

EKONOMI OCH SAMHÄLLE

Skrifter utgivna vid Svenska handelshögskolan
Publications of the Swedish School of Economics
and Business Administration

Nr 131

JAN ANTELL

ESSAYS ON THE LINKAGES BETWEEN
FINANCIAL MARKETS, AND
RISK ASYMMETRIES

Helsingfors 2004

Essays on the Linkages between Financial Markets, and Risk Asymmetries

Key words: Asset pricing, asymmetric volatility, cointegration, financial linkages, GARCH, GMM, volatility modeling, volatility transmission

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ISBN 951-555-841-7 (printed)
ISBN 951-555-842-5 (PDF)
ISSN 0424-7256

Yliopistopaino, Helsingfors 2004

Acknowledgments

My goal was already in an early stage very clear: to become a Ph.D. in Finance. I had the following simple plan: register as doctoral student, take Ph.D. courses, conduct research, and become a young doctor in a time span of approximately three years. Now, after almost nine years of doctoral studies and research I have to admit the plan might have been somewhat too ambitious. What is worse, I am not so young anymore. However, with this doctoral thesis the project is now just about completed. It would not have been possible without the help and understanding of several parties, whom I would gratefully like to thank.

I wish to thank the official pre-examiners of my doctoral manuscript, professors Gregory Koutmos (Fairfield University), and Seppo Pynnönen (University of Vaasa), who also acts as opponent. My research has clearly benefited from the valuable comments and suggestions provided by my thesis committee, professors Eva Liljebloom and Anders Löflund. In particular I am grateful to Eva for taking me as a researcher to the department, and her patience with me over the years. All colleagues at the Department of Finance and Statistics deserve to be mentioned for providing an interesting and intellectually challenging working environment.

The first essay was co-authored with Niklas Ahlgren. He deserves thanks for the numerous fruitful and sometimes less fruitful battles over the paper, but also for beneficial comments to my later research. Needless to say, any remaining errors in our article can be attributed to Niklas. During the process of transforming the manuscript to a book the help from Barbara Cavonius was valuable. Further, I would like to thank all my friends, of whom especially Mika Vaihekoski should be acknowledged. He has been a good friend and party-brother, commented my research, and helped me with the portfolio data used in two of the essays in this dissertation. That help has been extremely valuable.

Financial support from the following sources has been very encouraging and is gratefully acknowledged: Graduate school financing (GSFFA/KATAJA, Academy of Finland, Yrjö Jahnsson Foundation), Bergsrådet tekn. och ekon. dr H.C. Marcus Wallenbergs Stiftelse för företagsekonomisk forskning, Bröderna Lars och Ernst Krogius forskningsfond (Svenska litteratursällskapet), Börsstiftelsen, Hans Bang Stiftelsen, Kemira Foundation, Merita Banks Stiftelse, Oskar Öflunds Stiftelse, Osuuspankkiryhmän Tutkimussäätiö, Saskia Stenius Minnesfond (Svenska kulturfonden), Sparbankernas Forskningsstiftelse, and Stiftelsen för främjandet av värdepappersmarknaden i Finland.

I also wish to thank my muse Laura for her understanding and patience. Finally I would like to thank my parents Henry and Sirpa for their life-long support and belief in me.

Tack – Kiitos – Thank You!

Helsingfors
June 30, 2004

Jan Antell

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PART I: OVERVIEW OF THE DISSERTATION

1 Introduction

During the last few decades there have been far going financial market deregulation, reduction of government interventions, technical development, advances in information technology, and standardization of legislation between countries. These changes have enhanced the possibilities for international trade, finance, and investments. As a result of this development, one can expect that financial markets have grown more inter-linked, that the degree of price, return, and volatility linkages, and perhaps also market integration has grown stronger. New information is accounted for more rapidly than before, improving market efficiency. These cross-market connections have far-fetched implications for many financial market participants. Investment managers are keen to optimize their portfolios. A failure to understand the true linkages between geographic markets, and between different asset categories may have severe consequences on the performance of these managers. Failing to account for the connections has also implications on risk management, especially since the strength of the connection in crisis periods tends to be stronger, hence decreasing diversification benefits when they are most critically needed. Further, there are consequences with respect to asset pricing, the cost of capital, and the relation between risk and return. Finally, there are important policy and regulatory implications. For organizations like the World Bank, International Monetary Fund, and central banks it is vital to be aware of the true mechanisms of financial linkages, particularly in crisis periods. Even if only domestic financial markets were considered, there might be interactions that had not existed in a more segmented environment. Understanding the development in one market often requires a look at other markets.

Another financial market feature often encountered is volatility asymmetries, i.e., that the response of return shocks on volatility is different depending on the sign of the shock. More specifically, volatilities are asymmetric in the sense that negative return shocks tend to increase volatility more than positive shocks of equal magnitude. Further, many researchers have found both own volatility asymmetries, and cross-market asymmetries, meaning that a negative shock in one market is transmitted to another market more eagerly than a positive shock of equal magnitude. This is usually pronounced in periods of financial turmoil.

The first objective of this PhD thesis is to study the linkages between financial markets, by which are meant both international markets, and markets for different securities

within one country, in this case Finland. The second objective is to study the existence of risk asymmetries, both with respect to volatility, measuring total risk, and the CAPM- β , measuring systematic risk. While the former is a financial market stylized fact, there is less research on the latter.

Finnish data are present in all essays. The Finnish economy and financial markets exhibit some interesting features. First, since Finland is a small open economy dependent on foreign trade, it can be expected that there are financial price, return and volatility linkages to the rest of the world. Second, the deregulation of the financial markets was completed when foreign investors from the beginning of 1993 were allowed to freely invest in Finnish financial assets. Foreign ownership increased drastically, and market liquidity improved. The return generating process, and the degree of market linkages can be expected to have changed. Third, there was a severe economic recession in the beginning of the 1990's. Financial markets might behave differently during downturns than during "normal" periods.

This overview is organized as follows. Section 2 gives a literature review, beginning with a description of financial market stylized facts, followed by a discussion of the terminology used for describing linkages between markets, and ending with an examination of the empirical literature. Section 3 presents some econometric methods used in this thesis, i.e., cointegration analysis, generalized method of moments (henceforth GMM), and asymmetric specifications of models in the family of Generalized Autoregressive Conditional Heteroskedasticity (henceforth GARCH). Section 4 provides a summary of the four essays. Section 5 contains some concluding remarks.

2 Literature Review

2.1 Some Stylized Facts

Already Bachelier (1900) found that stock prices behave randomly. If markets are in equilibrium, current prices are the best predictors of tomorrow's prices, and all events are reflected in the market price. Based on the random walk hypothesis of Bachelier, Fama (1970) develops his famous market efficiency theory, continuing in Fama (1991). However, there are a number of empirical regularities regarding prices, returns, and volatilities of financial assets. Due to a large body of empirical evidence, many of the regularities can be considered stylized facts. Since three of the four essays deal with second moment characteristics, we here primarily concentrate on second moments instead of first moments. Volatility exhibits persistence or a tendency to cluster. That is, large return innovations of either sign tend to be followed by large innovations, or periods of high volatility with periods of high volatility. And periods of low volatility are followed by periods of low volatility. This effect was first discovered by Mandelbrot (1963), and Fama (1965). This implies that today's volatility is a good predictor of volatility in the next period. Many volatility models predict future volatility by current volatility.

Next, the volatility response is different depending on the sign of the innovation. More specifically, volatility tends to be higher following a negative shock than following a positive shock of equal magnitude, i.e., contemporaneous return and volatility are negatively correlated. For equity returns this asymmetry was termed the *leverage effect* in Black (1976) and Christie (1982) – increased financial leverage, i.e., risk, due to a drop in the value of a stock (negative return). However, asymmetric volatility responses could also be due to time-varying risk premia (Pindyck, 1984; French et al., 1987; Campbell and Hentschel, 1992; Wu, 2001). According to this *volatility feedback hypothesis*, if volatility is priced, an expected increase in volatility raises the required return on equity, leading to an immediate stock price decline. Existing research shows that the leverage explanation does not fully account for observed volatility asymmetries. The same applies for the volatility feedback story. See for example Bekaert and Wu (2000). Often the coefficient linking volatility to expected return is insignificant, and the sign is different depending on the study. Whatever the reason for asymmetry, it has important implications for the cost of capital. Following Veronesi's (1999) argument that markets tend to overreact to bad news during good economic states, and underreact to positive signals in recessions, De Goeij and Marquering (2003) name a third explana-

tion, *following-the-herd* effect. According to this psychological behavior, investors might pay less attention to fundamentals during a stock market crash, and therefore sell their stocks if everybody else is selling.

Both asset returns and volatilities are mean reverting in the long run. Periods of high or low values tend to be followed by periods of more “normal” values. In long-run volatility forecasts the mean reversion has to be accounted for. Although many volatility models utilize “own” historical values to estimate the conditional volatility, also many exogenous variables have been found to affect volatility, e.g. GDP, macroeconomic and firm-specific announcements, and the volatility of these. See for example Schwert (1989), and Hamilton and Lin (1996).

Finally, asset returns often exhibit high kurtosis, indicating non-normality. Traditional conditional (G)ARCH volatility models account for some of the unconditional heavy-tailedness. If the conditional density is Gaussian, the unconditional density exhibits excess kurtosis. However, there is no particular reason to believe that the conditional density would be Gaussian. Therefore, many researchers have used other distributions such as the *t*-distribution and the generalized error distribution, or some mixture of normals.

2.2 Co-Movements, Contagion, Interdependence, Linkages, Spillover, and Transmission

Despite large amount of research on financial market linkages, there are some ambiguities regarding terminology and definitions. There are many terms used for these linkages, and the definitions are often interlinked. In this thesis we use the terms “linkages” or “links” to express the interactions or transmissions between financial markets. The theoretical and empirical literature uses terms like “co-movement”, “contagion”, “interdependence”, “linkages”, “spillover”, and “transmission” to describe this phenomenon. Some of the terms and definitions are more restrictive than the other.

The background for the empirical literature on financial market linkages is the notion of simultaneity of financial events, especially financial crises like the October 1987 or Hong Kong 1997 stock market crashes, the ERM crisis of 1992, the devaluation of the Mexican Peso in 1994, the Asian currency crises 1997–1998, the 1998 Russian, and 1999 Brazil bond market bursts, the September 11, 2001, events, and so on. During

bond, equity and currency crises, and bank crashes, markets tend to co-vary stronger than during normal periods, and spread over from one market to the next, from one country to another, even if the initial shock was market-specific and the markets are different in size, structure, and geographic location. This transmission of shocks from one market to another is loosely named as *contagion*. Contagion can be defined in many different ways, but there is no universally accepted definition. The World Bank provides three definitions for contagion.¹ According to the *broad definition*, by contagion is understood “the cross-country transmission of shocks or the general cross-country spillover effects”. This is a very general definition, and does not restrict contagion to take place only in crises or “bad” times, but also in “good” times. It also includes fundamental linkages explainable by common factors such as financial, commercial, and institutional ties between markets. The *restrictive definition* states that contagion is the transmission or co-movement of shocks in excess of what can be explained by fundamentals. This requires the characterization of the fundamentals and the mechanism of contagion. According to the *very restrictive definition*, contagion is the change in the propagation mechanism of shocks between countries in periods of crisis. This definition usually rests on changes in the correlation coefficient, the probability of speculative attacks, and/or the transmission of innovations or volatility.

To clarify the definitions, Forbes and Rigobon (2001) use *shift-contagion* instead of contagion, and define the concept as “a significant increase in cross-market linkages after a shock to an individual market”. This definition is closely related to the very restrictive definition above. The same definition is used for example in Claessens et al. (2001), who present an overview of the literature on contagion, and Forbes and Rigobon (2002). The latter refer to *interdependence* if there is a continued level of high correlation between markets regardless of the economic state. Thus, if there are no linkages, there is no interdependence. If there are continuously strong linkages, there is interdependence. And if there is a shift in linkages, it is considered contagion. Depending on the definition of the concepts, the conclusion in different empirical studies might be different.

¹ <http://www1.worldbank.org/economicpolicy/managing%20volatility/contagion/index.html> (May 31, 2004). Although the World Bank refers to different countries, the definitions are applicable also on different financial markets within one country.

While interdependence refers to a more general type of market linkages, and is not necessarily tied to financial crises, the very restrictive definition of contagion is explicitly connected to crises. There are many theories of how innovations are transmitted between markets. However, these theories apply both to contagion, financial market linkages and spillovers in general. Forbes and Rigobon (2001) divide the theories into two main groups, crisis-contingent, and non-crisis-contingent theories. The former can be divided into three mechanisms, of which the first is *multiple equilibria*. Even if there are no observable fundamental ties between the markets, an initial shock in one market alters investors' expectations, thereby transforming the propagation mechanism in a way that did not exist previously in normal times. This is related to – rational or irrational – investor psychology. The second mechanism is *endogenous liquidity*. A crisis in one market may, due to margin calls, regulatory issues, or risk management considerations lead to a need to rebalance investors' portfolios, thus affecting other markets. The third mechanism, *political contagion*, is associated with agreed-upon principles, for example fixed exchange rates commitments. If one country fails this principle, it is easier for other countries to switch regimes as well. The common feature of all these mechanisms is the assumption that the transmission process is clearly different in crisis times compared to “normal” economic states.

The non-crisis-contingent theories consist of four mechanisms, referred to as real linkages since they are often founded on fundamentals. These state that large post-crisis correlations are continuation of linkages that existed already before the crisis. If innovations spread according to these theories, we can speak of “linkages”, “spillovers” or “transmission” in general terms, but not of contagion in the restrictive sense. The first mechanism is referred to as *trade linkages*. For example, the devaluation of a competitor country's currency will have an undesirable effect on currency and equity prices in the country. The second channel is *policy coordination*, agreed-upon policies that are relaxed in all markets if one market fails to meet the obligations, for example regarding budget deficit rules. The third mechanism is *country reevaluation or learning*. It means investors draw conclusions about one market based on experiences from another, similar market. The final mechanism, *random aggregate or global shocks*, could affect many markets simultaneously, for example through changes in commodity prices.

To sum up, contagion is in the recent literature defined as a significant change in the strength of cross-market linkages after a crisis. See for example Forbes and Rigobon

(2001, 2002), and Claessens et al. (2001). This is a fairly narrow and restrictive definition, since it requires a change in the strength of the linkages. It is not concerned with differentiating between different types of propagation mechanisms. According to this definition, a continued level of high correlation is not considered contagion, only interdependence. In this thesis we do not use the concept “contagion” per se. However, we use the terms “linkages”, “links”, “co-movement”, and “interdependence” as broad terms for financial market relations to each other, while “spillover”, and “transmission” refer to the general transmission of shocks between markets. The last two terms can be seen as a part of “linkages”, while the opposite is not necessarily true. We do not restrict ourselves to crisis periods, but study the degree of linkages and transmission more generally.

2.3 Empirical Evidence on Market Linkages, and Risk Asymmetries

First and second moment linkages between financial markets have been extensively studied, especially after the October 1987 stock market crash.² This event increased the interest in financial market linkages, since it seemed that the degree of interdependence significantly increased after the event. Researchers have utilized a number of techniques to assess the strength of financial market linkages, and changes therein. The basic method is cross-market correlation coefficients. More sophisticated methods include vector autoregressive models and cointegration analysis, methods belonging to the (G)ARCH family of models, and a variety of other models including probit, switching regime, and GMM estimation.

Correlation analysis is the most straightforward method for measuring market linkages. The first studies concentrated on international diversification, beginning with Grubel (1968), and Levy and Sarnat (1970). Goetzmann et al. (2002) provide a good study of the long-run development of international correlation coefficients. They find that correlation coefficients vary noticeably over time, and that they are high during periods of high integration. Post-1987 there have been a large amount of research on shifts in the correlation structure. As noted above, most of these papers have found an increased level of correlation during crisis periods. The first significant documentation of this is given by King and Wadhvani (1990), followed by Lee and Kim (1993), Meric and Meric

² For an early survey of international financial linkages, see von Furstenberg and Jeon (1989). A more recent survey is provided by Karolyi and Stulz (2002).

(1996, 1997), Karolyi and Stulz (1996), Claessens et al. (2001), Forbes and Rigobon (2001, 2002), and Rigobon (2003).

While the correlation coefficient is a measure of the short-run dynamics between markets, affected by short-term trading noise and unaffected by long-run relations, vector-autoregressive (henceforth VAR) models and cointegration analysis give a measure of long-run linkages. In a nine-country VAR model, Eun and Shim (1989) find the US equity market to be the most influential market in the world. Utilizing VAR estimated by GMM, Ammer and Mei (1996) find financial as well as real linkages between the UK and the USA, but there may be lags in the transmission of international shocks. Knif and Pynnönen (1999) use a combination of cointegration analysis and structural VAR to investigate the impact of local and global information. In an 11-country system, they find one cointegrating vector. There seem to be four blocs of markets, i.e., the USA as the leading market, Asian-Pacific markets, Western European markets, and finally the Scandinavian markets. In a cointegration setting, Kasa (1992) reports a single common trend between five stock markets. However, as pointed out in Ahlgren and Antell (2002), there are problems in Kasa's analysis. Arshanapalli and Doukas (1993) report that French, German, and UK stock markets, but not Japanese, became cointegrated with the US market post-1987. Cointegration analysis for the relation between stock prices is employed also by Corhay et al. (1993), Harris et al. (1995), Ben-Zion et al. (1996), Engsted and Lund (1997), Kanas (1998), Pynnönen and Knif (1998), and Ahlgren and Antell (2002).

One of the first studies to utilize GARCH-type of models to explore volatility spillovers between financial markets is Hamao et al. (1990). They find that US and UK stock volatility is transmitted to Japanese volatility, but that these markets are not influenced by other markets. Longin and Solnik (1995) find that the conditional correlation changes over time. Karolyi (1995) examines the price and volatility linkages between Canada and the USA. Bekaert and Harvey (1997) find that the influence of world factors on emerging market volatility has increased. Ng (2000) finds that the impact of world factors on Pacific-Basin stock market volatility is greater than of local factors. However, only a small proportion of volatility can be attributed to these factors.

Many of the papers using GARCH methods also model volatility asymmetries. Asymmetry is also found by, among others, Nelson (1991), Engle and Ng (1993), Glosten et

al. (1993), Koutmos and Booth (1995), Koutmos (1996, 1998), Bekaert and Harvey (1997), Booth et al. (1997), Bekaert and Wu (2000), and Wu (2001). Beta asymmetries are studied by Braun et al. (1995), Cho and Engle (1999), Brooks and Hendry (2001), and Koutmos and Knif (2002a, 2002b). While most studies have found volatility asymmetries, beta asymmetries are harder to detect. Already in the seminal papers on the leverage effect by Black (1976), and Christie (1982), and later in Schwert (1989), and Bekaert and Wu (2000), it was found that the leverage explanation cannot fully account for the observed asymmetry. Bekaert and Wu (2000) find that the main mechanism behind asymmetry is covariance asymmetry. The model developed by Wu (2001) incorporates both the leverage effect, and the volatility feedback hypothesis. He finds that both theories explain asymmetric volatility, and that the latter is significant both statistically and economically.

3 Econometrics

We use three different econometric techniques in this thesis. Essay 1 uses cointegration analysis, while Essays 2, 3, and 4 use GARCH-type volatility specifications. In Essay 3 we also use generalized method of moments estimation for testing the economic specification. GMM is used also for obtaining descriptive statistics in the latter three essays. Since (asymmetric) volatility estimation and GARCH models are the major tool used, they get more attention in this introductory part than the other two methods.

3.1 Cointegration

Cointegration can be thought of as long-run relations between variables imposed by an economic system. The concept was introduced by Granger (1981), and Engle and Granger (1987), and developed by Johansen (1988, 1991, 1996). If stock prices are cointegrated, prices in different markets tend to move together in the long run. If a variable \mathbf{X}_t is a $p \times 1$ vector of stock prices and integrated of order one, but some linear combination $\beta' \mathbf{X}_t$, $\beta \neq 0$, is stationary, \mathbf{X}_t is cointegrated with cointegrating vector β . The cointegrating rank is the number of linearly independent cointegrating vectors. Cointegration analysis starts with a vector autoregressive model:

$$\mathbf{X}_t = \Pi_1 \mathbf{X}_{t-1} + \dots + \Pi_k \mathbf{X}_{t-k} + \Phi \mathbf{D}_t + \boldsymbol{\varepsilon}_t, \quad \boldsymbol{\varepsilon}_t \sim \text{NID}_p(\mathbf{0}, \Sigma), \quad t = 1, \dots, T, \quad (1)$$

where, \mathbf{D}_t is a $d \times 1$ vector of deterministic terms, Π_i is a $p \times p$ coefficient matrix, $i = 1, \dots, k$, Φ is a $(p \times d)$ coefficient matrix, $\boldsymbol{\varepsilon}_t$ is a $p \times 1$ vector of independent and identically distributed Gaussian errors, and the values of $\mathbf{X}_{-k+1}, \dots, \mathbf{X}_0$ are fixed. Rewriting (1) in error correction form:

$$\Delta \mathbf{X}_t = \Pi \mathbf{X}_{t-1} + \Gamma_1 \Delta \mathbf{X}_{t-1} + \dots + \Gamma_{k-1} \Delta \mathbf{X}_{t-k+1} + \Phi \mathbf{D}_t + \varepsilon_t, \quad (2)$$

where $\Delta = 1-L$ is the difference operator, and L is the lag operator.

Here $\Pi = \sum_{i=1}^k \Pi_i - \mathbf{I}$ and $\Gamma_i = -\sum_{j=i+1}^k \Pi_j$.

The rank r , $r = 0, \dots, p$, of the matrix Π determines the number of cointegrating vectors. If Π is of full rank ($r = p$), \mathbf{X}_t is stationary, and if $\text{rank}(\Pi) = 0$, there is no cointegration. In the intermediate case, $\text{rank}(\Pi) = r < p$, Π can be decomposed as $\Pi = \alpha \beta'$, where α and β are $p \times r$ matrices. β defines the cointegrating vectors, and α the speed of adjustment to the long-run equilibrium. The higher the rank, $r < p$, the smaller is the number of common stochastic trends, $p - r$, and the tighter the variables are linked. The rank can be tested by two procedures (Johansen, 1996, Theorem 6.1). In the trace test the unrestricted hypothesis $H(r)$ is tested against the restricted $H(p)$. The test statistic is

$$\lambda_{\text{trace}} = -2 \log Q(H(r)|H(p)) = -T \sum_{i=r+1}^p \log(1 - \hat{\lambda}_i), \quad (3)$$

where $Q(\cdot)$ is the likelihood ratio test statistic, $\hat{\lambda}_{r+1}, \dots, \hat{\lambda}_p$ are the $p - r$ smallest eigenvalues that correspond to the squared canonical correlations between \mathbf{X}_{t-1} and $\Delta \mathbf{X}_t$, corrected for the lagged differences $\Delta \mathbf{X}_{t-i}$ and the deterministic terms \mathbf{D}_t . The maximum eigenvalue test tests the hypothesis $H(r)$ against $H(r+1)$, the test statistic being

$$\lambda_{\text{max}} = -2 \log Q(H(r)|H(r+1)) = -T \log(1 - \hat{\lambda}_{r+1}). \quad (4)$$

Both test statistics have non-standard asymptotic distributions, which depend on the deterministic terms in the data generating process and in the estimated model.

Financial returns often show evidence of (G)ARCH. This might affect the size and power of tests for cointegration. In a simulation study, Lee and Tse (1996) generate noncointegrated systems with GARCH(1,1) errors, and find that the “tests are generally oversized, but not very seriously”. For more persistent volatility processes the overrejection is more severe. They also generate t -distributed errors, and find that the size distortion is larger for low degrees of freedom. The same result is obtained also if the errors follow an exponential GARCH process, or the conditional covariances are time-varying.

3.2 Generalized Method of Moments

When using financial data, there are perhaps no reliable distributional assumptions. The generalized method of moments of Hansen (1982), and Hansen and Singleton (1982) allows estimation without the need to make strong distributional assumptions. Let \mathbf{w}_t be an h -dimensional data vector observed at time t . Further, let $\boldsymbol{\theta}$ be an unknown q -dimensional parameter vector, and $\mathbf{h}(\boldsymbol{\theta}, \mathbf{w}_t)$ an r -dimensional vector function. The functional form of $\mathbf{h}(\cdot)$ is determined by restrictions based on economic theory. Assume that the following $r \times 1$ orthogonality restriction holds:

$$E[\mathbf{h}(\boldsymbol{\theta}_0, \mathbf{w}_t)] = \mathbf{0}, \quad (5)$$

where $\boldsymbol{\theta}_0$ contains the true values of the parameter vector $\boldsymbol{\theta}$. $\mathbf{h}(\cdot)$ can be considered a residual, or a residual function.

Let $\mathbf{y}_T = (\mathbf{w}'_1, \dots, \mathbf{w}'_T)'$ be a $Th \times 1$ vector containing all observations in a sample of size T , and let $\mathbf{g}(\boldsymbol{\theta}, \mathbf{y}_T)$ be the sample average of $\mathbf{h}(\boldsymbol{\theta}, \mathbf{w}_t)$:

$$\mathbf{g}(\boldsymbol{\theta}, \mathbf{y}_T) = \frac{1}{T} \mathbf{h}(\boldsymbol{\theta}, \mathbf{w}_t) \mathbf{1}_T, \quad (6)$$

where $\mathbf{h}(\boldsymbol{\theta}, \mathbf{w}_t)$ is an $r \times T$ -dimensional matrix function, and $\mathbf{1}_T$ a $T \times 1$ vector of ones. The idea of GMM is to choose such a parameter vector $\boldsymbol{\theta}$ that makes the sample function $\mathbf{g}(\boldsymbol{\theta}, \mathbf{y}_T)$ as close to the population moment of zero as possible. The GMM estimator, $\hat{\boldsymbol{\theta}}_{GMM}$, contains the values of $\boldsymbol{\theta}$ that minimizes the quadratic form

$$J(\boldsymbol{\theta}, \mathbf{y}_T) = [\mathbf{g}(\boldsymbol{\theta}, \mathbf{y}_T)]' \mathbf{W}_T [\mathbf{g}(\boldsymbol{\theta}, \mathbf{y}_T)], \quad (7)$$

where \mathbf{W}_T is the weighting matrix that can be a function of the data \mathbf{y}_T . $T > r$ is required for \mathbf{W}_T to be identified. It can be shown that the optimal weighting matrix is the inverse of the asymptotic ($r \times r$) variance-covariance matrix of $\mathbf{g}(\boldsymbol{\theta}, \mathbf{y}_T)$ under the null, \mathbf{S}^{-1} , where

$$\hat{\mathbf{S}}_T = \lim_{T \rightarrow \infty} T E\{[\mathbf{g}(\boldsymbol{\theta}_0, \mathbf{y}_T)][\mathbf{g}(\boldsymbol{\theta}_0, \mathbf{y}_T)']\}. \quad (8)$$

If the number of orthogonality conditions is equal to the number of parameters to be estimated, $r = q$, the GMM system has a solution – given that it exists – that makes the sample orthogonality conditions equal to zero. In the overidentified case, $r > q$, this is usually not the case, i.e., $\mathbf{g}(\hat{\boldsymbol{\theta}}_{GMM}, \mathbf{y}_T) \neq \mathbf{0}$. If the deviation from zero is large enough the theoretical economic model underlying the empirical moment conditions is probably false. This can be tested by the test of overidentifying restriction

$$Q(\hat{\theta}_{GMM}, \mathbf{y}_T) = [\sqrt{T} \mathbf{g}(\hat{\theta}_{GMM}, \mathbf{y}_T)]' \hat{\mathbf{S}}_T^{-1} [\sqrt{T} \mathbf{g}(\hat{\theta}_{GMM}, \mathbf{y}_T)] = TJ(\hat{\theta}_{GMM}, \mathbf{y}_T) \sim \chi_{r-q}^2. \quad (9)$$

Hypothesis testing can be conducted by the GMM analogues to the classical likelihood ratio, Wald, and Lagrange multiplier maximum likelihood test statistics developed by Newey and West (1987). If the unrestricted specification is exactly identified, they will yield a numerically identical result. However, in the overidentified case they yield different values.

3.3 Asymmetric GARCH Specifications

A good volatility model captures the stylized facts mentioned above: volatility persistence, asymmetry, mean reversion, and fat tails. The Autoregressive Conditional Heteroskedasticity (ARCH) family of models was introduced by Engle (1982) and generalized by Bollerslev (1986). These models are univariate and do not allow for asymmetric volatility. However, later many extensions and refinements, allowing for example asymmetry, were developed. Good surveys can be found in Bollerslev et al. (1992, 1994), Hentschel (1995), and Kroner and Ng (1998).

3.3.1 The Univariate Case

The GARCH family of models consists of two equations, the mean equation, and the variance equation. For a financial series the former can be stated as follows:

$$r_{i,t+1} = E_t(r_{i,t+1}) + z_{t+1} h_{t+1}^{1/2}, \quad (10)$$

where $r_{i,t+1}$ is the return on a financial asset, $E_t(\cdot)$ is the conditional expectation operator, $\varepsilon_{t+1} = z_{t+1} h_{t+1}^{1/2} \sim iid(0, h_{t+1})$, and h_{t+1} the conditional variance. z_{t+1} is a zero mean and unit variance random variable. The mean equation can be any function describing future returns. However, most often linear specifications are used. If the conditional variance or volatility is a part of the mean equation, the model is called (G)ARCH-in-Mean. It was developed by Engle et al. (1987), and is suited for estimating and testing risk-return relationships.

The standard GARCH(1,1) specification of Bollerslev (1986) models the conditional variance as a function of past disturbances and conditional variances:

$$h_{t+1} = \omega + \alpha \varepsilon_t^2 + \beta h_t^2. \quad (11)$$

To ensure positivity of the conditional variance, we require that $\omega, \alpha, \beta \geq 0$. Further, for stationarity we require that $\alpha + \beta$ is less than unity. This basic model is empirically well suited for financial data. However, it does not account for asymmetric effects of shocks

on volatility, i.e., that the volatility is higher following negative shocks than positive shocks of equal magnitude. A more formal definition of asymmetry is presented by Bekaert and Wu (2000): $\text{var}(r_{i,t+1}|I_t, \varepsilon_{i,t} < 0) - h_{i,t} > \text{var}(r_{i,t+1}|I_t, \varepsilon_{i,t} > 0) - h_{i,t}$, where I_t is the conditioning information. Further, if $\text{var}(r_{i,t+1}|I_t, \varepsilon_{i,t} < 0) - h_{i,t} > 0$ and $\text{var}(r_{i,t+1}|I_t, \varepsilon_{i,t} > 0) - h_{i,t} < 0$, they refer to it as strong asymmetry.

To accommodate asymmetry, Hentschel (1995) suggests the following very general absolute value GARCH model for the standard deviation:

$$\frac{\sigma_{t+1}^\lambda - 1}{\lambda} = \omega + \alpha \sigma_t^\lambda f^\nu(z_t) + \beta \frac{\sigma_t^\lambda - 1}{\lambda}, \quad (12)$$

where

$$f(z_t) = |z_t - b| - c(z_t - b), \quad (13)$$

and $\sigma_{t+1}^2 = h_{t+1}$. z_t is defined as $N(0, 1)$.

By appropriately choosing the values for λ , ν , b , and c in equations (12) and (13) we obtain some well-known (asymmetric) variance specifications. The standard GARCH specification in (11) is obtained by setting $\lambda = \nu = 2$ and $b = c = 0$. For $\lambda = \nu = 2$, $b = 0$, and a free c parameter the result is the asymmetric GARCH model of Glosten et al. (1993), used in Essay 2,

$$\sigma_{t+1}^2 = \omega' + 2\alpha\sigma_t^2[(1 + c^2)z_t^2 - 2c|z_t|z_t] + \beta\sigma_t^2. \quad (14)$$

For $c > 0$ it can be shown that a negative shock results in a higher variance than a positive. In Essay 4 we use a multivariate specification of the Exponential GARCH of Nelson (1991). Its univariate counterpart is obtained by setting $\lambda = b = 0$, and $\nu = 1$ in equation (12):

$$\ln \sigma_{t+1}^2 = 2\omega' + 2\alpha[|z_t| - E|z_t| - cz_t] + \beta \ln \sigma_t^2. \quad (15)$$

Equation (15) is obtained by subtracting the unconditional mean of $f(z_t)$ from $f(z_t)$. One appealing feature of the EGARCH is that there is no need to restrict the parameter values to ensure positivity.

Here we have limited ourselves to the description of the GARCH–GJR and EGARCH specifications used in this thesis. However, the general setting of equations (12) and (13) nests many other asymmetric volatility models. The Absolute Value specification of Schwert (1989) is obtained by setting $\lambda = \nu = 1$, and $|c| \leq 1$, while adding the restriction $b = 0$ yields the Threshold GARCH of Zakoian (1994). For $\lambda = \nu = 2$, and $c = 0$ the Nonlin-

ear-Asymmetric GARCH of Engle and Ng (1993) is obtained. Finally, let $\lambda=\nu$, and $b = 0$. Then, $c=0$ results in the Nonlinear ARCH of Higgins and Bera (1992), and $|c| \leq 1$ in the Asymmetric Power ARCH of Ding et al. (1993).

3.3.2 The Multivariate Case

In finance, for example within the CAPM, portfolio mathematics, and risk management, conditional covariances are crucial. However, univariate models do not allow the estimation of these covariances. The univariate GARCH(1,1) in equation (11) was first made multivariate by Bollerslev et al. (1988):

$$\text{vech}(\mathbf{H}_{t+1}) = \mathbf{C} + \mathbf{A}\text{vech}(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t') + \mathbf{B}\text{vech}(\mathbf{H}_t), \quad (16)$$

$\text{vech}(\cdot)$ is the vector-half operator stacking the lower triangular elements of an $N \times N$ matrix as an $N(N+1)/2 \times 1$ vector. \mathbf{H}_{t+1} is the positive-definite conditional variance-covariance matrix with dimension $N \times N$, and elements $h_{ij,t+1}$. $\boldsymbol{\varepsilon}_{t+1}$ is an $N \times 1$ residual vector, \mathbf{A} and \mathbf{B} $N(N+1)/2 \times N(N+1)/2$ parameter matrices, and \mathbf{C} an $N(N+1)/2 \times 1$ column vector of constants. The total number of parameters to estimate in this multivariate vech GARCH(1,1) is $N(N+1)/2 \times (1+N(N+1))$. While a bivariate system has 21 parameters to estimate, a trivariate 78, a 4x4 system contains 210 parameters to estimate. Increasing the number of lags further increases the number of parameters. Also, the structure of constraints that has to be imposed on the parameters to ensure positive-definiteness gets very complicated. Bollerslev et al. (1988) propose diagonality of the matrices \mathbf{A} and \mathbf{B} , which decomposes \mathbf{H}_{t+1} into

$$h_{ij,t+1} = \gamma_{ij} + \alpha_{ij} \varepsilon_{i,t} \varepsilon_{j,t} + \beta_{ij} h_{ij,t}. \quad (17)$$

Now each equation is an individual GARCH model. A trivariate system has 18 parameters to estimate, while a 4x4 system has 30. The number of parameters has clearly decreased compared to the vech representation. Further, the model can be extended to account for asymmetry, but the extension is not straightforward. One way is to include an asymmetry component in equation (17) similar to the GARCH–GJR specification.

Other well-known multivariate volatility models include the constant correlation model of Bollerslev (1990), the Factor ARCH specification of Engle et al. (1990), and a multivariate extension of the EGARCH as in Braun et al. (1995) and Koutmos (1996). However, the next specification we describe here is the model that is used in Essay 4, the asymmetric BEKK GARCH, named after Baba, Engle, Kraft and Kroner, and first proposed by Engle and Kroner (1995). The advantage of this representation is that it en-

sures positive definiteness of the variance-covariance matrix per definition by using quadratic forms:

$$\mathbf{H}_{t+1} = \mathbf{C}'\mathbf{C} + \mathbf{A}'\boldsymbol{\varepsilon}_t\boldsymbol{\varepsilon}_t'\mathbf{A} + \mathbf{B}'\mathbf{H}_t\mathbf{B} + \mathbf{D}'\boldsymbol{\eta}_t\boldsymbol{\eta}_t'\mathbf{D}, \quad (18)$$

where, for the bivariate case,

$$\mathbf{C} = \begin{bmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{bmatrix}, \mathbf{A} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}, \mathbf{B} = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}, \text{ and } \mathbf{D} = \begin{bmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{bmatrix}. \quad (19)$$

$\boldsymbol{\eta}_t$ is defined as $\min(0, \boldsymbol{\varepsilon}_t)$, and aimed at capturing volatility asymmetries. The number of parameters is smaller than in the vech representation, but still fairly high. If the representation is bidimensional, there are 15 variance parameters. For the three-dimensional system there are 33 parameters, and for the four-dimensional 58 parameters. To reduce the number of parameters, one can impose diagonality and symmetry restrictions.

The estimation of (G)ARCH-type models is most often conducted with maximum likelihood methods, which require a distributional assumption. The likelihood function is a function of the distributional assumption, the data, and the parameters. The parameters are estimated such that the likelihood function gets maximized. The most common distribution is the normal. Although GARCH models with the normal distribution capture a large part of the unconditional kurtosis, a part of it might be unmodeled. This finding can be circumvented by assuming a t distribution (see Essay 4), the generalized error distribution (see Essay 2), the skew- t distribution, or a mixture of normal distributions, just to mention the most traditional. Alternatively, given that the mean and variance equations are correctly specified, the normal distribution yields consistent, but less efficient estimates under the quasi-maximum likelihood technique. See Bollerslev and Wooldridge (1988). Since the likelihood function is often very complex and non-linear, the estimation procedure easily gets complicated. There are a number of optimization algorithms that numerically optimize the target function. In this thesis we use the Berndt–Hall–Hall–Hausman (BHHH, 1974) algorithm.

4 The Essays

This PhD thesis, *Essays on the Linkages between Financial Markets, and Risk Asymmetries*, studies links between financial markets. It consists of four essays. The first essay considers the long-term price linkages between six European markets. The second essay deals with volatility linkages to the “world” market. The third essay examines the linkages between three domestic financial markets. The fourth essay concentrates purely on risk asymmetries, which are a common feature in three of the essays. Essays 2 and 3 model volatility asymmetries, while the fourth essay deals both with volatility, and beta asymmetries.

4.1 Summary of the Essays

The first essay, *Testing for Cointegration between International Stock Prices*, co-authored with Niklas Ahlgren, and published in *Applied Financial Economics* as Ahlgren and Antell (2002)³, reconsiders the evidence for cointegration between international stock prices. If two or more economic variables individually are nonstationary, they might nonetheless form a linear combination that is stationary, hence constraining the long-run movement of the variables. Examples of variables that logically might be cointegrated include consumption and income and/or wealth, spot- and futures prices, prices of similar goods in different countries (the purchasing power parity), and stock prices and dividends. In this essay we use international monthly and quarterly equity index data for the period January 1980–February 1997. There are $T = 206$ monthly observations, and $T = 69$ quarterly observations. The countries included are Finland, France, Germany, Sweden, the United Kingdom, and the USA. All indices are denominated in US dollars. If the stock prices are cointegrated, they are driven by a common stochastic process, and the benefits from international diversification would decrease.

Using monthly and quarterly USD denominated stock prices data, Johansen’s (1996) trace statistic finds one cointegrating vector for monthly data, while the maximum eigenvalue statistic is unable to detect any cointegration. In quarterly data no cointegrating vectors could be found. Using small-sample corrections, no cointegrating vectors were observed. If stock markets are perfectly cointegrated, there should be $r = p - 1 = 5$ cointegrating vectors, where p is the number of markets, leaving a single common

³ The article is reproduced in this dissertation with permission from the publisher, Taylor & Francis Ltd. The publisher’s journal Internet site is <http://www.tandf.co.uk/journals>.

stochastic trend. Increasing the VAR order actually increases the degree of cointegration, being full when the VAR order is increased enough. Johansen's likelihood ratio tests for cointegration are sensitive to the lag length selection. However, no cointegration is found if small-sample corrections are utilized. Hence there is a small-sample bias and size distortion in Johansen's tests for cointegration. For example Kasa (1992) finds almost perfect cointegration between the US, Canada, Germany, Japan, and the UK stock markets in a specification with a large number of lags relative to the amount of data. In Essay 1, we do not find evidence of cointegration. For this reason there are long-run international diversification opportunities.

Essay 2, *The Influence of World Factors on Finnish Stock Market Volatility*, copes with the return and volatility connection between the Finnish stock market and the "world" market. Volatility is modeled as an asymmetric function of past innovations, allowing volatility to be higher after negative return shocks than positive shocks of equal magnitude. Also the effect of the severe recession of the Finnish economy in the beginning of the 1990' is explored. Due to deregulation of the financial markets, we expect that the impact of world shocks would have increased over time, especially post-1993, the year when foreigners were allowed to freely invest in Finnish financial assets. We use return observations for the period January 2, 1987 to December 30, 1998 on Finnish leverage, industry, and size portfolios. There are $T = 3009$ daily observations. The volatilities are modeled by asymmetric GARCH specifications similar to Glosten et al. (1993), and Bekaert and Harvey (1997).

Finnish returns are best portrayed by local information variables, and only occasionally by "world" variables. However, the world residual enters significantly the domestic models, and the impact has increased after 1993. A possible explanation for the insignificance of the world set is that the world market return (or residual) stands as a proxy for the world information set. Although the estimated integration parameters increase over time, the returns of Finnish stock portfolios are clearly not fully integrated to the world. Therefore the returns are generated by at least a partially segmented asset pricing model. The variance is time-varying, but surprisingly non-asymmetric⁴, also for leverage portfolios. No verification for the leverage hypothesis as explanation for volatility asymmetries can be made. Also the variance has become more tied to the world after

⁴ Asymmetry is found only for the market as a whole, and one industry (Multi-business) and one leverage portfolio.

1993. The increased impact of the world applies also for variance ratios, and the correlations to the world. The larger the firm, the larger is the world impact. The conditional variance is higher during recessions. Generally, the world stock market shock affects the domestic returns, and the world volatility affects domestic volatilities. The impact has grown over time.

While the two previous essays consider the price and volatility linkages between international financial markets, Essay 3, *Volatility Linkages in the Finnish Stock, Bond, and Money Markets*, deals with the linkages between different asset categories (“markets”) within a single geographic market. Fleming et al. (1998) develop a trading model that predicts strong volatility linkages between stock, bond, and money markets. The linkages are based on common information affecting all markets, and information spillover due to cross-market hedging. This has implications for asset management, risk allocation, and regulatory policy. Indeed, for daily US data over the period January, 1983 to August, 1995, Fleming et al. (1998) find volatility linkages much stronger than traditional return correlations. However, the linkages are not perfect, and the markets are not driven by the same information process.

We use weekly return data for the period January 9, 1991 to December 30, 2003 to determine the strength of volatility linkages between the Finnish stock, bond, and money markets. The number of observations is $T = 678$. The stock market is approximated by two different measures: the HEX General Yield Index, and the restricted HEX Portfolio index. The econometric specification is operationalized as a similar GMM representation as in Fleming et al. (1998). To compare the results, also a more traditional vector-autoregressive trivariate EGARCH model is used.

Using HEX general as stock market measure, the results are very different from Fleming et al. (1998). The GMM volatility linkage for the stock–bond market pairing is insignificantly negative, and for the stock–money combination significantly negative. Both measures are also clearly lower than the return correlations. The bond–money market pairing is clearly positive and in line with the return correlation. If HEX Portfolio is used as stock market measure, the results are different. Both the stock–bond, and stock–money combinations are insignificantly positive, and slightly higher than the return correlations. Also the EGARCH results confirm the negative volatility connection between the bond and money markets to the stock market. While the stock volatility is not af-

ected by other markets' volatility, money market volatility is affected negatively both by stock and bond volatility. Hence the stock market is the most "independent", and the money market the most "dependent" on the other markets. Since the volatility linkages are found to be fairly weak, it is likely that the markets are driven by different investor clienteles.

Further, the EGARCH return correlations have decreased over the sample period for the stock–bond, and stock–money pairings, and increased for the bond–money pairing. Both the stock market and the money market exhibit asymmetric volatility. This indicates that the leverage hypothesis cannot be the sole explanation for asymmetric volatility. The volatility transmission is asymmetric from the stock market to the bond market, and the money market. However, the transmission is negative rather than positive. I.e., a negative shock on the stock market, increasing variance more than a positive shock of equal magnitude, decreases fixed income volatility.

In the final essay, *Time-Varying Betas and Asymmetric Effects of News on Risk*, we further examine the presence of asymmetries in Finnish equity markets. We explore the properties of both the volatility, a measure of the total risk, and the CAPM beta, a measure of systematic risk. It is fully possible that the beta exhibits asymmetries similar to the volatility. This has implications for asset pricing, portfolio management, risk allocation, and for assessing the cost of capital. The literature on beta asymmetries is much less extensive than on volatility asymmetries. In this paper we use daily return observations for seven Finnish industry portfolios, and ten size-sorted portfolios for the period January, 1987 to December, 2000. There are $T = 3511$ observations. The econometric setting is based on the bivariate BEKK GARCH specification developed in Engle and Kroner (1995), with mean equations based on a vector autoregressive moving average process. Time-varying betas (and correlations) for the stock portfolios are obtained as functions of the estimated variance-covariance matrix for the market and portfolio return.

Both the conditional volatilities and betas are highly time-varying and persistent, and the variance-covariance matrix is asymmetric. The Finnish stock market volatility is asymmetric, but it is mainly driven by "own asymmetry". In contrast, both portfolio asymmetry and covariance asymmetry are also mainly driven by the market component. Asymmetry, when it occurs, is generally determined by the market component,

not the portfolio component. Since the beta is a function of two components, the conditional covariance to the market, and the conditional market variance, both of which can be asymmetric, we expect it to be hard to find beta asymmetries. However, there are some beta asymmetries. However, the asymmetry is negative more often than positive. Investing in portfolios with negative downside beta might yield favorable risk-return opportunities. Again, the market component is better able to explain asymmetries than the portfolio specific component. The betas have decreased post-1993, and been somewhat higher during the economic recession.

To sum up, essays 1,2 and 3 deal with financial market linkages, Essay 1 with price linkages, and essays 2 and 3 with both return and volatility linkages, with the emphasis on the latter. Volatility asymmetries are modeled in essays 2, 3 and 4. In the last essay the weight is given beta asymmetries. In the first two essays international data are used, and in the last two domestic data. In other words, financial market linkages are investigated in three of the essays, and risk asymmetries also in three essays. Market linkages and risk asymmetries are combined in two of the essays. The thesis starts with a "pure" financial linkages paper, continues with two papers combining market linkages and volatility asymmetries, and ends with a paper focusing purely on risk asymmetries. The final deregulation of the Finnish financial markets in the beginning of 1993, and the severe economic recession in the beginning of the 1990's are incorporated in essays 2, 3 and 4. Hence, many of the issues in this thesis are present in several essays.

4.2 Statistical Versus Economic Significance

The four essays are based on an extensive use of econometric methods. Some of the results are statistically significant, while others are not. What is the economic significance of the obtained statistical results? For example Kroner and Ng (1998) illustrate that the choice of method for estimating the variance-covariance matrix is essential also economically in terms of asset pricing, portfolio selection, and risk management. One of their results is that the correlations between risk-minimizing hedge ratios based on different volatility models are low, sometimes being negative. The actions of a portfolio manager will be very different depending on which model he chooses.

Statistical cointegrating vectors can be considered constraints an economic system imposes on the variables in the long run. If there is cointegration between financial vari-

ables, they cannot diverge excessively from each other. On the other hand, if there is no cointegration, the variables may depart from each other without restrictions. This has implications especially on diversification, and to some extent on financial market integration, but not on market efficiency albeit this stance is taken in some cointegration papers, e.g. Chan et al. (1997), and Caporale and Pittis (1998). If there is a high degree of cointegration, the benefits of long-run international diversification decrease. In contrast, lack of cointegration implies that there are diversification opportunities. On the other hand, one should be more cautious regarding the relation between statistical cointegration and financial market integration, meaning that the return generating process of different markets is common. It should be noted that markets might be cointegrated for other reasons than economic integration. However, as we show in Essay 1 (Ahlgren and Antell, 2002), financial market integration implies statistical cointegration. The same applies for all measures of linkages, transmission, and spillover – a high degree of linkages is not sufficient to validate integration. On the other hand, if markets were financially integrated, we would expect strong linkages. The third relation of interest is that between cointegration and financial market efficiency. While the connection with economic integration is inconclusive, the relationship to efficiency is clear. If we define efficiency as the lack of arbitrage opportunities from predictable asset returns, cointegration does not exclude efficiency, even if it implies predictability. As a result, some caution should be addressed when interpreting the implications of cointegration.

5 Summary and Conclusions

In this thesis we study the price, return, and volatility linkages between international financial markets, and between different asset categories within one country. Further, we study the asymmetric properties of total risk and systematic risk. These issues have implications for investment and risk management, diversification, asset pricing, and regulation. The data in all essays are associated to Finland for an interesting time period in the 1980's and 1990's.

In the first essay, cointegration analysis is used to assess the number of common stochastic trends. Since no cointegration is found, there are still benefits to international diversification. In the second essay we examine the influence of world factors on Finnish returns and volatilities, and find that the impact of the “world” has increased over time. The domestic volatility is higher during recessions. In the third essay the volatility linkages between stock, bond, and money markets are studied. Using the trading

model of Fleming et al. (1998), predicting perfect volatility linkages, we find that the volatility linkages are surprisingly weak. However, money market volatility is affected by both stock, and bond volatility, while stock market volatility is the most independent, and is not affected by the others. The fairly weak evidence of volatility linkages suggests that different asset categories are dominated by different investor clienteles, and that market participants do not necessarily need to consider correlation measures beyond traditional return correlations. Surprisingly, not only stock market volatility exhibit asymmetric volatility, but also money market volatility. The last essay concentrates on risk asymmetries, and finds that there are both volatility and beta asymmetries. The market component is the main driver behind market, portfolio, and covariance asymmetry. The beta is more often positively asymmetric than negatively, indicating that there might be favorable investment opportunities when investing in portfolios with lower downside systematic risk.

References

- Ahlgren N. & Antell, J. (2002): "Testing for Cointegration between International Stock Prices." *Applied Financial Economics*, Vol. 12, No. 12, pp. 851–861.
- Ammer, J. & Mei, J. (1996): "Measuring International Economic Linkages with Stock Market Data." *Journal of Finance*, Vol. 51, No. 5, pp. 1743–1763.
- Arshanapalli, B., Doukas, J. & Lang, L. H. P. (1997): "Common Volatility in the Industrial Structure of Global Capital Markets." *Journal of International Money and Finance*, Vol. 16, No. 2, pp. 189–209.
- Bachelier, L. (1900): "Theorie de la Speculation." *Annals de l'Ecole Normale Supérieure*, Ser. 3, No. 17, pp. 21–84.
- Bekaert, G. & Harvey, C. R. (1997): "Emerging Market Volatility." *Journal of Financial Economics*, Vol. 43, No. 1, pp. 29–77.
- Bekaert, G. & Wu, G. (2000): "Asymmetric Volatility and Risk in Equity Markets." *Review of Financial Studies*, Vol. 13, No. 1, pp. 1–42.
- Ben-Zion, U., Choi, J. J. & Hauser, S. (1996): "The Price Linkages Between Country Funds and National Stock Markets: Evidence from Cointegration and Causality Tests of Germany, Japan and UK Funds." *Journal of Business Finance & Accounting*, Vol. 23, No. 7, pp. 1005–1017.
- Berndt, E., Hall, B., Hall, R. & Hausman, J. (1974): "Estimation and Inference in Nonlinear Structural Models." *Annals of Economic and Social Management*, 3/4, pp. 653–665.
- Black, F. (1976): "Studies in Price Volatility Changes." *Proceedings of the 1976 Meeting of the Business and Economics Statistics Section*, American Statistical Association, pp. 177–181.
- Bollerslev, T. (1986): "Generalized Autoregressive Conditional Heteroskedasticity." *Journal of Econometrics*, Vol. 31, No. 3, pp. 307–327.
- Bollerslev, T. (1990): "Modelling the Coherence in Short-Run Nominal Exchange Rates: A Multivariate Generalized Arch Approach." *Review of Economics and Statistics*, Vol. 72, No. 2, pp. 498–505.
- Bollerslev, T., Chou, R. Y. & Kroner, K. F. (1992): "ARCH Modeling in Finance." *Journal of Econometrics*, Vol. 52, No. 1–2, pp. 5–59.
- Bollerslev, T., Engle, R. & Nelson, D. (1994): "Arch Models." In Engle, R. & McFadden, D. (eds.): *Handbook of Econometrics*, Vol. 4, North Holland, pp. 2959–3038.
- Bollerslev, T., Engle, R. F. & Wooldridge, J. M. (1988): "A Capital Asset Pricing Model with Time-varying Covariances." *Journal of Political Economy*, Vol. 96, No. 11, pp. 116–131.

Bollerslev, T. & Wooldridge, J. M. (1992): "Quasi-Maximum Likelihood Estimation and Inference in Dynamic Models with Time-Varying Covariances." *Econometric Reviews*, Vol. 11, No. 1, pp. 143–172.

Booth, G. G., Martikainen, T. & Tse, Y. (1997): "Price and Volatility Spillovers in Scandinavian Stock Markets." *Journal of Banking and Finance*, Vol. 21, No. 6, pp. 811–823.

Braun, P. A., Nelson, D. P. & Sunier, A. M. (1995): "Good News, Bad News, Volatility, and Betas." *Journal of Finance*, Vol. 50, No. 5, pp. 1575–1603.

Brooks, C. & Henry, Ó. T. (2001): "The Impact of News on Measures on Undiversifiable Risk: Evidence from the UK Stock Market." University of Melbourne, Department of Economics, Research Paper No. 733.

Campbell, J. Y. & Hentschel, L. (1992): "No News is Good News: An Asymmetric Model of Changing Volatility in Stock Returns." *Journal of Financial Economics*, Vol. 31, No. 3, pp. 281–318.

Caporale, G. M. & Pittis, N. (1998): "Cointegration and Predictability of Asset Prices." *Journal of International Money and Finance*, Vol. 17, No. 3, pp. 411–453.

Chan, K. C., Gup, B. E. & Pan, M.–S. (1997): "International Stock Market Efficiency and Integration: A Study of Eighteen Nations." *Journal of Business Finance and Accounting*, Vol. 24, No. 6, pp. 803–813.

Cho, Y.–E. & Engle R. F. (1999): "Time-Varying Betas and Asymmetric Effects of News: Empirical Analysis of Blue Chip Stocks." NBER Working Paper 7330.

Christie, A. (1982): "The Stochastic Behaviour of Common Stock Variance: Value, Leverage and Interest Rate Effects." *Journal of Financial Economics*, Vol. 10, No. 4, pp. 407–432.

Claessens, S., Dornbusch, R. & Park, Y. C. (2001): "Contagion: How It Spreads and How It Can Be Stopped". In Claessens, S. & Forbes, K. J. (eds.): *International Financial Contagion*, Kluwer Academic Publishers, Norwell, MA).

Corhay, A., Tourani Rad, A. & Urbain, J.–P. (1993): "Common Stochastic Trends in European Stock Markets." *Economics Letters*, Vol. 42, No. 4, pp. 385–390.

De Goeij, P. & Marquering, W. (2003): "Modeling the Conditional Covariance Between Stock and Bond Returns: A Multivariate GARCH Approach." Working Paper, University of Leuven/ Erasmus University Rotterdam.

Ding, Z, Granger, C. W. J. & Engle, R. F. (1993): "A Long Memory Property of Stock Market Returns and a New Model." *Journal of Empirical Finance*, Vol. 1, No. 1, pp. 73–106.

Engle, R. F. (1982): "Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of U.K. Inflation." *Econometrica*, Vol. 50, No. 4, pp. 987–1007.

Engle, R. F. & Granger, C. W. J. (1987): "Co-Integration and Error Correction: Representation, Estimation, and Testing." *Econometrica*, Vol. 55, No. 2, pp. 251–276.

Engle, R. F. & Kroner, K. (1995): "Multivariate Simultaneous Generalized ARCH." *Econometric Theory*, Vol. 11, No. 1, pp. 122–150.

Engle, R. F., Liliien, D. M. & Robins, R. P. (1987): "Estimating the Time Varying Risk Premia in the Term Structure: The ARCH-M Model." *Econometrica*, Vol. 55, No. 2, pp. 391–407.

Engle, R. F. & Ng, V. G. (1993): "Measuring and Testing the Impact of News on Volatility." *Journal of Finance*, Vol. 48, No. 5, pp. 1749–1778.

Engle, R. F. & Ng, V. G. & Rotschild, M. (1990): "Asset Pricing with a Factor ARCH Covariance Structure: Empirical Estimates for Treasury Bills." *Journal of Econometrics*, Vol. 45, No. 1–2, pp. 213–238.

Engsted, T. & Lund, J. (1997): "Common Stochastic Trends in International Stock Prices and Dividends: An Example of Testing Overidentifying Restrictions on Multiple Cointegration Vectors." *Applied Financial Economics*, Vol. 7, No. 6, pp. 659–665.

Eun, C. S. & Shim, S. (1989): "International Transmission of Stock Market Movements." *Journal of Financial and Quantitative Analysis*, Vol. 24, No. 2, pp. 241–256.

Fama, E. F. (1965): "The Behavior of Stock Market Prices." *Journal of Business*, Vol. 38, No. 1, pp. 34–105.

Fama, E. F. (1970): "Efficient Capital Markets: A Review of Theory and Empirical Work." *Journal of Finance*, Vol. 25, No. 2, pp. 383–417.

Fama, E. F. (1991): "Efficient Capital Markets II." *Journal of Finance*, Vol. 46, No. 5, pp. 1575–1617.

Fleming, J., Kirby, C. & Ostdiek, B. (1998): "Information and Volatility Linkages in the Stock, Bond, and money Markets." *Journal of Financial Economics*, Vol. 49, No. 1, pp. 111–137.

Forbes, K. J. & Rigobon, R. (2001): "Measuring Contagion : Conceptual and Empirical Issues." In Claessens, S. & Forbes, K. J. (eds.): *International Financial Contagion*, Kluwer Academic Publishers, Norwell, MA.

Forbes, K. J. & Rigobon, R. (2002) : "No Contagion, Only Interdependence : Measuring Stock Market Comovements." *Journal of Finance*, Vol. 57, No. 5, pp. 2223–2261.

French, K. R., Schwert, G. W. & Stambaugh, R. (1987): "Expected Stock Returns and Volatility." *Journal of Financial Economics*, Vol. 19, No. 1, pp. 3–29.

von Furstenberg, G. M. & Jeon, B. N. (1989): "International Stock Price Movements: Links and Messages." In Brainard, W. C. & Perry, G. C., eds.: *Brookings Papers on Economic Activity*, Vol. 1989, No. 1, pp. 125–179.

Glosten, L. R., Jagannathan, R. & Runkle, D. E. (1993): "On the Relation between the Expected Value and the Volatility of the Nominal Excess Return on Stocks." *Journal of Finance*, Vol. 48, No. 5, pp. 1779–1801.

Goetzmann, W. N., Li, L. & Rouwenhorst, K. G. (2002): "Long-Term Global Market Correlations." Yale ICF Working Paper No. 00-60.

Granger, C. W. J. (1981); "Some Properties of Time Series Data and Their Use in Econometric Model Specification." *Journal of Econometrics*, Vol. 16, No. 1, pp. 121-130.

Grubel, H. G. (1968): "Internationally Diversified Portfolios." *American Economic Review*, Vol. 58, No. 5, 1299-1314.

Hamao, Y., Masulis, R. W. & Ng, V. (1990): "Correlations in Price Changes and Volatility across International Stock Markets." *Review of Financial Studies*, Vol. 3, No. 2, pp. 281-307.

Hamilton, J. D. & Lin, G. (1996): "Stock Market Volatility and the Business Cycle." *Journal of Applied Econometrics*, Vol. 11, No. 5, pp. 573-593.

Hansen, L. P. (1982): "Large Sample Properties of Generalized Method of Moments Estimators", *Econometrica*, Vol. 50., No. 4, pp. 1029-1054.

Hansen, L. P. & Singleton, K. J. (1982): "Generalized Instrumental Variables Estimation of Nonlinear Rational Expectations Models." *Econometrica*, Vol. 50, No. 2, pp. 1269-1286.

Harris, F. H. deB, McInish, T. H., Shoesmith, G. L. & Wood R. A. (1995): "Cointegration, Error Correction, and Price Discovery on Informationally Linked Security Markets." *Journal of Financial and Quantitative Analysis*, Vol. 30, No. 4, pp. 563-579.

Hentschel, L. (1995): "All in the Family: Nesting symmetric and Asymmetric GARCH models." *Journal of Financial Economics*, Vol. 39, No. 1, pp. 71-104.

Higgins, M. L. & Bera, A. K. (1992): "A Class of Nonlinear ARCH Models." *International Economic Review*, Vol. 33, No. 1, pp. 137-158.

Johansen, S. (1988): "Statistical Analysis of Cointegration Vectors." *Journal of Economic Dynamics and Control*, Vol. 12, No. 2-3, pp. 231-254.

Johansen, S. (1991): "Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models." *Econometrica*, Vol. 59, No. 6, pp. 1551-1580.

Johansen, S. (1996): *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*. Oxford: Oxford University Press.

Kanas, A. (1998): "Linkages between the US and European Equity Markets: Further Evidence from Cointegration Tests." *Applied Financial Economics*, Vol. 8, No. 6, pp. 607-614.

Karolyi, G. A. (1995): "A Multivariate GARCH Model of International Transmission of Stock Returns and Volatility: The Case of the U.S. and Canada." *Journal of Business & Economic Statistics*, Vol. 13, No. 1, pp. 11-25.

- Karolyi, G. A. & Stulz, R. M. (1996): "Why Do Markets Move Together? An Investigation of U.S.–Japan Stock Return Comovements." *Journal of Finance*, Vol. 51, No. 3, pp. 951–986.
- Karolyi, G. A. & Stulz, R. M. (2002): "Are Financial Assets Priced Locally or Globally?" NBER Working Paper 8994.
- Kasa, K. (1992): "Common Stochastic Trends in International Stock Markets." *Journal of Monetary Economics*, Vol. 29, No. 1, pp. 95–124.
- King, M., Sentana, E. & Wadhvani, S. (1990): "Transmission of Volatility between Stock Markets." *Review of Financial Studies*, Vol. 3, No. 1, pp. 5–33.
- Knif, J. & Pynnönen, S. (1999): "Local and Global Price Memory of International Stock Markets." *Journal of International Financial Markets, Institutions and Money*, Vol. 9, No. 2, pp. 129–147.
- Koutmos, G. (1996): "Modeling the Dynamic Interdependence of Major European Stock Markets." *Journal of Business Finance and Accounting*, Vol. 23, No. 7, pp. 975–988.
- Koutmos, G. (1998): "Asymmetries in the Conditional Mean and the Conditional Variance: Evidence from Nine Stock Markets." *Journal of Economics and Business*, Vol. 50, No. 3, pp. 277–290.
- Koutmos, G. & Booth, G. G. (1995): "Asymmetric Volatility Transmission in International Stock Markets." *Journal of International Money and Finance*, Vol. 14, No. 6, pp. 747–762.
- Koutmos, G. & Knif, J. (2002a): "Time Variation and Asymmetry in Systematic Risk: Evidence from the Finnish Stock Exchange." *Journal of Multinational Financial Management*, Vol. 12, No. 3, pp. 261–271.
- Koutmos, G. & Knif, J. (2002b): "Estimating Systematic Risk Using Time Varying Distributions." *European Financial Management*, Vol. 8, No. 1, pp. 59–73.
- Kroner, K. F. & Ng, V. K. (1998): "Modeling Asymmetric Comovements of Asset Returns." *Review of Financial Studies*, Vol. 11, No. 4, pp. 817–844.
- Lee, S. B. & Kim, K. J. (1993): "Does the October 1987 Crash Strengthen the Comovements among National Stock Markets?" *Review of Financial Studies*, Vol. 3, No. 1, pp. 89–102.
- Lee, T.–H. & Tse, Y. (1996): "Cointegration Tests with Conditional Heteroskedasticity." *Journal of Econometrics*, Vol. 73, No. 2, pp. 401–410.
- Levy, H. & Sarnat, M. (1970): "International Diversification of Investment Portfolios." *American Economic Review*, Vol. 60, No. 4, pp. 668–675.
- Longin, F. & Solnik, B. (1995): "Is the Correlation in International Equity Returns Constant: 1960–1990?" *Journal of International Money and Finance*, Vol. 14, No. 1, pp. 3–26.

Mandelbrot, B. (1963): "The Variation of Certain Speculative Prices." *Journal of Business*, Vol. 36, No. 4, pp. 394–419.

Meric, I. & Meric, G. (1996): "Inter-Temporal Stability in the Long-Term Co-Movements of the World's Stock Markets." *Journal of Multinational Financial Management*, Vol. 6, No. 4, pp. 73–83.

Meric, I. & Meric, G. (1997): "Co-Movements of European Equity Markets Before and After the 1987 Crash." *Multinational Finance Journal*, Vol. 1, No. 2, pp. 137–152.

Nelson, D. (1991): "Conditional Heteroskedasticity in Asset Returns: A New Approach." *Econometrica*, Vol. 59, No. 2, pp. 347–370.

Newey, W. K. & West, K. D. (1987): "Hypothesis Testing with Efficient Method of Moments Estimation." *International Economic Review*, Vol. 28, No. 3, pp. 777–787.

Ng, A. (2000): "Volatility Spillover Effects from Japan and the US to the Pacific-Basin." *Journal of International Money and Finance*, Vol 19, No. 2, pp. 207–233.

Pindyck, R. S. (1984): "Risk, Inflation and the Stock Market." *American Economic Review*, Vol. 74, No. 3, pp. 335–351.

Pynnönen, S. & Knif, J. (1998): "Common Long-Term and Short-Term Price Memory in Two Scandinavian Stock Markets." *Applied Financial Economics*, Vol. 8, No. 3, pp. 257–265.

Rigobon, R. (2003): "On the Measurement of the International Propagation of Shocks: Is the Transmission Stable?" *Journal of International Economics*, Vol 61, No. 2, pp. 261–283.

Schwert, G. W. (1989): "Why Does Stock Market Volatility Change Over Time?" *Journal of Finance*, Vol. 44, No. 5, pp. 1115–1153.

Veronesi, P. (1999): "Stock Market Overreaction to Bad News in Good Times: A Rational Expectations Equilibrium Model." *Review of Financial Studies*, Vol. 12, No. 5, pp. 975–1007.

Wu, G. (2001): "The Determinants of Asymmetric Volatility." *Review of Financial Studies*, Vol. 14, No. 3, pp. 837–859.

Zakoian, J.-M. (1994): "Threshold Heteroskedastic Models." *Journal of Economic Dynamics and Control*, Vol. 18, No. 5, pp. 931–955.