factor risk, equation (6.1) can be written as

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[6] There are 2L orthogonality conditions and L+1 parameters to estimate, leaving L-1 overidentifying restrictions to test.

$$E(R_t / Z_{t-1}) = E(F_t / Z_{t-1}) * B$$

where B is a K*N vector of sensitivities of the asset return to the excess returns on the 1*K mimicking portfolios. If we define $u_t$ as the N*1 vector of disturbances, then

$$u_t = (R_t - F_t B)' \tag{6.7}$$

(6.7) is a system of N equations with N*L orthogonality conditions and N*K betas to estimate, leaving N*(L-K) overidentifying restrictions to be tested. System (6.7) is estimated for individual contracts, for groups of futures, and for the whole cross section of futures contracts. Each time the orthogonality conditions are tested.

## 3. Conditional Asset Pricing Models with Time-Varying Moments

We finally test whether models with time-varying covariances and time-varying prices of covariance risk explain the predictability of futures returns. In this purpose, we assume that none of the parameters in equation (6.1) are constant. Namely, we assume that all three moments - the means, the variances, and the covariances - are time-varying with the information set available at time t-1.

Because of the definition of the variance and the covariance and after rearranging terms, equation (6.1) becomes

$$0 = E(R_t / Z_{t-1}) - \sum_{j=1}^{K} \frac{E\left[(R_t - E(R_t / Z_{t-1}))(F_{jt} - E(F_{jt} / Z_{t-1})) / Z_{t-1}\right]}{E\left[(F_{jt} - E(F_{jt} / Z_{t-1}))^2 / Z_{t-1}\right]} E\left[F_{jt} / Z_{t-1}\right] \tag{6.8}$$

If we recall that the returns on individual futures and on the excess return on the mimicking portfolios can be expressed as a linear function of the instruments

$$u1_t = R_t - Z_{t-1}\delta \qquad (6.9a)$$

$$u2_t = F_t - Z_{t-1}\gamma \qquad (6.9b),$$

then equation (6.8) becomes

$$0 = Z_{t-1}\delta - \frac{E\left[u1_t u2_t / Z_{t-1}\right]}{E\left[u2_t^2 / Z_{t-1}\right]} Z_{t-1}\gamma$$

We define the disturbance $u3_t$ as

$$u3_t = \left[Z_{t-1}\delta\right] - \frac{u1_t u2_t}{u2_t^2}\left[Z_{t-1}\gamma\right] = \left[Z_{t-1}\delta\right] - \frac{u1_t}{u2_t}\left[Z_{t-1}\gamma\right] \qquad (6.9c)$$

Equation (6.9c) defines the conditional betas that are assumed to be time-varying with the information set. Literally speaking, equation (6.9c) defines $u3_t$ as the residuals from the conditional asset pricing model with time-varying means, variances and covariances. Stacking together equations (6.9a), (6.9b), and (6.9c) gives the system that lays the basis of our econometric test

$$u_t = \left(u1_t \quad u2_t \quad u3_t\right) = \begin{pmatrix} (R_t - Z_{t-1}\delta)' \\ (F_t - Z_{t-1}\gamma)' \\ \left(Z_{t-1}\delta - (u1_t / u2_t) Z_{t-1}\gamma\right)' \end{pmatrix}' \qquad (6.9)$$

System (6.9) implies the following moment conditions

$$E\left[u_t / Z_{t-1}\right] = 0$$

With N futures contracts, K mimicking portfolios, and L instruments, there are 2N+K innovations, (2N+K)*L orthogonality conditions, and (N+K)*L parameters to estimate, leaving N*L overidentifying restrictions to test.

### 4. The Generalised Method of Moments

The methodology employed to formally estimate the conditional asset pricing models is the generalised method of moments (GMM) introduced by Hansen (1982). The GMM approach consists in finding the parameter estimates that set the residuals orthogonal to the instruments. This is done by minimising the criterion function, $g'Wg$, where $g = \mathrm{vec}(u'Z)$ is a vector of orthogonality conditions and W is the weighting matrix that makes g close to zero.

As mentioned above, if the number of orthogonality conditions exceeds the number of estimated parameters, one can consider the minimised value of the criterion function as a test of the overidentifying restrictions. This test is distributed as $\chi^2$ with a number of degrees of freedom equal to the difference between the number of orthogonality conditions and the number of estimated parameters. If the model is a valid representation of the predictable movements in asset returns, the restriction that the moment conditions equal zero should be accepted. The test of the overidentifying restrictions can therefore be interpreted as a test of the ability of the model to explain the variation in expected returns. If the minimised value of the criterion function is low, the residuals are orthogonal to the instrumental variables, which means that the model is a valid representation of the predictable variation of asset returns. Similarly a high $\chi^2$ suggests that the moment conditions do not hold, and hence that the model is ill-defined.

## IV. Preliminary Results and Hypotheses Tested

Since futures returns are predictable using a set of instruments available at time t-1 (chapter IV), the rest of this chapter aims at testing whether the pattern of forecastability is consistent with conditional asset pricing models such as the conditional CAPM and the conditional APT. System (6.4) assumes time-varying covariances between any asset return and the excess return on the factor mimicking portfolio. It also imposes the constraints that the prices of covariance risk are constant. Equation (6.7) on the other hand assumes that the sensitivities of futures returns to the excess returns on mimicking portfolios is constant and explains the time-variation in futures returns through variation in the prices of systematic risk. Finally, system (6.9) assumes that all moments (the means, the variances, and the covariances) are time-varying with the level of the information variables. Before actually estimating these systems, it is therefore interesting to test the accuracy of the assumptions underlying the models. We do so for the model with time-varying covariances and constant prices of covariance risk. In this respect, we estimate systems (6.5) and (6.6), thereby testing the null hypotheses that the covariances and rewards per unit of covariance risk are constant. This might give us some preliminary insight regarding the sources of predictability in futures markets.

We first regress the product of the unconditional futures returns and the mimicking portfolio residuals on the instrumental variables and test the hypothesis that the regressors can be excluded from the regression (for more details, see Harvey (1989)). The test is conducted at the individual asset level. We also estimate systems of seemingly unrelated regressions for each group of futures (agricultural, metal and oil, and financial), regress the conditional covariances on the instruments, and test the hypothesis that the *ex-ante* variables do not predict the covariance terms within a group. We finally consider the whole cross section of futures returns and examine if the conditional covariances between the 26 futures returns and the excess returns on the factor mimicking portfolios are jointly constant. The results are reported in table 6.1.

The null hypothesis of constant covariance is accepted in most cases at the individual asset level. A comparison of the results in tables 6.1 and 4.4 (which displays the sensitivities of futures returns to the instruments) indicates that the futures that exhibit time-varying risk premia present significant time-varying covariances. The results for groups of futures and for the whole sample clearly suggest that the conditional covariances are time-varying. The $\chi^2$ statistics indeed indicate that the null hypothesis of constant covariance is rejected at traditional levels of statistical significance. This concerns the conditional covariances between the whole set of futures returns and the excess return on the mimicking portfolios associated with the Standard & Poor's returns, the term structure of interest rates, unexpected inflation, the change in expected inflation, and industrial production. The evidence regarding the presence of time variation in the covariances between default spread and the futures returns is however not as clear-cut (probability value of 0.17). This consideration notwithstanding, the results displayed in table 6.1 point toward the conclusion that the variation through time in the sensitivities of futures returns to the excess returns on mimicking portfolios is a likely source of predictability in futures markets.

We then test the hypothesis that the ratio of the expected excess return on the mimicking portfolio divided by the variance of the portfolio return is constant. In this respect, we estimate system (6.6) and consider the test of the overidentifying restrictions as a test of whether the reward to covariance risk ratio is constant (for a discussion on this issue, see Harvey (1989)). The results, displayed in table 6.2, suggest the presence of time-varying price of covariance risk for the term structure of interest rates only. For unexpected inflation, the change in expected inflation, default spread, industrial production, and the return on the Standard & Poor's index, the overidentifying restrictions are accepted at conventional levels of statistical significance. This suggests that models with constant prices of covariance risk and time-varying covariances do a good job at tracking the predictable components in the excess returns of these mimicking portfolios.

It follows from these tests that one of the likely sources of predictability in futures markets is the covariance between the excess returns on the factor mimicking portfolio and the futures returns. However, since one cannot rule out completely the hypothesis that the prices of covariance risk are constant, the variation though time in the rewards per unit of covariance risk could also account for some of the predictable movements in

# Table 6.1: Test for the Presence of Time-Varying Covariances:
# Regression of the Product of the Unconditional Futures Returns and the Mimicking Portfolio Residuals on the Instruments

$$u2_{jt} R_t = \alpha_0 + \alpha Z_{t-1} + \varepsilon_t$$

| Futures Contracts | Conditional CAPM | | Conditional APT | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Standard & Poor's Return | | Term Structure | | Unexpected Inflation | | Change in Expected Inflation | | Default Spread | | Unexpected Change Industrial Production | |
| | $\chi^2$ (a) | p-value (a) | $\chi^2$ | p-value | $\chi^2$ | p-value | $\chi^2$ | p-value | $\chi^2$ | p-value | $\chi^2$ | p-value |
| **Panel A: Commodities** | | | | | | | | | | | | |
| Cocoa | 3.5706 | 0.61 | 4.0668 | 0.54 | 2.5026 | 0.78 | 4.0128 | 0.55 | 17.7867 | <0.01 | 2.6168 | 0.76 |
| Coffee | 10.9167 | 0.05 | 6.8026 | 0.24 | 8.7555 | 0.12 | 10.3121 | 0.07 | 3.4281 | 0.63 | 8.9427 | 0.11 |
| Corn | 5.0831 | 0.41 | 2.3853 | 0.79 | 4.4513 | 0.49 | 5.6350 | 0.34 | 2.6986 | 0.75 | 5.8359 | 0.32 |
| Cotton | 5.6838 | 0.34 | 7.2045 | 0.21 | 6.3796 | 0.27 | 7.0920 | 0.21 | 6.4259 | 0.27 | 5.9203 | 0.31 |
| Oats | 4.2377 | 0.52 | 6.5247 | 0.26 | 3.4541 | 0.63 | 3.2824 | 0.66 | 2.7164 | 0.74 | 2.0456 | 0.84 |
| Soybeans | 6.6513 | 0.25 | 1.9053 | 0.86 | 6.6037 | 0.25 | 7.3249 | 0.20 | 4.1647 | 0.53 | 6.3814 | 0.27 |
| Soybean Meal | 6.3289 | 0.28 | 10.6053 | 0.06 | 3.7505 | 0.59 | 4.8228 | 0.44 | 8.8176 | 0.12 | 4.1750 | 0.52 |
| Soybean Oil | 6.3690 | 0.27 | 2.8588 | 0.72 | 2.6527 | 0.75 | 2.9664 | 0.71 | 2.9805 | 0.70 | 3.5068 | 0.62 |
| Sugar | 4.7492 | 0.45 | 5.6949 | 0.34 | 3.3859 | 0.64 | 6.5028 | 0.26 | 3.7061 | 0.59 | 7.7988 | 0.17 |
| Wheat | 8.2075 | 0.15 | 4.8655 | 0.43 | 8.2562 | 0.14 | 4.1337 | 0.53 | 5.4962 | 0.36 | 4.5003 | 0.48 |
| Lean Hogs | 6.4556 | 0.26 | 2.7251 | 0.74 | 8.8250 | 0.12 | 9.2953 | 0.10 | 4.3783 | 0.50 | 9.4772 | 0.09 |
| Lumber | 2.7532 | 0.74 | 5.7590 | 0.33 | 4.3688 | 0.50 | 3.5852 | 0.61 | 9.1530 | 0.10 | 4.7625 | 0.45 |
| Pork Bellies | 10.2964 | 0.07 | 7.4070 | 0.19 | 13.8103 | 0.02 | 12.4789 | 0.03 | 6.4915 | 0.26 | 14.9148 | 0.01 |
| All Agricultural ($\chi^2(65)$) | 89.9507 | 0.02 | 83.0688 | 0.06 | 87.7421 | 0.03 | 85.3933 | 0.05 | 75.5766 | 0.17 | 84.9052 | 0.05 |
| **Panel B: Metal and Oil** | | | | | | | | | | | | |
| Gold | 10.2125 | 0.07 | 10.1565 | 0.07 | 7.5708 | 0.18 | 6.8620 | 0.23 | 9.9952 | 0.08 | 5.3836 | 0.37 |
| Heating Oil | 11.0872 | 0.05 | 8.4427 | 0.13 | 11.3469 | 0.04 | 10.9694 | 0.05 | 11.0341 | 0.05 | 11.0925 | 0.05 |
| Silver | 4.5887 | 0.47 | 15.4501 | 0.01 | 4.4632 | 0.48 | 5.8578 | 0.32 | 6.1635 | 0.29 | 5.2295 | 0.39 |
| Platinum | 5.2746 | 0.38 | 9.6637 | 0.09 | 8.1781 | 0.15 | 11.1343 | 0.05 | 6.8397 | 0.23 | 11.8218 | 0.04 |
| All Metal ($\chi^2(20)$) | 34.3382 | 0.02 | 75.4382 | <0.01 | 36.0817 | 0.02 | 29.2638 | 0.08 | 18.9101 | 0.53 | 30.9941 | 0.06 |

# Table 6.1 - *Continued*

| Futures Contracts | Conditional CAPM | | Conditional APT | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Standard & Poor's Return | | Term Structure | | Unexpected Inflation | | Change in Expected Inflation | | Default Spread | | Unexpected Change Industrial Production | |
| | $\chi^2$ (a) | p-value (a) | $\chi^2$ | p-value | $\chi^2$ | p-value | $\chi^2$ | p-value | $\chi^2$ | p-value | $\chi^2$ | p-value |
| **Panel C: Financial** | | | | | | | | | | | | |
| NYSE | 17.2018 | <0.01 | 10.1673 | 0.07 | 22.3593 | <0.01 | 22.2662 | <0.01 | 7.7436 | 0.17 | 19.1271 | <0.01 |
| SP500 | 16.1598 | 0.01 | 10.9667 | 0.05 | 21.5438 | <0.01 | 22.1675 | <0.01 | 7.1798 | 0.21 | 18.7947 | <0.01 |
| Treasury-Bill | 8.3949 | 0.14 | 3.5847 | 0.61 | 2.2862 | 0.81 | 2.2704 | 0.81 | 3.8245 | 0.57 | 2.3642 | 0.80 |
| Treasury-Note | 6.7417 | 0.24 | 1.3083 | 0.93 | 2.4300 | 0.79 | 2.8340 | 0.73 | 7.5739 | 0.18 | 1.1120 | 0.95 |
| Treasury-Bond | 6.6104 | 0.25 | 2.8654 | 0.72 | 3.7390 | 0.59 | 3.7918 | 0.58 | 7.1725 | 0.21 | 1.7350 | 0.88 |
| Deutsch Mark | 8.6065 | 0.13 | 5.7456 | 0.33 | 1.4526 | 0.92 | 2.7489 | 0.74 | 3.8695 | 0.57 | 1.6105 | 0.90 |
| Japanese Yen | 8.8987 | 0.11 | 4.1281 | 0.53 | 1.3763 | 0.93 | 1.6982 | 0.89 | 3.9853 | 0.55 | 1.2872 | 0.94 |
| Swiss Franc | 9.8321 | 0.08 | 3.6179 | 0.61 | 2.3612 | 0.80 | 4.0922 | 0.54 | 3.8888 | 0.57 | 2.6078 | 0.76 |
| UK Pound | 8.1738 | 0.15 | 4.2302 | 0.52 | 2.9487 | 0.71 | 3.9565 | 0.56 | 3.0212 | 0.70 | 3.9131 | 0.56 |
| All Financial ($\chi^2(45)$) | 72.4715 | 0.01 | 115.1518 | <0.01 | 50.0292 | 0.28 | 69.9648 | 0.01 | 43.0945 | 0.55 | 53.5141 | 0.18 |
| All Futures ($\chi^2(130)$) | 236.4449 | <0.01 | 272.8651 | <0.01 | 192.8454 | <0.01 | 190.671 | <0.01 | 145.6053 | 0.17 | 177.577 | <0.01 |

(a) $\chi^2$ is a heteroscedasticity and serial correlation consistent test of the null hypothesis that the covariance terms are unrelated to the instruments, p-value is the probability of rejecting the null hypothesis when it is true. Unless specified otherwise, the tests are distributed as $\chi^2$ with 5 degrees of freedom.

# Table 6.2: Test for the Presence of Constant Reward to Risk Ratios

$$\varepsilon_{jt} = \left(\varepsilon 2_{jt} \quad \varepsilon 3_{jt}\right) = \begin{pmatrix} \left(F_{jt} - Z_{t-1}\gamma_j\right)' \\ \left(F_{jt} - \lambda_j \varepsilon 2_{jt} \varepsilon 2_{jt}\right)' \end{pmatrix}'$$

| Parameter Held Constant: Reward to Risk Ratio Associated with the Mimicking Portfolio on | Estimate | $\chi^2$ (a) | p-value (a) |
|---|---|---|---|
| Return on the Market Portfolio | 2.2884 | 7.8139 | 0.17 |
| Shock to Term Structure | 7.5747 | 78.8165 | <0.01 |
| Unexpected Inflation | 3.2478 | 6.2112 | *0.29* |
| Change in Expected Inflation | 3.0030 | 8.0248 | 0.15 |
| Shock to Default Spread | 79.4218 | 4.3293 | 0.50 |
| Unexpected Industrial Production | 3.1206 | 5.7314 | 0.33 |

(a) $\chi^2$ is the minimised value of the GMM criterion function, it tests the null hypothesis that the residuals from the GMM system are orthogonal to the instruments, p-value is the probability of rejecting the null hypothesis erroneously. For each system, there are 12 orthogonality conditions and 7 parameters, leaving 5 overidentifying restrictions to be tested.

futures returns. It seems therefore interesting to estimate conditional asset pricing models that allow for time-variation in different parameters. We first turn our attention to the estimation of conditional models with time-varying covariances; we then allow the prices of risk to vary with the level of the information variables; and, finally, estimate models that do not restrict any parameters to be constant.

To test the ability of each model to explain the predictable components in futures returns, we undertake a set of three tests that are in the spirit of Harvey (1989, 1991). We first consider the test of the overidentifying restrictions as a test of the hypothesis that the model's residuals are orthogonal to the information variables. This test, distributed as $\chi^2$ with a number of degrees of freedom equal to the number of overidentifying restrictions, can be viewed as a test of the conditional mean-variance efficiency of the market portfolio or alternatively as a test of the conditional mean-variance efficiency of the combination of the Chen, Roll, and Ross (1986) factors (see Harvey (1989), Evans (1994)). If the model is correctly specified, the null hypothesis should be accepted.

Second, we regress the residuals from the conditional asset pricing models ($u3_t$ in (6.4) and in (6.9) and $u_t$ in (6.7)) on the instruments and test the restrictions that the regressors can be deleted from the regressions (see, for example, Campbell (1987), Ferson and Harvey (1993)). These tests are distributed as $\chi^2$ with 5 degrees of freedom.[7] The resulting standard errors are adjusted for heteroscedasticity and serial correlation using Newey and West (1987) correction. This test is undertaken at the individual futures level, for groups of futures (agricultural, metal and oil, and financial), and for the whole cross section. We also look at the R-squared of these regressions. If the conditional asset pricing model does a good job at tracking the predictable variation in futures returns, the restrictions of constant conditional residuals should easily be accepted and the R-squared should be low compared to the R-squared of a regression of futures returns on the instruments (table 4.4).

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[7] The second test is therefore similar to the first one. It does not impose however the additional restrictions that the mimicking portfolios residuals ($u2_t$ in (6.4) and in (6.9)) and the asset's residuals ($u1_t$ in (6.9)) are orthogonal to the instruments.

Finally, we compute the average mispricing error $\overline{u3}$ measured as

$$\overline{u3} = \frac{1}{T}\sum_{t=1}^{T} u3_t$$

and compare its size to the average conditional mean futures returns, measured as the mean fitted return of a regression of futures returns on the instruments. $u3_t$ are the conditional residuals from equations (6.4), (6.7), and (6.9). The model is underpricing (overpricing) when actual average returns are higher than expected returns; namely, when $\overline{u3}$ is positive (negative). If the model explains the predictability of futures returns, we expect the average pricing errors to be insignificant and small compared to the conditional mean returns.

## V. Empirical Results: the Conditional Capital Asset Pricing Model

Tables 6.3, 6.4, and 6.5 report tests of the properties of the conditional pricing errors for each specification of the conditional CAPM. Table 6.3 focuses on the conditional CAPM with time-varying covariances and constant price of covariance risk; table 6.4 concentrates on the conditional CAPM with time-varying price of market risk and constant beta; finally, table 6.5 reports the results for the conditional CAPM with time-varying parameters. In each table, the first columns display the tests of the overidentifying restrictions; the second columns focus on the null hypothesis that the conditional asset pricing residuals are unrelated to the instruments; and the third columns look at the average pricing errors and compare them to the mean fitted returns.

### 1. Conditional CAPM with Time-Varying Covariances

Table 6.3 assumes that the covariances between futures returns and the excess returns on the market portfolio are time-varying and constraints the price of covariance risk to be constant. Under this specification, the sensitivities of futures returns to the reward per unit of covariance risk are assumed to be the only source of predictability in futures returns.

The overidentifying restrictions are accepted in most cases. There is however some evidence against the model's restrictions at the individual level for 4 out of 26 futures. This concerns the futures on soybeans, gold, NYSE, and SP500. For these contracts, the $\chi^2$ statistics and p-values suggest that the residuals fail to be orthogonal to the level of the instrumental variables. As mentioned above however, the specification of the conditional CAPM at the individual level fails to impose the asset pricing restrictions that the price of covariance risk and the sensitivities of the market excess returns to the instruments are the same across futures. Therefore, a failure to reject the orthogonality restrictions at the individual level might simply suggest that not all of the conditional CAPM cross sectional restrictions have been imposed. More reliable tests can be undertaken by estimating system (6.4) for groups of assets and for the whole set of futures. When $\lambda_M$ and $\gamma_M$ in (6.4) are restricted to be the same across futures, the model's restrictions are accepted at any standard degree of statistical significance for the agricultural and metal groups and for the set of 26 futures contracts, suggesting that the market portfolio is conditionally mean-variance efficient at least for these futures. However the conditional CAPM fails to describe the predictable variation in financial futures returns (p-value of 0.02). This rejection is consistent with out earlier results concerning the NYSE and the SP500 futures contracts.

Column 2 compares the R-squared of a regression of the conditional CAPM residuals on the instruments to the R-squared of a regression of futures returns on the instruments (table 4.4). With relatively few exceptions (coffee, corn, cotton, soybean oil, platinum, and Japanese Yen), the former are smaller than the latter. The decrease in R-squared after accounting for time-varying covariances is however small. The goodness-of-fit statistics of a regression of the residual on the instruments exceed 5 percent for soybeans, soybean meal, soybean oil, gold, silver, and platinum futures. This suggests that the conditional residuals are predictable using the level of the information variables and therefore that the conditional CAPM fails to track all of the predictable variation in futures returns. A more

## Table 6.3: Properties of the Pricing Errors from the Conditional CAPM with Time-Varying Covariances and Constant Price of Covariance Risk

| Futures Contracts | Overidentifying Restrictions | | Regression of $u3_{it}$ on the IV and Variable Deletion Test | | | | Average Pricing Error | |
|---|---|---|---|---|---|---|---|---|
| | $\chi^2$ (a) | p-value (a) | $R^2$ (b) | $R^2$ (b) | $\chi^2$ (c) | p-value (c) | $\overline{u3}$ (d) | E(R) (d) |
| **Panel A: Agricultural Commodities** | | | | | | | | |
| Cocoa | 2.387 | 0.79 | 0.014 | 0.015 | 2.88 | 0.72 | 0.0036 | 0.0028 |
| Coffee | 4.006 | 0.55 | 0.024 | 0.022 | 3.25 | 0.66 | 0.0048 | 0.0048 |
| Corn | 2.606 | 0.76 | 0.025 | 0.015 | 5.62 | 0.35 | 0.0039 | 0.0029 |
| Cotton | 0.324 | 1.00 | 0.010 | 0.003 | 3.77 | 0.58 | 0.0016 | 0.0044 |
| Oats | 2.723 | 0.74 | 0.010 | 0.015 | 3.95 | 0.56 | 0.0045 | 0.0042 |
| Soybeans | 10.464 | 0.06 | 0.063 | 0.069 | 16.01 | 0.01 | 0.0006 | 0.0022 |
| Soybean Meal | 3.878 | 0.57 | 0.057 | 0.064 | 11.48 | 0.04 | 0.0004 | 0.0032 |
| Soybean Oil | 6.861 | 0.23 | 0.051 | 0.040 | 12.15 | 0.03 | 0.0024 | 0.0039 |
| Sugar | 3.387 | 0.64 | 0.007 | 0.015 | 2.12 | 0.83 | 0.0124 | 0.0123 |
| Wheat | 1.807 | 0.88 | 0.009 | 0.012 | 1.78 | 0.88 | 0.0029 | 0.0029 |
| Lean Hogs | 4.640 | 0.46 | 0.023 | 0.030 | 5.19 | 0.39 | 0.0041 | 0.0029 |
| Lumber | 4.176 | 0.52 | 0.007 | 0.030 | 2.60 | 0.76 | 0.0002 | 0.0115 |
| Pork Bellies | 6.092 | 0.30 | 0.018 | 0.034 | 2.55 | 0.77 | 0.0078 | 0.0081 |
| All Agricultural ($\chi^2(77)$) | 62.324 | 0.89 | | $\chi^2(65)$ | 48.29 | 0.94 | | |
| **Panel B: Metal and Oil Commodities** | | | | | | | | |
| Gold | 15.885 | 0.01 | 0.055 | 0.091 | 13.85 | 0.02 | 0.0021 | 0.0020 |
| Heating Oil | 5.579 | 0.35 | 0.012 | 0.031 | 2.51 | 0.78 | 0.0031 | 0.0039 |
| Silver | 7.974 | 0.16 | 0.052 | 0.084 | 12.81 | 0.03 | -0.0010 | 0.0017 |
| Platinum | 1.352 | 0.93 | 0.091 | 0.041 | 16.44 | 0.01 | -0.0014 | 0.0046 |
| All Metal ($\chi^2(23)$) | 28.942 | 0.18 | | $\chi^2(20)$ | 32.19 | 0.04 | | |
| **Panel C: Financial** | | | | | | | | |
| NYSE | 9.965 | 0.08 | 0.028 | 0.052 | 7.07 | 0.22 | 0.0040 | 0.0112 |
| SP500 | 10.518 | 0.06 | 0.027 | 0.053 | 6.76 | 0.24 | 0.0043 | 0.0117 |
| Treasury-Bill | 2.611 | 0.76 | 0.029 | 0.079 | 5.77 | 0.33 | 0.0004 | 0.0005 |
| Treasury-Note | 3.918 | 0.56 | 0.039 | 0.044 | 8.25 | 0.14 | -0.0015 | 0.0029 |
| Treasury-Bond | 3.873 | 0.57 | 0.035 | 0.061 | 9.02 | 0.11 | -0.0016 | 0.0042 |
| Deutsch Mark | 2.458 | 0.78 | 0.020 | 0.041 | 5.41 | 0.37 | 0.0003 | 0.0034 |
| Japanese Yen | 2.616 | 0.76 | 0.039 | 0.037 | 10.01 | 0.07 | 0.0014 | 0.0053 |
| Swiss Franc | 1.417 | 0.92 | 0.016 | 0.023 | 3.59 | 0.61 | 0.0001 | 0.0035 |
| UK Pound | 3.156 | 0.68 | 0.013 | 0.035 | 4.12 | 0.53 | -0.0006 | 0.0002 |
| All Financial ($\chi^2(53)$) | 76.506 | 0.02 | | $\chi^2(45)$ | 51.27 | 0.24 | | |
| All Futures ($\chi^2(155)$) | 167.11 | 0.24 | | $\chi^2(130)$ | 141.95 | 0.22 | | |

(a) $\chi^2$ is the minimised value of the GMM criterion function, it tests the null hypothesis that the residuals from the GMM system are orthogonal to the instruments, p-value is the probability of rejecting the null hypothesis erroneously Unless specified otherwise, there are 12 orthogonality conditions and 7 parameters, leaving 5 overidentifying restrictions to be tested

(b) The first $R^2$ is the goodness-of-fit statistic from a regression of the residuals of the conditional asset pricing model on the instruments, the second $R^2$ is the goodness-of-fit statistic from a regression of futures returns on the instruments (table 4 4).

(c) $\chi^2$ is a heteroscedasticity and serial correlation consistent test of the null hypothesis that the coefficients of a regression of the conditional asset pricing residuals on the instruments are jointly zero, p-value is the associated probability of rejecting the null hypothesis when it is true Unless specified otherwise, the test is distributed as $\chi^2$ with 5 degrees of freedom

(d) $\overline{u3}$ is the average pricing error, E(R) is the average conditional return, measured as the mean of the fitted values from a regression of futures returns on the instruments formal test of the null hypothesis that the coefficients on the instruments (apart from the constant) are jointly zero is also reported. This test confirms our former analysis. For soybeans, soybean meal, soybean oil, gold, silver, platinum, and Japanese yen futures, the lagged instruments predict the conditional residuals. Similarly, the results within a group suggest that the null hypothesis of constant conditional residuals is rejected for metal futures. Once again, this suggests, at least as far as these futures are concerned, a failure of the conditional CAPM at picking up the predictable variation in futures returns.

Finally, the third specification test looks at the size of the average pricing error and compares it to the mean conditional futures return, measured as the mean of the fitted values of a regression of futures returns on the instruments. The former are generally smaller than the latter. The decrease in commodity futures means after accounting for time-varying covariances is however small. For example, the coffee average measure of mispricing equals the mean fitted return on the contract, suggesting that the model does not properly explain the time-variation in coffee futures returns. Similarly, the result for heating oil suggests that the mean pricing error equals 0.0031 while the mean expected return equals 0.0039. Hence the reduction in means is so small that the conditional CAPM most likely only picks up a small proportion of the predictable variation in heating oil futures returns. Note also that the pricing errors are mostly positive, suggesting hence that the conditional CAPM is underpricing.

To summarise our findings so far, it appears that the conditional CAPM with time-varying covariances fails to track the variation trough time in futures returns. Most importantly, the overidentifying restrictions are rejected for financial futures and the information variables predict some of the conditional residuals. Some alternative specification might therefore better describe the predictable variation in futures returns. We turn then our attention to the conditional CAPM with time-varying price of market risk.

## 2. Conditional CAPM with Time-Varying Expected Returns

We now allow the price of market risk to vary with the level of the information variables and impose the restrictions that the conditional betas are constant. We therefore assume that the variation trough time in the excess returns on the market portfolio explains the predictability of futures returns identified in chapter IV. The results are summarised in table 6.4.

The overidentifying restrictions in column 1 are accepted for 22 out of 26 futures contracts. The null hypothesis that the residuals of (6.7) are orthogonal to the instruments is rejected at the individual asset level for the futures contracts on soybeans, soybean meal, gold, and silver. Since equation (6.7) does not impose the restrictions that the time-variation in the excess return on the market index is common across futures, we stack the individual equations into four systems. The first three systems comprise agricultural, metal, and financial futures, while the last one considers the 26 futures included in this study. While we fail to reject the overidentifying restrictions for agricultural and metal futures, the results clearly indicate that the specification of the conditional CAPM with time-varying price of market risk fails to describe the predictable movements in financial futures returns (p-value of 0.01). The restrictions are also rejected when the system is estimated for the whole set of futures (p-value of 0.09). This rejection is somehow to be expected since the results in table 6.2 indicate that the excess returns on the market index is constant.

The following column reports the R-squared from a regression of the conditional residuals on the instruments. They are of similar amplitude as the R-squared of a regression of futures returns on the instruments. Hence the conditional CAPM with time-varying price of market risk is only explaining a small fraction of the total predictable variation in futures returns. Some of the goodness-of-fit statistics remain impressively high. For example, the R-squared for the conditional residuals on gold futures equals 9 percent. Similarly, the instruments explain 7.9 percent of the variation in the silver conditional residuals. It is not surprising then to reject the hypothesis that the coefficients of a regression of the conditional gold and silver residuals on the instruments are jointly zero. At the individual asset level, the hypothesis of constant conditional residuals is also

## Table 6.4: Properties of the Pricing Errors from the Conditional CAPM with Time-Varying Expected Returns and Constant Betas

| Futures Contracts | Overidentifying Restrictions | | Regression of $u3_{it}$ on the IV and Variable Deletion Test | | | | Average Pricing Error | |
|---|---|---|---|---|---|---|---|---|
| | $\chi^2$ (a) | p-value (a) | $R^2$ (b) | $R^2$(b) | $\chi^2$(c) | p-value (c) | $\overline{u3}$ (d) | E(R) (d) |
| **Panel A: Agricultural Commodities** | | | | | | | | |
| Cocoa | 2.798 | 0.73 | 0.015 | 0.015 | 3.35 | 0.65 | 0.0021 | 0.0028 |
| Coffee | 4.045 | 0.54 | 0.022 | 0.022 | 5.00 | 0.42 | 0.0048 | 0.0048 |
| Corn | 2.645 | 0.75 | 0.015 | 0.015 | 4.57 | 0.47 | 0.0014 | 0.0029 |
| Cotton | 0.928 | 0.97 | 0.004 | 0.003 | 1.98 | 0.85 | 0.0037 | 0.0044 |
| Oats | 2.754 | 0.74 | 0.015 | 0.015 | 6.15 | 0.29 | 0.0043 | 0.0042 |
| Soybeans | 10.240 | 0.07 | 0.052 | 0.069 | 10.11 | 0.07 | 0.0048 | 0.0022 |
| Soybean Meal | 9.497 | 0.09 | 0.045 | 0.064 | 11.12 | 0.05 | 0.0064 | 0.0032 |
| Soybean Oil | 7.271 | 0.20 | 0.038 | 0.040 | 9.91 | 0.08 | 0.0045 | 0.0039 |
| Sugar | 3.470 | 0.63 | 0.012 | 0.015 | 2.58 | 0.76 | 0.0137 | 0.0123 |
| Wheat | 2.035 | 0.84 | 0.008 | 0.012 | 1.78 | 0.88 | 0.0043 | 0.0029 |
| Lean Hogs | 4.099 | 0.54 | 0.024 | 0.030 | 5.77 | 0.33 | -0.0010 | 0.0029 |
| Lumber | 7.418 | 0.19 | 0.032 | 0.030 | 4.23 | 0.52 | 0.0107 | 0.0115 |
| Pork Bellies | 6.309 | 0.28 | 0.032 | 0.034 | 6.09 | 0.30 | 0.0091 | 0.0081 |
| All Agricultural ($\chi^2$(65)) | 55.844 | 0.78 | | $\chi^2$(65) | 55.05 | 0.81 | | |
| **Panel B: Metal and Oil Commodities** | | | | | | | | |
| Gold | 15.989 | 0.01 | 0.090 | 0.091 | 12.63 | 0.03 | 0.0024 | 0.0020 |
| Heating Oil | 5.412 | 0.37 | 0.031 | 0.031 | 5.32 | 0.38 | 0.0030 | 0.0039 |
| Silver | 13.800 | 0.02 | 0.079 | 0.084 | 17.53 | <0.01 | 0.0031 | 0.0017 |
| Platinum | 7.719 | 0.17 | 0.043 | 0.041 | 6.02 | 0.30 | 0.0029 | 0.0046 |
| All Metal ($\chi^2$(20)) | 27.634 | 0.12 | | $\chi^2$(20) | 29.24 | 0.08 | | |
| **Panel C: Financial** | | | | | | | | |
| NYSE | 7.634 | 0.18 | 0.021 | 0.052 | 4.36 | 0.50 | 0.0027* | 0.0112 |
| SP500 | 7.856 | 0.16 | 0.021 | 0.053 | 4.56 | 0.47 | 0.0028* | 0.0117 |
| Treasury-Bill | 5.912 | 0.31 | 0.034 | 0.079 | 4.92 | 0.43 | -0.0002 | 0.0005 |
| Treasury-Note | 7.894 | 0.16 | 0.046 | 0.044 | 9.75 | 0.08 | -0.0001 | 0.0029 |
| Treasury-Bond | 8.436 | 0.13 | 0.049 | 0.061 | 9.82 | 0.08 | 0.0005 | 0.0042 |
| Deutsch Mark | 8.086 | 0.15 | 0.041 | 0.041 | 5.72 | 0.33 | 0.0026 | 0.0034 |
| Japanese Yen | 6.633 | 0.25 | 0.033 | 0.037 | 6.03 | 0.30 | 0.0029 | 0.0053 |
| Swiss Franc | 5.024 | 0.41 | 0.024 | 0.023 | 3.24 | 0.66 | 0.0027 | 0.0035 |
| UK Pound | 5.015 | 0.41 | 0.027 | 0.035 | 6.15 | 0.29 | 0.0016 | 0.0002 |
| All Financial ($\chi^2$(45)) | 71.288 | 0.01 | | $\chi^2$(45) | 69.57 | 0.01 | | |
| All Futures ($\chi^2$(130)) | 152.18 | 0.09 | | $\chi^2$(130) | 162.71 | 0.03 | | |

(a) $\chi^2$ is the minimised value of the GMM criterion function, it tests the null hypothesis that the residuals from the GMM system are orthogonal to the instruments, p-value is the probability of rejecting the null hypothesis erroneously Unless specified otherwise, there are 6 orthogonality conditions and 1 parameter, leaving 5 overidentifying restrictions to be tested

(b) The first $R^2$ is the goodness-of-fit statistic from a regression of the residuals of the conditional asset pricing model on the instruments, the second $R^2$ is the goodness-of-fit statistic from a regression of futures returns on the instruments (table 4 4)

(c) $\chi^2$ is a heteroscedasticity and serial correlation consistent test of the null hypothesis that the coefficients of a regression of the conditional asset pricing residuals on the instruments are jointly zero, p-value is the associated probability of rejecting the null hypothesis when it is true Unless specified otherwise, the test is distributed as $\chi^2$ with 5 degrees of freedom

(d) $\overline{u3}$ is the average pricing error, E(R) is the average conditional return, measured as the mean of the fitted values from a regression of futures returns on the instruments

* denotes significant at the 5 percent level

rejected for the futures on soybeans, soybean meal, soybean oil, Treasury-note, and Treasury bond. When stacked into groups, the metal and financial residuals fail to meet the basic requirements of being unrelated to the instruments. The same conclusion applies to the whole set of conditional residuals. Hence, the evidence presented in table 6.4 clearly indicate that the conditional CAPM with time-varying price of market risk fails to describe the predictable movements in futures returns.

The size of the average pricing error in table 6.4 column 3 is similar to the size of the mean fitted returns. At least as far as agricultural and metal futures are concerned, the reduction in means after accounting for the time variation in the market price of risk is very small. This suggests, once again, that the conditional CAPM fails to pick up all of the movements in the expected returns of agricultural and metal futures. In spite of the statistical significance of the average pricing errors for the NYSE and SP500 futures, the conditional CAPM seems to fare better for financial futures. Altogether, the results presented here suggest that the conditional CAPM fails to describe the predictable time variation in futures returns. Most importantly, when the whole sample is considered, the overidentifying restrictions are rejected and the instruments explain the conditional residuals. We now turn our focus on the conditional CAPM with time-varying market price of risk and time-varying covariances.

### 3. Conditional CAPM with Time-Varying Moments

To date we reject the specifications that allow for either the conditional covariances or the conditional price of market risk to vary with the information set available at time t-1. If the conditional means, variances, and covariances are time-varying (while we assumed so far that at least one of the moments was constant), then the residuals in the models estimated above might well be correlated with the instruments. The tests mentioned above rely on a joint hypothesis that specifies that the conditional CAPM captures the predictability of the futures returns and is correctly specified. Namely, rejecting the orthogonality restrictions does not necessarily imply that the conditional CAPM fails to explain the predictable variation in futures returns, as any incorrect assumption about the nature of the predictability in futures markets might result in wrong inferences regarding the ability of the conditional CAPM to explain the predictability of futures returns. In this section therefore we assume that all the parameters in equation (6.1) are time-varying and test whether the pattern of forecastability is consistent with a conditional version of the CAPM that assumes time-varying means, variances, and covariances. Table 6.5 summarises the results.

With respect to the hypothesis that the overidentifying restrictions hold, the conditional CAPM residuals fail to meet the basic requirements of being orthogonal to the instruments for the futures contracts on soybeans, soybean meal, gold, silver, NYSE, and SP500 at the individual level and for the group of financial futures.[8] The expected variation in these futures is too wide to be accounted for in terms of conditional market risk premium and conditional risk exposure. It follows that the conditional CAPM fails to describe the predictable movements in futures returns.

With relatively few exceptions, the goodness-of-fit statistics from a regression of the conditional CAPM residuals on the instruments are smaller than the R-squared from a regression of futures returns on the instruments. However the reduction in R-squared is usually small, which suggests that the conditional CAPM might not pick up all of the variation through time in futures returns. In particular, the results for the stock index futures contracts indicate that the conditional residuals are highly predictable. When the null hypothesis of constant conditional residuals is tested for groups of futures, the $\chi^2$ statistics point towards the conclusion that the conditional residuals on financial futures are highly predictable. The same conclusion applies for the whole cross section. This suggests once again that the conditional CAPM does not accurately proxy for the predictable movements in futures returns. The average pricing errors however are extremely small compared to the mean fitted returns. With respect to this hypothesis therefore, the conditional CAPM seems to fit properly.

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[8] It is not computationally feasible to estimate (6.9) for the whole cross section of futures. Hence the restriction that that the sensitivities of the market portfolio excess returns to the instruments are the same across assets could not be tested. Similar conclusions apply for the conditional APT model with time-varying moments.

# Table 6.5: Properties of the Pricing Errors from the Conditional CAPM with Time-Varying Means, Variances, and Covariances

| Futures Contracts | Overidentifying Restrictions | | Regression of $u3_{it}$ on the IV and Variable Deletion Test | | | | Average Pricing Error | |
|---|---|---|---|---|---|---|---|---|
| | $\chi^2$ (a) | p-value (a) | $R^2$ (b) | $R^2$ (b) | $\chi^2$ (c) | p-value (c) | $\overline{u3}$ (d) | E(R) (d) |
| **Panel A: Agricultural Commodities** | | | | | | | | |
| Cocoa | 3.172 | 0.79 | 0.015 | 0.015 | 3.12 | 0.68 | 0.0000000 | 0.0028 |
| Coffee | 3.503 | 0.74 | 0.016 | 0.022 | 4.48 | 0.48 | 0.0000006 | 0.0048 |
| Corn | 2.755 | 0.84 | 0.009 | 0.015 | 2.37 | 0.80 | 0.0000003 | 0.0029 |
| Cotton | 1.041 | 0.98 | 0.010 | 0.003 | 2.58 | 0.76 | 0.0000005 | 0.0044 |
| Oats | 3.383 | 0.76 | 0.017 | 0.015 | 3.01 | 0.70 | 0.0000002 | 0.0042 |
| Soybeans | 11.603 | 0.07 | 0.014 | 0.069 | 1.99 | 0.85 | 0.0000002 | 0.0022 |
| Soybean Meal | 11.908 | 0.06 | 0.042 | 0.064 | 5.47 | 0.36 | 0.0000015 | 0.0032 |
| Soybean Oil | 5.974 | 0.43 | 0.025 | 0.040 | 2.22 | 0.82 | 0.0000002 | 0.0039 |
| Sugar | 2.161 | 0.90 | 0.032 | 0.015 | 7.73 | 0.17 | 0.0000036 | 0.0123 |
| Wheat | 2.159 | 0.90 | 0.007 | 0.012 | 2.95 | 0.71 | 0.0000000 | 0.0029 |
| Lean Hogs | 5.331 | 0.50 | 0.019 | 0.030 | 4.89 | 0.43 | 0.0000001 | 0.0029 |
| Lumber | 7.961 | 0.24 | 0.012 | 0.030 | 4.16 | 0.53 | 0.0000017 | 0.0115 |
| Pork Bellies | 7.707 | 0.26 | 0.026 | 0.034 | 2.03 | 0.84 | 0.0000017 | 0.0081 |
| All Agricultural ($\chi^2(78)$) | 61.735 | 0.91 | | $\chi^2(65)$ | 63.76 | 0.52 | | |
| **Panel B: Metal and Oil Commodities** | | | | | | | | |
| Gold | 14.394 | 0.03 | 0.034 | 0.091 | 6.01 | 0.31 | -0.000001 | 0.0020 |
| Heating Oil | 6.065 | 0.42 | 0.015 | 0.031 | 1.69 | 0.89 | 0.0000020 | 0.0039 |
| Silver | 10.813 | 0.09 | 0.020 | 0.084 | 4.28 | 0.51 | 0.0000007 | 0.0017 |
| Platinum | 6.277 | 0.39 | 0.010 | 0.041 | 1.13 | 0.95 | 0.0000019 | 0.0046 |
| All Metal ($\chi^2(24)$) | 29.462 | 0.20 | | $\chi^2(20)$ | 21.42 | 0.37 | | |
| **Panel C: Financial** | | | | | | | | |
| NYSE | 46.845 | <0.01 | 0.118 | 0.052 | 22.42 | <0.01 | 0.0000002 | 0.0112 |
| SP500 | 61.724 | <0.01 | 0.040 | 0.053 | 10.49 | 0.06 | -0.00001* | 0.0117 |
| Treasury-Bill | 10.205 | 0.12 | 0.018 | 0.079 | 5.66 | 0.34 | 0.0000000 | 0.0005 |
| Treasury-Note | 9.274 | 0.16 | 0.046 | 0.044 | 7.51 | 0.19 | 0.0000001 | 0.0029 |
| Treasury-Bond | 7.679 | 0.26 | 0.044 | 0.061 | 7.88 | 0.16 | 0.0000003 | 0.0042 |
| Deutsch Mark | 8.622 | 0.20 | 0.021 | 0.041 | 3.54 | 0.62 | 0.0000001 | 0.0034 |
| Japanese Yen | 9.648 | 0.14 | 0.040 | 0.037 | 2.69 | 0.75 | 0.0000002 | 0.0053 |
| Swiss Franc | 6.190 | 0.40 | 0.027 | 0.023 | 4.10 | 0.54 | 0.0000001 | 0.0035 |
| UK Pound | 6.635 | 0.36 | 0.025 | 0.035 | 5.48 | 0.36 | -0.000001 | 0.0002 |
| All Financial ($\chi^2(54)$) | 121.24 | <0.01 | | $\chi^2(45)$ | 93.22 | <0.01 | | |
| All Futures | | | | $\chi^2(130)$ | 260.08 | <0.01 | | |

(a) $\chi^2$ is the minimised value of the GMM criterion function, it tests the null hypothesis that the residuals from the GMM system are orthogonal to the instruments, p-value is the probability of rejecting the null hypothesis erroneously Unless specified otherwise, there are 18 orthogonality conditions and 12 parameters, leaving 6 overidentifying restrictions to be tested

(b) The first $R^2$ is the goodness-of-fit statistic from a regression of the residuals of the conditional asset pricing model on the instruments, the second $R^2$ is the goodness-of-fit statistic from a regression of futures returns on the instruments (table 4 4)

(c) $\chi^2$ is a heteroscedasticity and serial correlation consistent test of the null hypothesis that the coefficients of a regression of the conditional asset pricing residuals on the instruments are jointly zero, p-value is the associated probability of rejecting the null hypothesis when it is true Unless specified otherwise the test is distributed as $\chi^2$ with 5 degrees of freedom

(d) $\overline{u3}$ is the average pricing error, E(R) is the average conditional return, measured as the mean of the fitted values from a regression of futures returns on the instruments

* denotes significant at the 1 percent level

The evidence presented in this section indicate that conditional versions of the CAPM fail to describe the predictable movements in futures returns. This inference is robust to different assumptions regarding the source of predictability in futures markets. Figures 6.1 to 6.3 plot the security market line for the three specifications of the conditional CAPM. Figure 6.1 plots the relationship between mean futures returns and average conditional covariances[9] from the model with time-varying covariances and constant price of covariance risk. Figure 6.2 reports similar results for the specification with constant conditional betas and time-varying price of market risk. Finally, figure 6.3 plots the relationship between mean conditional covariances and actual mean returns for the conditional CAPM with time-varying moments. The CAPM assumes a linear upward-sloping ordering between systematic risk measures (betas or average covariances) and mean returns. It is clear from these figures that the security market lines are non-linear and upward-sloping for only half of the contracts. A careful look at the data indicates that commodity futures mainly present a risk-return relationship that fails to be consistent with the trade-off implied by the conditional CAPM.

The results presented in this section are consistent with the evidence in McCurdy and Morgan (1991, 1992) for currency futures. Evans (1994) concludes that, with the NYSE stocks as a proxy for the true market portfolio, the conditional CAPM also fails to account for all of the variation in the expected excess returns on stocks, bills and bonds. Harvey (1991) reports similar conclusions for international equity excess returns.[10] The inability of the conditional CAPM to describe the variation through time in expected futures returns parallels the failure of the traditional CAPM to price futures contracts (evidenced in chapter II) and is also consistent with the conditional CAPM literature in the stocks market and the market for fixed-income securities.

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[9] The average conditional covariances are measured as the mean of the cross-product of the unconditional futures returns and the market portfolio conditional residuals ($u2_tR_t$ in (6.4)). Of course such estimates are not completely meaningful in a conditional asset pricing framework where time-varying covariances are assumed. If the conditional pricing models are to explain the predictability of futures returns, we should test the null hypothesis that the conditional covariances are *at each point in time* positively and linearly related to actual returns. We hope nonetheless that the security market lines plotted hereafter will support the positive linear trade-off implied by the CAPM.

[10] Harvey (1991) shows that the predictable variation in stock index returns is not totally captured by conditional international versions of the CAPM. In particular, the models' restrictions are consistently rejected for Japan.

Figure 6.1: Security Market Line: Conditional CAPM with Time-Varying Covariances and Constant Price of Covariance Risk

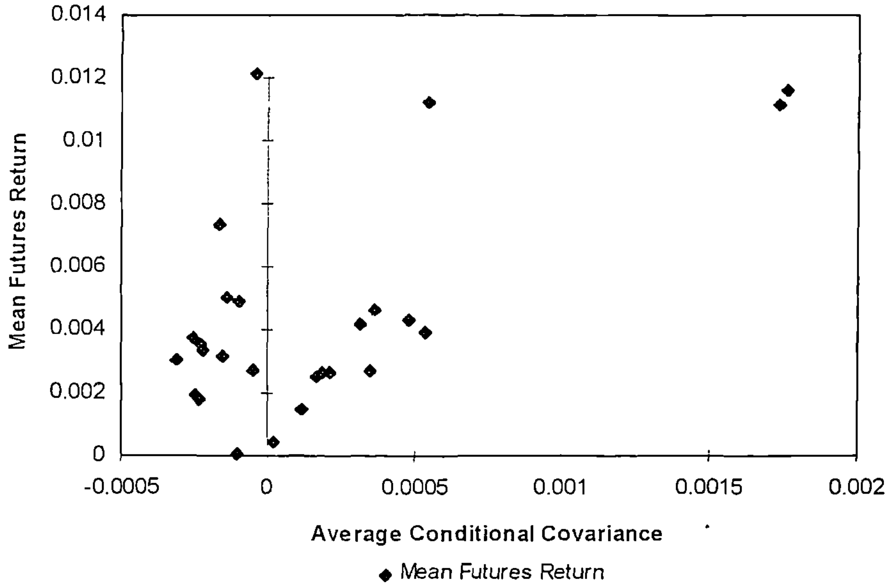


Figure 6.2: Security Market Line: Conditional CAPM with Time-Varying Price of Market Risk and Constant Conditional Betas

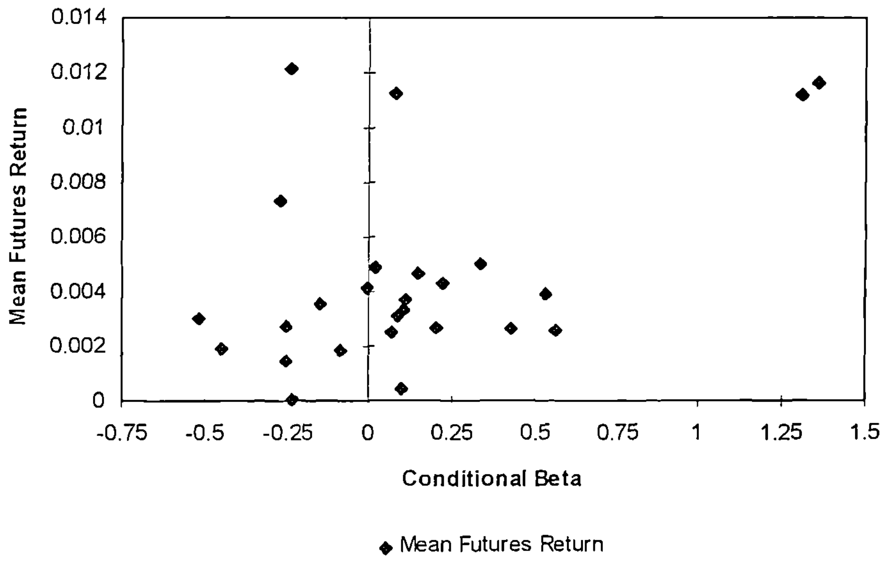
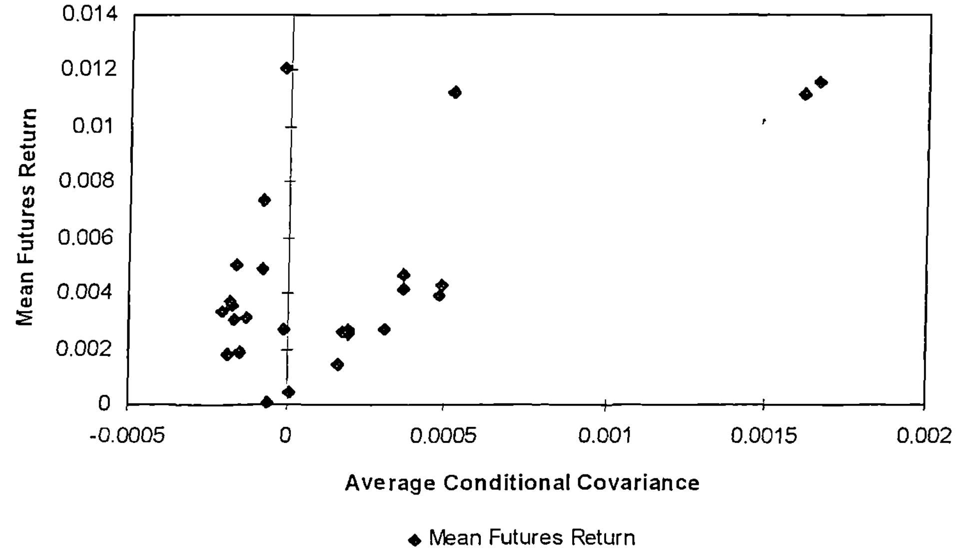


Figure 6.3: Security Market Line: Conditional CAPM with Time-Varying Expected Returns, Variances, and Covariances



# VI. Empirical Results: the Conditional Arbitrage Pricing Theory

Given the failure of the conditional CAPM in capturing the change in expected futures returns, we now turn our attention to conditional versions of the APT. The rationale for so doing is that a more dissagregate risk structure might be a better proxy for the predictable variation in futures returns. Multiple risk factors might indeed capture the change in the investment opportunity set over time better than the conditional market portfolio. The risk factors we consider are the mimicking portfolios on term and default spreads, unexpected inflation, the change in expected inflation, and the unexpected change in industrial production. To test the ability of conditional multifactor models to explain the predictable movements in futures returns, we undertake the same tests as in section 5. Tables 6.6, 6.7, and 6.8 report tests of the properties of the conditional pricing errors for each specification of the conditional APT. The results from the conditional multifactor model with time-varying covariances and constant prices of covariance risk are summarised in table 6.6; the evidence for the conditional APT with time-varying prices of risk and constant betas are displayed in table 6.7; finally, table 6.8 recapitulates the results for the conditional APT with time-varying means, variances, and covariances.

## 1. Conditional APT with Time-Varying Covariances

Table 6.6 assumes that the covariances between the asset returns and the excess returns on the factor mimicking portfolios are time-varying and constraints the prices of covariance risk to be constant (system (6.4)). Under this specification, the sensitivities of futures returns to the rewards per unit of covariance risk are assumed to be the only source of predictability in futures returns.

With only one exception (soybean oil futures), the overidentifying restrictions are accepted at the individual asset level, for groups of futures, and when the whole set of 26 futures contracts is considered. Hence the combination of the Chen, Roll, and Ross (1986) factors is conditionally mean-variance efficient and the specification of the conditional APT with time-varying covariances and constant rewards to systematic risk does a very good job at explaining the predictable component of futures returns. This result is somehow to be expected since the results in table 6.1 indicate that the conditional covariances between futures returns and the excess returns on the factor mimicking portfolios are time-varying.

Leaving out the futures on soybean meal, the results in column 2 suggest that the conditional residuals are consistently unrelated to the instruments. Besides the goodness-of-fit statistics of a regression of the conditional asset pricing residuals on the instruments are generally smaller than the R-squared of a regression of futures returns on the instruments. This suggests that the predictable variation in futures returns that are not picked up by the model are small compared to the total predictable variation in futures returns. Consistent with the above is the result that the null hypothesis of constant conditional residuals is accepted at the individual asset level, within groups, and for the whole cross-section.

Finally, according to column 3, the average pricing errors are in all cases smaller than the mean fitted returns. For example, the average pricing error for the whole set of agricultural futures only equals 0.05 percent. The model appears to fit quite well for the financial futures too with an average pricing error within the group that is less than 0.01 percent. This compares favourably with the mean fitted returns within each group (equal to 0.51 and 0.48 percents for the agricultural and financial futures respectively). This suggests once again that the model does a good job at tracking the predictable variation in futures returns. Hence the restrictions imposed by the conditional multifactor model with time-varying covariances and constant rewards of covariance risk seem to be a valid representation of the predictable movements in futures returns.

## 2. Conditional APT with Time-Varying Expected Returns

In table 6.2 we rejected the hypothesis that the price of risk associated with the term structure of interest rates is constant. Hence time-variation in the risk premia associated

# Table 6.6: Properties of the Pricing Errors from the Conditional APT Model with Time-Varying Covariances and Constant Prices of Covariance Risk

| Futures Contracts | Overidentifying Restrictions | | Regression of $u3_{it}$ on the IV and Variable Deletion Test | | | | Average Pricing Error | |
|---|---|---|---|---|---|---|---|---|
| | $\chi^2$ (a) | p-value (a) | $R^2$ (b) | $R^2$(b) | $\chi^2$(c) | p-value (c) | $\overline{u3}$ (d) | E(R) (d) |
| **Panel A: Commodities** | | | | | | | | |
| Cocoa | 0.004 | 0.95 | 0.007 | 0.015 | 0.85 | 0.97 | 0.0005 | 0.0028 |
| Coffee | 0.116 | 0.73 | 0.018 | 0.022 | 4.17 | 0.52 | 0.0010 | 0.0048 |
| Corn | 1.024 | 0.31 | 0.014 | 0.015 | 4.67 | 0.46 | 0.0000 | 0.0029 |
| Cotton | 0.048 | 0.83 | 0.018 | 0.003 | 8.60 | 0.13 | 0.0007 | 0.0044 |
| Oats | 0.442 | 0.51 | 0.012 | 0.015 | 2.60 | 0.76 | 0.0003 | 0.0042 |
| Soybeans | 0.343 | 0.56 | 0.029 | 0.069 | 4.75 | 0.45 | -0.0019 | 0.0022 |
| Soybean Meal | 0.056 | 0.81 | 0.054 | 0.064 | 9.44 | 0.09 | 0.0014 | 0.0032 |
| Soybean Oil | 2.796 | 0.09 | 0.048 | 0.040 | 7.62 | 0.18 | -0.0010 | 0.0039 |
| Sugar | 0.006 | 0.94 | 0.006 | 0.015 | 0.92 | 0.97 | 0.0006 | 0.0123 |
| Wheat | 0.005 | 0.94 | 0.042 | 0.012 | 6.26 | 0.28 | 0.0002 | 0.0029 |
| Lean Hogs | 0.386 | 0.53 | 0.024 | 0.030 | 3.71 | 0.59 | 0.0024 | 0.0029 |
| Lumber | 0.001 | 0.98 | 0.002 | 0.030 | 0.72 | 0.98 | 0.0000 | 0.0115 |
| Pork Bellies | 0.262 | 0.61 | 0.009 | 0.034 | 1.90 | 0.86 | 0.0027 | 0.0081 |
| All Agricultural ($\chi^2$(73)) | 57.920 | 0.90 | | $\chi^2$(65) | 49.58 | 0.92 | | |
| **Panel B: Metal and Oil** | | | | | | | | |
| Gold | 0.107 | 0.74 | 0.045 | 0.091 | 6.85 | 0.23 | -0.0014 | 0.0020 |
| Heating Oil | 0.071 | 0.79 | 0.009 | 0.031 | 1.66 | 0.89 | -0.0011 | 0.0039 |
| Silver | 0.052 | 0.82 | 0.025 | 0.084 | 2.91 | 0.71 | 0.0008 | 0.0017 |
| Platinum | 0.539 | 0.46 | 0.031 | 0.041 | 7.87 | 0.16 | 0.0017 | 0.0046 |
| All Metal ($\chi^2$(19)) | 21.800 | 0.29 | | $\chi^2$(20) | 17.77 | 0.60 | | |
| **Panel C: Financial** | | | | | | | | |
| NYSE | 0.291 | 0.59 | 0.008 | 0.052 | 2.51 | 0.77 | 0.0005 | 0.0112 |
| SP500 | 0.200 | 0.65 | 0.010 | 0.053 | 2.88 | 0.72 | 0.0004 | 0.0117 |
| Treasury-Bill | 0.043 | 0.84 | 0.034 | 0.079 | 4.72 | 0.45 | 0.0000 | 0.0005 |
| Treasury-Note | 1.120 | 0.29 | 0.038 | 0.044 | 6.28 | 0.28 | 0.0001 | 0.0029 |
| Treasury-Bond | 0.768 | 0.38 | 0.014 | 0.061 | 4.50 | 0.48 | -0.0003 | 0.0042 |
| Deutsch Mark | 0.007 | 0.93 | 0.009 | 0.041 | 1.62 | 0.90 | 0.0009 | 0.0034 |
| Japanese Yen | 0.185 | 0.67 | 0.012 | 0.037 | 2.23 | 0.82 | 0.0006 | 0.0053 |
| Swiss Franc | 0.003 | 0.96 | 0.005 | 0.023 | 1.30 | 0.93 | 0.0002 | 0.0035 |
| UK Pound | 0.065 | 0.80 | 0.007 | 0.035 | 1.87 | 0.87 | -0.0015 | 0.0002 |
| All Financial ($\chi^2$(49)) | 46.976 | 0.56 | | $\chi^2$(45) | 30.16 | 0.96 | | |
| All Futures ($\chi^2$(151)) | 157.03 | 0.35 | | $\chi^2$(130) | 105.96 | 0.94 | | |

(a) $\chi^2$ is the minimised value of the GMM criterion function, it tests the null hypothesis that the residuals from the GMM system are orthogonal to the instruments. p-value is the probability of rejecting the null hypothesis erroneously Unless specified otherwise, there are 36 orthogonality conditions and 35 parameters, leaving 1 overidentifying restriction to be tested

(b) The first $R^2$ is the goodness-of-fit statistic from a regression of the residuals of the conditional asset pricing model on the instruments, the second $R^2$ is the goodness-of-fit statistic from a regression of futures returns on the instruments (table 4 4)

(c) $\chi^2$ is a heteroscedasticity and serial correlation consistent test of the hypothesis that the conditional residuals are constant, p-value is the associated probability of rejecting the null hypothesis when it is true Unless specified otherwise, the test is distributed as $\chi^2$ with 5 degrees of freedom

(d) $\overline{u3}$ is the average pricing error, E(R) is the average conditional return, measured as the mean fitted returns from a regression of futures returns on the instruments

with the APT factors could also account for some of the predictable movements in futures returns. This offers us some incentive to test whether the pattern of forecastability identified in chapter IV is consistent with a conditional version of the APT that assumes time variation in the excess returns on the mimicking portfolios. In this section, we estimate equation (6.7) and therefore impose the restrictions that the conditional betas are constant. The results are presented in table 6.7.

The results from the tests of the overidentifying restrictions are consistent with our earlier findings regarding the conditional CAPM with time-varying price of market risk. The restrictions in column 1 are accepted for 24 out of 26 futures. The hypothesis that the conditional residuals are orthogonal to the instruments is rejected at the individual asset level for the silver and Standard & Poor's 500 futures, for the group of financial futures, and for the whole set of futures. This suggests that the specification of the conditional APT with time-varying prices of risk and constant betas fails to describe the variation through time in expected futures returns. Such a result is consistent with the hypothesis that the prices of risk associated unexpected inflation, change in expected inflation, default spread, and industrial production are constant (table 3).

With respect to the other hypotheses, the conditional APT seems however to fare remarkably well. The goodness-of-fit statistics from regressions of the conditional residuals on the instruments consistently suggest that the model explains the predictable movements in futures returns. The null hypothesis that the conditional residuals are unrelated to the instruments is also systematically accepted at the individual asset level, within each group, and for the whole cross-section. The p-values in column 2, table 6.7 indicate that the probability of erroneously rejecting the null hypothesis equals on average 0.91 at the individual asset level. Hence the failure to reject is very strong. The average pricing errors also point us towards the conclusion that the model fares exceptionally well. The average conditional residuals are indeed small compared to the mean fitted returns. Hence the part of the predictable variation that is explained by the model is larger than the part of the predictable variation that is relegated to the residuals.

# Table 6.7: Properties of the Pricing Errors from the Conditional APT Model with Time-Varying Expected Returns and Constant Betas

| Futures Contracts | Overidentifying Restrictions | | Regression of $u3_{it}$ on the IV and Variable Deletion Test | | | | Average Pricing Error | |
|---|---|---|---|---|---|---|---|---|
| | $\chi^2$ (a) | p-value (a) | $R^2$ (b) | $R^2$ (b) | $\chi^2$ (c) | p-value (c) | $\overline{u3}$ (d) | E(R) (d) |
| **Panel A: Agricultural Commodities** | | | | | | | | |
| Cocoa | 0.760 | 0.38 | 0.004 | 0.015 | 0.73 | 0.98 | -0.0011 | 0.0028 |
| Coffee | 0.053 | 0.82 | 0.000 | 0.022 | 0.26 | 1.00 | 0.0003 | 0.0048 |
| Corn | 0.107 | 0.74 | 0.001 | 0.015 | 0.16 | 1.00 | -0.0010 | 0.0029 |
| Cotton | 0.164 | 0.69 | 0.001 | 0.003 | 0.59 | 0.99 | 0.0011 | 0.0044 |
| Oats | 0.026 | 0.87 | 0.000 | 0.015 | 0.07 | 1.00 | 0.0004 | 0.0042 |
| Soybeans | 1.027 | 0.31 | 0.006 | 0.069 | 1.23 | 0.94 | -0.0011 | 0.0022 |
| Soybean Meal | 0.107 | 0.74 | 0.001 | 0.064 | 0.49 | 0.99 | 0.0003 | 0.0032 |
| Soybean Oil | 1.314 | 0.25 | 0.007 | 0.040 | 1.42 | 0.92 | -0.0018 | 0.0039 |
| Sugar | 0.045 | 0.83 | 0.000 | 0.015 | 0.05 | 1.00 | -0.0014 | 0.0123 |
| Wheat | 0.211 | 0.65 | 0.001 | 0.012 | 0.35 | 1.00 | -0.0006 | 0.0029 |
| Lean Hogs | 1.175 | 0.28 | 0.007 | 0.030 | 1.42 | 0.92 | 0.0027 | 0.0029 |
| Lumber | 0.170 | 0.68 | 0.001 | 0.030 | 0.47 | 0.99 | -0.0022 | 0.0115 |
| Pork Bellies | 0.166 | 0.68 | 0.001 | 0.034 | 0.36 | 1.00 | -0.0004 | 0.0081 |
| All Agricultural ($\chi^2(13)$) | 8.694 | 0.80 | | $\chi^2(65)$ | 9.78 | 1.00 | | |
| **Panel B: Metal and Oil Commodities** | | | | | | | | |
| Gold | 1.817 | 0.18 | 0.010 | 0.091 | 2.04 | 0.84 | -0.0011 | 0.0020 |
| Heating Oil | 1.937 | 0.16 | 0.011 | 0.031 | 2.54 | 0.77 | 0.0034 | 0.0039 |
| Silver | 4.221 | 0.04 | 0.023 | 0.084 | 3.98 | 0.55 | -0.0037 | 0.0017 |
| Platinum | 2.119 | 0.15 | 0.012 | 0.041 | 1.93 | 0.86 | -0.0018 | 0.0046 |
| All Metal ($\chi^2(4)$) | 5.819 | 0.21 | | $\chi^2(20)$ | 6.00 | 1.00 | | |
| **Panel C: Financial** | | | | | | | | |
| NYSE | 2.336 | 0.13 | 0.013 | 0.052 | 2.89 | 0.72 | 0.0003 | 0.0112 |
| SP500 | 4.505 | 0.03 | 0.025 | 0.053 | 5.65 | 0.34 | 0.0005 | 0.0117 |
| Treasury-Bill | 0.162 | 0.69 | 0.001 | 0.079 | 0.19 | 1.00 | -0.0002 | 0.0005 |
| Treasury-Note | 0.030 | 0.86 | 0.000 | 0.044 | 0.07 | 1.00 | -0.0002 | 0.0029 |
| Treasury-Bond | 0.000 | 0.98 | 0.000 | 0.061 | 0.07 | 1.00 | 0.0000 | 0.0042 |
| Deutsch Mark | 0.691 | 0.41 | 0.004 | 0.041 | 0.96 | 0.97 | 0.0010 | 0.0034 |
| Japanese Yen | 0.190 | 0.66 | 0.001 | 0.037 | 0.21 | 1.00 | -0.0003 | 0.0053 |
| Swiss Franc | 0.657 | 0.42 | 0.004 | 0.023 | 1.00 | 0.96 | 0.0009 | 0.0035 |
| UK Pound | 0.969 | 0.33 | 0.005 | 0.035 | 0.87 | 0.97 | 0.0010 | 0.0002 |
| All Financial ($\chi^2(9)$) | 20.737 | 0.01 | | $\chi^2(45)$ | 22.50 | 1.00 | | |
| All Futures ($\chi^2(26)$) | 41.853 | 0.03 | | $\chi^2(130)$ | 53.96 | 1.00 | | |

(a) $\chi^2$ is the minimised value of the GMM criterion function. it tests the null hypothesis that the residuals from the GMM system are orthogonal to the instruments. p-value is the probability of rejecting the null hypothesis erroneously Unless specified otherwise, there are 6 orthogonality conditions and 5 parameters. leaving 1 overidentifying restriction to be tested

(b) The first $R^2$ is the goodness-of-fit statistic from a regression of the residuals of the conditional asset pricing model on the instruments, the second $R^2$ is the goodness-of-fit statistic from a regression of futures returns on the instruments (table 4 4)

(c) $\chi^2$ is a heteroscedasticity and serial correlation consistent test of the hypothesis that the conditional residuals are constant, p-value is the associated probability of rejecting the null hypothesis when it is true Unless specified otherwise, the test is distributed as $\chi^2$ with 5 degrees of freedom

(d) $\overline{u3}$ is the average pricing error, E(R) is the average conditional return, measured as the mean fitted returns from a regression of futures returns on the instruments

## 3. Conditional APT with Time-Varying Moments

We finally turn our attention to a conditional version of the APT that assumes time-varying means, variances, and covariances. In this purpose we therefore estimate system (6.9), thereby assuming that all the parameters in equation (6.1) are time-varying. Table 6.8 summarises the results.

The results indicate that the overidentifying restrictions do not hold at the individual asset level for the futures on coffee and sugar. Hence, the evidence at the individual futures level suggest that the combination of the prespecified pervasive factors is not conditionally mean-variance efficient. Since the estimation of system (6.9) at the individual futures level does not impose the cross-sectional restriction that the conditionally expected prices of pervasive risk to the conditional variance of the pervasive factors are the same across futures ($\gamma_i=\gamma$ in (6.9)), we estimate (6.9) for groups of futures. The results clearly indicate that, irrespectively of the group considered, the conditional residuals fail to meet the basic requirements of being orthogonal to the instruments. Hence the conditional APT with time-varying means, variances, and covariances fails to describe the predictable movements in futures returns.

These considerations notwithstanding, the conditional residuals are unpredictable and the hypothesis of constant conditional residuals is sustained at the individual asset level, for groups of futures, and for the whole cross-section (table 6.8, column 2). This confirms that the rejection of the overidentifying restrictions for groups of futures in column 1 reflects the fact that the restrictions of an unique vector of sensitivities of the mimicking portfolio excess returns to the instruments within a group ($\gamma$ in (6.9)) does not hold. The results in column 3 confirm the failure of the conditional APT to describe the variation in expected futures returns. The average pricing errors are indeed well above the mean fitted returns in absolute term. In sum the model with time-varying expected returns, variances, and covariances seems to be doing worse than the model with constant prices of covariance risk.

# Table 6.8: Properties of the Pricing Errors from the Conditional APT Model with Time-Varying Means, Variances, and Covariances

| Futures Contracts | Overidentifying Restrictions | | Regression of $u3_{it}$ on the IV and Variable Deletion Test | | | | Average Pricing Error | |
|---|---|---|---|---|---|---|---|---|
| | $\chi^2$ (a) | p-value (a) | $R^2$ (b) | $R^2$ (b) | $\chi^2$ (c) | p-value (c) | $\overline{u3}$ (d) | E(R) (d) |
| **Panel A: Agricultural Commodities** | | | | | | | | |
| Cocoa | 7.296 | 0.29 | 0.016 | 0.015 | 6.44 | 0.27 | 0.2107 | 0.0028 |
| Coffee | 15.876 | 0.01 | 0.019 | 0.022 | 3.16 | 0.68 | 0.9290 | 0.0048 |
| Corn | 0.437 | 1.00 | 0.026 | 0.015 | 2.35 | 0.80 | 0.1075 | 0.0029 |
| Cotton | 3.261 | 0.78 | 0.025 | 0.003 | 2.39 | 0.79 | 0.1518 | 0.0044 |
| Oats | 1.507 | 0.96 | 0.028 | 0.015 | 4.69 | 0.45 | -0.9999 | 0.0042 |
| Soybeans | 1.222 | 0.98 | 0.020 | 0.069 | 3.75 | 0.59 | -0.2330 | 0.0022 |
| Soybean Meal | 0.293 | 1.00 | 0.006 | 0.064 | 1.39 | 0.93 | -0.0390 | 0.0032 |
| Soybean Oil | 8.374 | 0.21 | 0.048 | 0.040 | 3.40 | 0.64 | 0.1507 | 0.0039 |
| Sugar | 27.794 | <0.01 | 0.022 | 0.015 | 5.13 | 0.40 | -1.3711 | 0.0123 |
| Wheat | 0.095 | 1.00 | 0.039 | 0.012 | 4.84 | 0.44 | -0.0240 | 0.0029 |
| Lean Hogs | 0.913 | 0.99 | 0.005 | 0.030 | 6.47 | 0.26 | -0.4648 | 0.0029 |
| Lumber | 4.982 | 0.55 | 0.010 | 0.030 | 5.10 | 0.40 | 0.3607 | 0.0115 |
| Pork Bellies | 0.318 | 1.00 | 0.008 | 0.034 | 2.13 | 0.83 | -0.0665 | 0.0081 |
| All Agricultural ($\chi^2(78)$) | 237.11 | <0.01 | | $\chi^2(65)$ | 48.69 | 0.93 | | |
| **Panel B: Metal and Oil Commodities** | | | | | | | | |
| Gold | 2.605 | 0.86 | 0.018 | 0.091 | 5.57 | 0.35 | 0.1577 | 0.0020 |
| Heating Oil | 2.456 | 0.87 | 0.048 | 0.031 | 4.58 | 0.47 | 0.6189 | 0.0039 |
| Silver | 2.473 | 0.87 | 0.007 | 0.084 | 3.90 | 0.56 | -0.1859 | 0.0017 |
| Platinum | 0.160 | 1.00 | 0.008 | 0.041 | 4.52 | 0.48 | 0.1673 | 0.0046 |
| All Metal ($\chi^2(24)$) | 181.37 | <0.01 | | $\chi^2(20)$ | 12.98 | 0.88 | | |
| **Panel C: Financial** | | | | | | | | |
| NYSE | 0.578 | 1.00 | 0.032 | 0.052 | 7.33 | 0.20 | -0.0745 | 0.0112 |
| SP500 | 0.199 | 1.00 | 0.015 | 0.053 | 4.29 | 0.51 | -0.0128 | 0.0117 |
| Treasury-Bill | 0.350 | 1.00 | 0.006 | 0.079 | 0.90 | 0.97 | 0.0013 | 0.0005 |
| Treasury-Note | 0.280 | 1.00 | 0.011 | 0.044 | 2.77 | 0.74 | 0.0156 | 0.0029 |
| Treasury-Bond | 4.344 | 0.63 | 0.015 | 0.061 | 1.76 | 0.88 | 0.0219 | 0.0042 |
| Deutsch Mark | 0.816 | 0.99 | 0.005 | 0.041 | 3.53 | 0.62 | 0.1370 | 0.0034 |
| Japanese Yen | 0.202 | 1.00 | 0.005 | 0.037 | 1.80 | 0.88 | -0.0190 | 0.0053 |
| Swiss Franc | 1.202 | 0.98 | 0.038 | 0.023 | 6.15 | 0.29 | 0.0646 | 0.0035 |
| UK Pound | 0.138 | 1.00 | 0.011 | 0.035 | 7.05 | 0.22 | 0.0284 | 0.0002 |
| All Financial ($\chi^2(54)$) | 197.24 | <0.01 | | $\chi^2(45)$ | 23.19 | 1.00 | | |
| All Futures | | | | $\chi^2(130)$ | 106.61 | 0.93 | | |

(a) $\chi^2$ is the minimised value of the GMM criterion function, it tests the null hypothesis that the residuals from the GMM system are orthogonal to the instruments, p-value is the probability of rejecting the null hypothesis erroneously Unless specified otherwise, there are 42 orthogonality conditions and 36 parameters, leaving 6 overidentifying restrictions to be tested

(b) The first $R^2$ is the goodness-of-fit statistic from a regression of the residuals of the conditional asset pricing model on the instruments, the second $R^2$ is the goodness-of-fit statistic from a regression of futures returns on the instruments (table 4 4)

(c) $\chi^2$ is a heteroscedasticity and serial correlation consistent test of the hypothesis that the conditional residuals are constant, p-value is the associated probability of rejecting the null hypothesis when it is true Unless specified otherwise, the test is distributed as $\chi^2$ with 5 degrees of freedom

(d) $\overline{u3}$ is the average pricing error, E(R) is the average conditional return, measured as the mean fitted returns from a regression of futures returns on the instruments

We estimate conditional multifactor asset pricing models that allow for time variation in either the covariances, the prices of covariance risk, or all moments. We show convincing evidence that, while the prices of risk associated with the APT factors are mainly constant, the sensitivities of futures returns to the mimicking portfolios conditional residuals are time-varying. Consistent with these results, we find that the pattern of forecastability in futures markets is captured by a conditional APT model with time-varying covariances and constant prices of covariance risk. It follows that assumptions regarding the source of predictability in futures markets are of primary importance in attempting to explain the movements in expected of futures returns. Studies such as Bessembinder and Chan (1992) indeed focus on time-varying factor risk premia and abstract from possible time variation in betas. We show here that this assumption might well be unsustainable in futures markets.

It is important to notice however that the evidence presented here are somehow unexpected when compared to the results from the stock and bond markets. The studies from the stock and bond markets indeed indicate that the contribution of time-varying betas to the predictable variation in stock and bond returns is small compared to the proportion of the variance of expected returns that is explained by shifts in the prices of risk (see, for example, Ferson and Harvey (1991, 1993), Evans (1994), and Ferson and Korajczyk (1995)). This implicitly suggests that models with constant betas and time-varying risk premia give a better representation of the predictable movements in stock and bond returns than models that assume constant prices of risk and time-varying covariances.

## VII. Implications in Terms of Market Efficiency

The evidence presented so far suggest that the movements in expected futures returns can be described in a conditional asset pricing framework. This result is encouraging in terms of the EMH since it indicates that the predictable variation in futures returns reflects the rational change across time in the preferences of economic agents between consumption and investment. We wish now to estimate how much of the time variation in futures returns is explained by the conditional APT with time-varying covariances and constant prices of covariance risk. This should give us some further insight as to whether the predictability of futures returns reflects rational change in required returns or stands as a proof against the EMH. If most of the time variation in futures returns is explained by the conditional APT, the EMH will be sustained. On the other hand, if the forecastability of futures returns reflects weak-form market inefficiency, the conditional APT model should only explain a very small portion (or even none) of the predictable movements in futures returns.

In this purpose, we proceed as Ferson and Harvey (1991), Evans (1994), and Ferson and Korajczyk (1995) and compute two variance ratios. The first one, VR1, represents the proportion of the predictable movements in futures returns that is explained by the conditional APT model. It is computed as the ratio of the variance of a projection of the conditional APT fitted returns on the instruments divided by the variance of a projection of the futures returns on the instruments. Hence, VR1 equals

$$\mathrm{VR1} = \frac{\sigma^2\left[P(\lambda u2_t R_t / Z_{t-1})\right]}{\sigma^2\left[P(R_t / Z_{t-1})\right]} \tag{6.10}$$

$\sigma^2$ is the variance operator, $P(./Z_{t-1})$ represents the fitted values of a linear projection onto $Z_{t-1}$, $\lambda u2_t R_t$ are the conditional fitted returns as defined from the conditional APT model with time-varying covariances and constant prices of covariance risk (see system (6.4)), and $R_t$ is a vector of futures returns.

We also compute VR2, the proportion of the predictable movements in futures returns that is not picked up by the conditional APT model. In this respect we divide the variance of a projection of the conditional APT residuals on the instruments by the variance of a projection of the futures returns on the instruments. Hence, VR2 equals

$$VR2 = \frac{\sigma^2\left[P\left(u3_t / Z_{t-1}\right)\right]}{\sigma^2\left[P\left(R_t / Z_{t-1}\right)\right]} \tag{6.11}$$

where $u3_t$ are the conditional residuals as defined in system (6.4) and the other parameters are as previously defined. If the conditional APT picks up the predictable variation in futures returns, then $VR1 = 1$ and $VR2 = 0$. On the other hand, if the model does a poor job at capturing the predictability of futures returns, then VR1=0 and VR2=1. Since no asset pricing model is expected to perfectly fit the data, a result that VR1 is close to 1 while VR2 is close to 0 will be consistent with the hypothesis that futures markets are efficient.

To estimate the denominators of VR1 and VR2, we regress actual futures returns on the instruments and compute $\sigma^2\left[P\left(R_t / Z_{t-1}\right)\right]$ as the element by element multiplication of the resulting fitted values. To calculate the nominators of VR1 and VR2, we first decompose actual returns into two components: the conditional fitted returns measured as $\lambda u2_t R_t$ and the conditional residuals defined as $u3_t$. We then regress each component onto the instrument set and compute the numerators in (6.10) and (6.11) as the element by element multiplication of the resulting fitted values. Finally we estimate the following regressions

$$\sigma^2\left[P\left(\lambda u2_t R_t / Z_{t-1}\right)\right] = \alpha + VR1 * \sigma^2\left[P\left(R_t / Z_{t-1}\right)\right] \tag{6.12}$$

$$\sigma^2\left[P\left(u3_t / Z_{t-1}\right)\right] = \alpha + VR2 * \sigma^2\left[P\left(R_t / Z_{t-1}\right)\right] \tag{6.13}$$

(6.12) is simply an OLS regression of $\sigma^2\left[P\left(\lambda u2_t R_t / Z_{t-1}\right)\right]$, the variance of a projection of the conditional APT fitted values on the instruments, on (1) a constant and (2) the variance of a projection of actual returns on the instruments. Similarly, (6.13) defines VR2 as the slope of a regression of the variance of the predictable component of the conditional APT residuals on the variance of the predictable component of actual futures returns.

Table 6.9 reports estimates of the slope coefficients of the OLS regressions (6.12) and (6.13) along with the results of the tests that $VR1 = 1$ and $VR2 = 0$. With only two exceptions (soybeans oil and Treasury bill), VR1 exceeds VR2. Hence the proportion of the predictable variance of returns that is explained by the conditional APT exceeds the proportion of the predictable variance of returns that is relegated to the conditional residuals. Although the null hypothesis that VR1 is equal to one is rejected in most cases, the estimates of VR1 are close to 1. The mean of the VR1 estimates across the 26 futures equals 0.85. Hence the conditional APT model explains on average 85 percent of the predictable variance of futures returns. With relatively few exceptions (soybeans oil and Treasury bill), the estimates of VR2 are close to zero. The mean of the VR2 estimates equals 0.07. Hence the proportion of the predictable variation of futures returns that is not explained by the model is only equal to 7 percent of the total predictable variance of returns. Since most of the predictability can be explained in term of conditional risk, the predictable variation in futures returns seems to reflect rational pricing in an efficient market.

## VIII. Conclusions

Since futures returns are predictable using a set of instruments available at time t-1, the purpose of this chapter was to analyse whether the variation in expected futures returns reflects rational pricing in an efficient market or is the result of weak-form market inefficiency. The issue is investigated with respect to the hypothesis that the predictable variation in futures returns is captured by conditional asset pricing models with time-varying covariances and/or time-varying prices of covariance risk. Doing so we offer the first formal link between the variation through time in expected futures returns and the time-varying risk and risk premia associated with prespecified economic factors.

Since both the price of risk associated with term spread and the covariances between futures returns and the excess returns on the factor mimicking portfolios are time-varying,

## Table 6.9: Estimates of the Fraction of the Predictable Variance of Futures Returns that is Explained by the Conditional APT with Time-Varying Covariances and Constant Prices of Covariance Risk

$$\sigma^2\left[P\left(\lambda u2_t R_t / Z_{t-1}\right)\right]^{*} = \alpha + VR1 * \sigma^2\left[P\left(R_t / Z_{t-1}\right)\right]^{**}$$

$$\sigma^2\left[P\left(u3_t / Z_{t-1}\right)\right]^{***} = \alpha + VR2 * \sigma^2\left[P\left(R_t / Z_{t-1}\right)\right]$$

| Futures Contracts | VR1 | | | VR2 | | |
|---|---|---|---|---|---|---|
| | Estimate | Std Error | $H_0$: VR1=1 | Estimate | Std Error | $H_0$: VR2=0 |
| **Panel A: Agricultural Commodities** | | | | | | |
| Cocoa | 1.4362 | 0.0341 | 12.78 | 0.0142 | 0.0028 | 5.15 |
| Coffee | 0.9873 | 0.0381 | -0.33 | -0.0272 | 0.0217 | -1.25 |
| Corn | 0.3748 | 0.1060 | -5.90 | 0.1981 | 0.0607 | 3.26 |
| Cotton | 0.7680 | 0.0243 | -9.55 | 0.0074 | 0.0074 | 0.99 |
| Oats | 0.7185 | 0.0328 | -8.57 | -0.0021 | 0.0087 | -0.24 |
| Soybeans | 0.8032 | 0.0311 | -6.34 | 0.0103 | 0.0086 | 1.21 |
| Soybean Meal | 1.0838 | 0.0181 | 4.63 | 0.0034 | 0.0018 | 1.96 |
| Soybean Oil | 0.0787 | 0.0126 | -73.05 | 0.4712 | 0.0330 | 14.28 |
| Sugar | 1.0296 | 0.0121 | 2.44 | 0.0002 | 0.0007 | 0.27 |
| Wheat | 1.0194 | 0.0183 | 1.06 | -0.0003 | 0.0010 | -0.26 |
| Lean Hogs | 0.5990 | 0.0393 | -10.21 | 0.0478 | 0.0211 | 2.27 |
| Lumber | 1.0071 | 0.0053 | 1.36 | -0.0001 | 0.0000 | -2.05 |
| Pork Bellies | 0.4930 | 0.0200 | -25.29 | 0.0863 | 0.0095 | 9.05 |
| **Panel B: Metal and Oil Commodities** | | | | | | |
| Gold | 0.2937 | 0.5722 | -1.23 | 0.1119 | 0.0195 | 5.74 |
| Heating Oil | 1.1525 | 0.0288 | 5.30 | 0.0100 | 0.0024 | 4.21 |
| Silver | 1.2795 | 0.0446 | 6.27 | 0.0520 | 0.0152 | 3.43 |
| Platinum | 0.9816 | 0.0275 | -0.67 | -0.0073 | 0.0076 | -0.96 |
| **Panel C: Financial** | | | | | | |
| NYSE | 1.3931 | 0.0636 | 6.18 | 0.0289 | 0.0115 | 2.50 |
| SP500 | 1.4910 | 0.0785 | 6.25 | 0.0531 | 0.0141 | 3.76 |
| Treasury-Bill | 0.0049 | 0.0073 | -137.26 | 0.4671 | 0.0124 | 37.64 |
| Treasury-Note | 0.9379 | 0.0637 | -0.98 | 0.0565 | 0.0202 | 2.80 |
| Treasury-Bond | 0.6774 | 0.0493 | -6.54 | 0.0512 | 0.0150 | 3.41 |
| Deutsch Mark | 1.0682 | 0.0134 | 5.09 | 0.0016 | 0.0016 | 1.01 |
| Japanese Yen | 0.9180 | 0.0844 | -0.97 | 0.0656 | 0.0178 | 3.69 |
| Swiss Franc | 1.0883 | 0.0084 | 10.52 | 0.0007 | 0.0003 | 2.42 |
| UK Pound | 0.6427 | 0.0200 | -17.83 | 0.0331 | 0.0105 | 3.16 |

* $\sigma^2\left[P\left(\lambda u2_t R_t \; Z_{t-1}\right)\right]$ is the variance of a projection of the conditional APT fitted returns on the instruments.

** $\sigma^2\left[P\left(R_t \; Z_{t-1}\right)\right]$ is the variance of a projection of the futures returns on the instruments.

*** $\sigma^2\left[P\left(u3_t \; Z_{t-1}\right)\right]$ is the variance of a projection of the conditional APT residuals on the instruments.

it is intuitively appealing to estimate conditional asset pricing models that allow for time variation in different parameters. Unlike previous studies of the time-varying risk premia in futures markets, we do not make any assumption regarding the nature of the predictability and estimate conditional CAPM and APT models that allow for time variation in either the covariances, the prices of systematic risk, or all moments.

It appears that, irrespectively of the model's specifications, the five factor model does a better job at tracking the variation in futures returns than the single factor model. Besides we find that the pattern of forecastability in futures markets is captured by a conditional APT model with time-varying covariances and constant prices of covariance risk. Our tests therefore suggest that the variation in the sensitivities of futures returns to the economic factors is the primary source of predictability in futures markets. This result is somehow surprising since the literature on conditional asset pricing indicates that the predictable variation in stock and bond returns results from a change in the prices of risk rather than a change in betas (see, for example, Ferson and Harvey (1991), Evans (1994), or Ferson and Korajczyk (1995)).

We then estimate the proportion of the predictable variance of futures returns that is explained by the conditional APT with time-varying covariances and constant prices of covariance risk. With relatively few exceptions, the proportion of the predictable variance of returns that is explained by the conditional APT exceeds the proportion of the predictable variance of returns that is relegated to the conditional residuals. We find that the model explains on average 85 percent of the predictability of futures returns and that the conditional residuals capture only 7 percent of the predictable variance of futures returns. Since most of the predictable variation in futures returns is described by the conditional APT model, the evidence seem to suggest that the predictable movements in futures returns reflect rational pricing in an efficient market

The implications of our research is twofold. First, fund managers interested in time-varying expected return models should consider conditional models that allow for time variation in the sensitivities of futures returns to the economic risk factors. Second, conditional asset pricing models capture the predictable variation in futures returns; hence, futures market participants can reasonably base their hedging, arbitrage, and speculative decisions on the quoted futures prices.

# Conclusions and Extensions for Future Research

The purpose of the thesis was to provide a thorough analysis of the pricing of systematic risk in futures markets and to make use of constant and time-varying expected return asset pricing models to investigate the normal backwardation theory, the integration between the futures and underlying spot markets, and the efficiency of the futures markets. We now present a synopsis of our findings and investigate possible areas of future research.

## 1. The Normal Backwardation Theory

Studies of the normal backwardation theory in an asset pricing framework traditionally search for the presence of futures risk premia that compensate speculators for undertaking the risk of price fluctuation hedgers fail to transfer to one another at no cost. These studies however either assume market integration (and hence a similar vector of prices of systematic risk across the equity and futures markets) or rely on the two-step methodology (as such they might erroneously assume a strict factor structure, suffer from an EIV problem, and do not recognise the endogenous nature of the market portfolio). It follows that both approaches might lead to wrong inferences regarding the presence of a risk premium in futures markets. In chapter II, we make use of two methodologies (NLSUR and NL3SLS) that are free from these problems and therefore draw some clear inferences with respect to the validity of the normal backwardation theory. Our results indicate that normal backwardation is not normal in the futures markets for agricultural commodities: short and long hedgers balance their risk to one another, leaving no incentive to speculators to enter futures markets. On the other hand most financial and metal futures carry significant risk premia: the imbalance between long and short hedging is eliminated by speculators who require a premium to bear that part of risk hedgers fail to transfer to one another at no cost.

We show in chapter IV that futures returns are time-varying. Hence assuming constant expected return while testing the normal backwardation theory might be inaccurate and tests of the presence of futures risk premia should better be implemented in a conditional asset pricing framework. Following McCurdy and Morgan (1992) and given that conditional asset pricing models with time-varying covariances and constant prices of covariance risk describe the variation in expected futures returns (chapter VI), future studies of the validity of the normal backwardation theory should estimate the following multifactor model

$$u_t = \begin{pmatrix} u1_t & u2_t \end{pmatrix} = \begin{pmatrix} \left(F_t - Z_{t-1}\gamma\right)' \\ \left(R_t - \delta\left(\lambda u1_t R_t\right)\right)' \end{pmatrix}'$$

$u1_t$ and $u2_t$ are vectors of errors that are orthogonal to the instruments $Z_{t-1}$, $R_t$ is a vector of futures returns, $F_t$ is a K-vector of mimicking portfolio excess returns, $\delta$, $\gamma$, and $\lambda$ are the estimated parameters. $\delta$ is included to test for the presence of time-varying risk premia. If the normal backwardation is valid, $\delta = 1$ and speculators require a premium proportional to the time-varying risk of the futures contract to compensate them for underwriting hedgers' risk of price fluctuation. On the other hand, if $\delta = -1$, the normal contango theory will be supported. Finally, evidence that $\delta = 0$ would suggest that there is no risk transfer in futures markets.

## 2. Market Integration between the Futures and Underlying Asset Markets

Chapter III analyses the implications of market integration on the decision making process of market participants and tests the null hypothesis of an uniform vector of prices of risk across the futures markets and the commodity, currency, and equity spot markets. While the futures and spot markets for financial securities are integrated, we present new evidence that the futures markets and the commodity spot markets are segmented. It follows that market participants who invest in futures as well as in commodities should consider the prices of risk present in both markets before adjusting the riskiness of their portfolio and evaluating portfolio performance. On the other hand investors who trade futures, equity, and currencies can estimate the quantity of risk of their portfolio as the weighted average of the quantities of risk of the assets that comprise the portfolio and can use the traditional measures of abnormal return (Treynor's reward to volatility ratio and Jensen's alpha) as a way to evaluate portfolio performance and detect mispriced securities.

Chapter III tests the null hypothesis of market integration against an unspecified hypothesis and does not attempt to explain why the futures and commodity markets are segmented. Our guess is that market segmentation reflects the presence of market imperfections such as trade restrictions and transaction costs that might hinder arbitrage between the futures and commodity spot markets. However the tests implemented in this thesis do not enable us to ascertain that such a supposition holds. Models that incorporate market microstructure might in the future improve our understanding of this conclusion.

Another area of future research could be to investigate the issue of market integration in a conditional asset pricing framework, thereby allowing for time-variation in spot and futures returns. A simple test could consist in testing the validity of the overidentifying restrictions for a pooled system of futures and spot assets. Alternatively one could simply estimate a conditional multifactor model with time-varying covariances and constant prices of covariance risk in the underlying spot markets and test the restriction that the rewards per unit of systematic risk across markets are the same. My conjecture is that such tests will fail to support the null hypothesis of market integration. The evidence in chapter VI indeed indicate that shift in the covariances of futures returns to the constant prices of covariance risk is the primary source of predictability in futures markets. On the other hand, evidence from the stock and bond markets indicate that it is the variation in the prices of systematic risk that accounts for most of the predictability in stock and bond returns. Hence it seems highly unlikely that the hypothesis of an unique vector of risk prices across markets will hold.

## 3. Time-Varying Futures Risk Premia and Market Efficiency

Given that futures returns are predictable using a set of instruments available at time t-1, the remainder of the thesis aimed at testing whether the variation through time in expected futures returns reflects rational pricing in an efficient market or is the result of weak-form market inefficiency. In this respect, three hypotheses were tested. The first one investigates whether a trading rule based on available information generates abnormal return on a risk and transaction costs adjusted basis; the second one looks at whether the variation in expected futures returns is the same across markets and is related to economic conditions; finally, the third hypothesis analyses whether the pattern of forecastability in futures markets is consistent with conditional versions of asset pricing models (such as the conditional CAPM and the conditional APT).

Irrespectively of the hypothesis tested, the results indicate that futures markets are efficient. First, when risk is allowed to be time-varying, the trading rule derived in chapter IV is not capable of generating abnormal returns. Second, the evidence presented in chapter V suggest that the information variables forecast futures returns because of their ability to proxy for change in the business cycle. Third, chapter VI establishes that a conditional multifactor model with time-varying covariances and constant prices of covariance risk captures on average 85 percent of the predictable movements in futures returns, leaving little variation to be explained in terms of market inefficiency. It follows therefore that the predictable movements in futures returns most likely result from variation in the tastes of economic agents for current versus future consumption. Such a finding is of primary importance to market participants who rely on quoted futures prices to make hedging, speculation, or arbitrage decisions. As a result, models that assume conditional expected returns should be favoured to traditional models of constant expected returns as a way to proxy for risk and evaluate portfolio performance.

While investigating the issue of market efficiency, we also address two issues that are at the forefront of modern research on asset pricing and that have never been analysed for futures markets. The contribution of chapters V and VI is also unique in this respect.

Chapter V analyses the link between time-varying expected futures returns and business conditions. Consistent with the findings from the stock and bond markets and with extant economic theories (e.g. traditional asset pricing models and the consumption smoothing theory), the evidence for metal, stock index, and Treasury security futures suggest that expected futures returns increase when business conditions are poor and decrease when economic prospects are better. Chapter V also raises some interesting observations that have not been evidenced to date in the literature on predictability. To address the matter broadly, it appears that the evidence from the stock and bond markets do not extend to currency and agricultural commodity futures. For these contracts, the time-variation in expected returns are not consistent with traditional theoretical explanations of the trade-off between risk and expected return either. This calls for some theoretical work to account for what we can only call so far an "anomaly". Some further research on the link between time-varying expected returns and economic activity seems to be required before one can extend the evidence from the stock and bond markets to any other market. It would seem indeed misleading to suppose that the evidence from the stock and bond markets can be extended to any other markets and it might therefore be interesting to examine whether agricultural commodities and currencies also behave procyclically. Quoting Fama (1991), this suggests that "we should deepen the search for links between time-varying expected returns and business conditions, as well as for tests of whether the links conform to common sense and the predictions of asset-pricing models".

Chapter VI investigates the relationship between the time-varying risk premia present in futures markets and the conditional cross sectional variation in expected returns. This study is the first attempt to relate the variation in expected futures returns to the time-varying risk and prices of risk associated with macroeconomic and financial factors. Unlike previous authors, we do not make any strong assumption regarding the source of predictability in futures markets and estimate the proportion of the predictable variation in futures returns explained by conditional asset pricing models. We also study an unprecedently large cross section of futures contracts. The results indicate that shift in the sensitivities of futures returns to the constant prices of covariance risk accounts for most of the predictable movements in futures returns. This result is somehow surprising since the change in the prices of risk is the main source of predictability in the stock and bond markets. This calls for more research on the link between time-varying expected returns and conditional asset pricing.

Finally and maybe most interestingly the conditional asset pricing framework described in chapter VI can be used to test the hypothesis that the time-varying risk premia embedded in the basis reflect the presence of "futures risk premia which covary with their stock and bond market counterparts" (Bailey and Chan (1993, page 558)). Bailey and Chan argue that commodities whose spot price is highly correlated with the *ex-post* risk factors exhibit a basis that covaries with the *ex-ante* stock and bond variables. There is thus an association between the time-varying risk premia present in the basis and the macroeconomic risks found in the commodity spot price change. This suggests that the basis is sensitive to the macroeconomic factors common to all asset markets. Very few direct tests of the hypothesis that the predictable variation in the basis reflects rational pricing in an efficient market have been implemented thus far. Hence forthcoming research on futures pricing might attempt to use conditional asset pricing models to capture the predictable variation in the basis and relate the predictability of the basis to business conditions and to the conditional cross section of expected returns. Studying the ways in which the basis evolves should be of primary interest to hedgers who will then be able to adapt their positions to their anticipation of the change in the futures and spot prices. Provided anticipations are accurate, the speculative component of the hedge will result in a profit based on the expected change in the basis while the hedging component will cover the risk of price fluctuation in the underlying cash market. Since the basis plays an essential role in determining hedging effectiveness, future research should concentrate on the macroeconomic forces that drive changes in the basis.

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