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2002

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JEL codes: G15 G18 F36 C15

February 16, 2002

Abstract

This paper uses a multivariate regime-switching framework to investigate and endogenously date changes in return characteristics on the four largest Nordic stock markets. We find that the deregulated time-period, specifically after 1982, is associated with higher expected return, higher volatility, stronger links with international stock markets and higher correlation between the Nordic stock markets. This higher correlation is mainly driven by common higher correlation with international stock returns and not by higher correlation between country specific components of return. Further, our evidence support the argument that market liberalization creates excess volatility but also that Nordic investors are more than compensated for this by higher expected returns and the opportunity to cross-border diversification after liberalization.

Keywords: stock market liberalization; excess volatility; portfolio diversification; multivariate regime-switching models; simulated annealing

*I am indebted to Eric Bentzen, David Edgerton, Björn Hansson, Jesper Rangvid, Lena Sellgren, Lorne Switzer as well as to seminar participants at the EFMA conference in Athens for many valuable comments and suggestions. Telephone: +46 (0)46 222 79 12. Fax: +46 (0)46 222 41 18. Email: birger.nilsson@nek.lu.se.

1 Introduction

The process towards more integrated financial markets during the last decades suggests that the investment opportunities as well as the environment for politically induced policy decisions have changed. Financial deregulation of the stock markets could itself be seen as a sequence of policy decisions aiming at removing different barriers preventing cross-border trade of financial assets. Examples of such barriers relevant for the Nordic markets are legal restrictions on ownership of foreign stocks or on foreign ownership of domestic stocks and currency controls preventing free cross-border capital flows. Not only the removal of legal barriers has created more integrated stock markets, also the rapid development and more widespread use of information technology have probably contributed significantly to the integration process. The main purpose of this paper is to document to what extent this liberalization process could be associated with changes in return behavior on the four largest Nordic stock markets, Sweden, Finland, Denmark and Norway.

The elimination of legal barriers preventing free cross-border trade of stocks in the Nordic countries has certainly been a gradual process stretching over several decades. The process accelerated in the beginning of the 1980s and at the end of 1992 almost all restrictions on both cross-border ownership and capital flows were officially removed. The barriers were most severe for Sweden and Finland; in the 1970s and earlier Swedish and Finnish investors' were effectively prevented to diversify by portfolio investments abroad and foreign exchange controls were prohibitive. These barriers were successively removed and 1990 both restrictions on domestic investors ability to foreign financial investments and currency controls had been abandoned. The remaining restrictions on foreign ownership of Swedish and Finnish stocks were finally removed at the end of 1992. In contrast, accompanying the Danish EU membership, foreign investors have had access to the Danish stock market since 1973. However, it was not until 1984 restrictions for Danish investors to buy foreign stock were completely removed. In Norway, financial deregulation was implemented during the 1980s and in 1990 most remaining foreign exchange rate controls were abolished. Norway is however different from the other Nordic countries considered in the respect that there are still indirect ownership restrictions due to substantial state ownership in many industries.

The Nordic countries belong to the small open economy category, with large imports and exports in relation to gross domestic products.[1] One interesting implication of this is

[1]The individual average openness ratios for the four Nordic countries are 0.57 (Sweden), 0.53 (Finland),

that companies, and hence stock markets, are likely to be highly sensitive to international business conditions. Hence, it is possible that common stock market characteristics, at least partly, follow from similar shocks affecting segmented, rather than integrated markets. Another problem is that legal restrictions may be non-binding, i.e. they are possible to circumvent by for example large institutional investors, which also makes it difficult to use prespecified dates for integration.

For these reasons, i.e. in order to preserve generality, we specify an empirical model to endogenously date structural breaks in the return behavior and to allow for different return characteristics at different points in time. In particular, a priori expectations based on for example an asset pricing argument of common priced sources of risk, implies that stock market liberalization is associated with stronger links to international stock markets. This is because in perfectly integrated markets all assets with identical risk exposure also command identical expected returns, see Campbell and Hamao (1992) and Bekaert and Harvey (1995) for thorough discussions. We measure the changing international dependence of the Nordic stock markets by allowing for regime dependent sensitivities, i.e. different "betas" with international stock returns at different points in time.

Another interesting issue in international finance is if stock market liberalization creates an increased volatility, sometimes termed excess volatility. This may be due to noise trading, i.e. investors entering and leaving a stock market for reasons other than fundamental, see e.g. Black (1986) and Grossman (1995). Sellin (1996) finds evidence of increased noise trading after remaining ownership restrictions on Swedish stock were lifted in 1992. He does, however, not relate his finding of this particular trading pattern to any measure of volatility. To investigate the question of excess volatility, we directly allow for different country specific volatility in different regimes and decompose the total variance over time into components attributable to international variance and country specific variance. In addition, the multivariate nature of our model also facilitates a corresponding decomposition of covariances and we discuss how market liberalization has affected common movements and correlations between the Nordic stock markets.

There is a well known problem of multimodality of the likelihood function for the mixture class of models. This means that in principle a very large number of starting values must be used, a number that grows exponentially in the number of parameters.

0.64 (Denmark) and 0.80 (Norway). As a comparison the corresponding average for the US is 0.16. There are differences in openness for the first and the second half of the sample 1957:6-1999:6, but these are surprisingly small. Import, export and GDP figures are taken from the IFS CD-ROM.

For example, Hamilton (1996), referring to relatively simple univariate models, writes: "In practice, an econometrician should investigate several hundred values from which to start the maximization iterations". Needless to say, the situation is even worse for a multivariate model. Our answer to this problem is to use simulated annealing, a global stochastic optimization algorithm in the Markov Chain Monte Carlo family with the appealing feature that it is able to escape from truly local optima.

The remainder of the paper is organized as follows. Section 2 outlines the empirical specification and the estimation of the model. Section 3 provides a brief description of the data. Section 4 presents the complete estimation results together with tests of a number of hypotheses. Section 5 contains a discussion of changes in Nordic stock return characteristics in the context of financial liberalization and of economic implications for Nordic stock market investors. Section 6 summarizes and concludes.

2 Empirical specification and estimation

The Markovian regime-switching model of Goldfeld and Quandt (1973) provides a convenient way to simultaneously model endogenously determined structural breaks in the parameters and the temporal dependence between time-series observations. This very general class of models allows for structural breaks in both mean and variance parameters. In this paper we use a multivariate extension of the well-known model in Hamilton (1989). The basic idea is that a given observation, i.e. a vector of returns $\mathbf{r}_t$, belongs to one out of a number of specific probability density functions. These multivariate density functions, one for each regime, differ from each other both in terms of mean vectors and variance-covariance matrices. Technically, an unobserved Markov-switching state- variable z_t governs the switches between regimes and facilitates an endogenous classification of each observation $\mathbf{r}_t$. This classification associates a given observation with each of the density functions in terms of a probability.

2.1 Mean and variance-covariance parameterizations

To allow for structural breaks in international dependence, we specify the mean equations to reflect the possibility of weak versus strong international dependence. Weak international dependence can be thought of as low betas with international stock returns and strong international dependence as high betas with international stock returns. We use stock returns from the US, Japan, the UK and Germany as exogenous variables and the mean equation within each regime s is parameterized according to

$$\boldsymbol{\mu}_{st} = \boldsymbol{\alpha}_s + \mathbf{B}_s \mathbf{x}_t + \sum_{l=1}^{L} \Psi_{sl} \mathbf{r}_{t-l}, \; s = 1, ..., N \tag{1}$$

where we restrict attention to the case $N = 2$, i.e. a two-regime model.[2] The parameter matrix $\mathbf{B}_s$ contains the betas for regime s and $\mathbf{x}_t = (x_{USt}, x_{JPNt}, x_{UKt}, x_{GERt})'$ is the vector of exogenous variables. To account for potential predictability lagged returns, $\mathbf{r}_{t-l} = \left(r_{SWE,t-l}, r_{FIN,t-l}, r_{DEN,t-l}, r_{NOR,t-l}\right)'$, are included in the mean equations. The parameter matrix Ψ_{sl} contains the AR-parameters for lag l and regime s, where the number of included lags L could differ between the countries. We restrict Ψ_{sl} to be diagonal, i.e. only own lagged returns influence the return process for each country.[3]

The possibility of excess volatility is captured by a regime-dependent specification of the covariance matrix of idiosyncratic returns. The volatility regimes may be thought of as low volatility and high volatility. The covariance matrix within each regime s is parameterized according to

$$\Sigma_s = \begin{bmatrix} \sigma^2_{s,SWE} & \rho_{s,SWEFIN}\sigma_{s,SWE}\sigma_{s,SWE} & \rho_{s,SWEDEN}\sigma_{s,SWE}\sigma_{s,DEN} & \rho_{s,SWENOR}\sigma_{s,SWE}\sigma_{s,NOR} \\ & \sigma^2_{s,FIN} & \rho_{s,FINDEN}\sigma_{s,FIN}\sigma_{s,DEN} & \rho_{s,FINNOR}\sigma_{s,FIN}\sigma_{s,NOR} \\ & & \sigma^2_{s,DEN} & \rho_{s,DENNOR}\sigma_{s,DEN}\sigma_{s,NOR} \\ & & & \sigma^2_{s,NOR} \end{bmatrix}. \tag{2}$$

This parameterization also implies that we allow for non-zero and regime-dependent correlations between the country-specific components of returns. Note that although the covariance matrix is constant given the regime, this does not imply that variances and covariances are constant over time. Because of the switches between regimes and the fact that regimes are not known with certainty, a regime-switching model allows for very rich variance and covariance dynamics.

[2] The complexity of the multivariate two-regime model prevents us from estimating an even larger model. However, we implement some Monte Carlo experiments using univariate models to test for the existence of regimes, see Appendix A. We strongly reject the null hypothesis of a linear model for all four Nordic countries.

[3] We performed some experiments with lagged cross-country influences, but these variables do not seem to add any explanatory power.

2.2 The log-likelihood function

We assume that the conditional probability density functions are of the multivariate Student-t variety. It is argued in Klassen (1999) that the use of the Student-t distribution will give rise to more persistent regimes. The reason is that the tail-probabilities are potentially higher when compared to the usually applied Normal distribution, and thus even an observation relatively far from the mean of a particular regime could be accommodated by that regime. The multivariate m-dimensional Student-t density function for the observation $\mathbf{r}_t$ conditional on the regime, the history of returns $\mathbf{R}_{t-1} = \{\mathbf{r}_{t-1}, \mathbf{r}_{t-2}, ...\}$ and the exogenous variables can be parameterized as

$$g_{st}\left(\mathbf{r}_t | z_t = s, \mathbf{x}_t, \mathbf{R}_{t-1}; \boldsymbol{\theta}_s\right) = \frac{\Gamma\left(\frac{v_s+m}{2}\right)}{\Gamma\left(\frac{v_s}{2}\right)\pi^2\left(\nu_s - 2\right)^2} |\boldsymbol{\Sigma}_s|^{-\frac{1}{2}} \left[1 + \frac{1}{\nu_s - 2}\left(\mathbf{r}_t - \boldsymbol{\mu}_{st}\right)' \boldsymbol{\Sigma}_s^{-1}\left(\mathbf{r}_t - \boldsymbol{\mu}_{st}\right)\right]^{-\frac{(v_s+m)}{2}} \tag{3}$$

where the vector of parameters $\boldsymbol{\theta}_s$ contains the parameters in $\boldsymbol{\mu}_{st}$ and Σ_s together with the degrees of freedom parameter, ν_s. In our setting, the dimension of the return vector is $m = 4$.

We postulate a first order Markov chain with constant transition probabilities. Then, by definition the transition probability to move from regime s at time $t-1$ to regime k at time t is $\Pr\left(z_t = k | z_{t-1} = s\right) = p_{sk},\ s, k = 1, ..., N$. Following Hamilton (1994) the optimal inference of the probability that $\mathbf{r}_t$ belongs to regime s can be calculated as

$$\Pr\left(z_t = s | \mathbf{r}_t, \mathbf{x}_t, \mathbf{R}_{t-1}; \boldsymbol{\theta}\right) = \frac{\Pr\left(z_t = s | \mathbf{x}_t, \mathbf{R}_{t-1}; \boldsymbol{\theta}\right) g_{st}\left(\mathbf{r}_t | z_t = s, \mathbf{x}_t, \mathbf{R}_{t-1}; \boldsymbol{\theta}\right)}{\sum_{k=1}^{N} \Pr\left(z_t = k | \mathbf{x}_t, \mathbf{R}_{t-1}; \boldsymbol{\theta}\right) g_{kt}\left(\mathbf{r}_t | z_t = k, \mathbf{x}_t, \mathbf{R}_{t-1}; \boldsymbol{\theta}\right)} \tag{4}$$

where $\boldsymbol{\theta}$ is the full vector of parameters to be estimated. These are the parameters $\boldsymbol{\phi}_s$ characterizing the distributions g_{st} of $\mathbf{r}_t$ together with $N(N-1)$ nonredundant transition probabilities. To evaluate the log-likelihood function, the optimal prediction of the probability that $\mathbf{r}_{t+1}$ belongs to regime k is needed which can be calculated as[4]

$$\Pr\left(z_{t+1} = k | \mathbf{x}_{t+1}, \mathbf{R}_t; \boldsymbol{\theta}\right) = \sum_{s=1}^{N} p_{sk} \Pr\left(z_t = s | \mathbf{x}_{t+1}, \mathbf{R}_t; \boldsymbol{\theta}\right);\ k = 1, .., N. \tag{5}$$

[4] We follow the usual approach and assume statistical independence between the predicted probabilities and the exogenous variables, i.e. we have $\Pr\left(z_t = s | \mathbf{x}_t, \mathbf{R}_{t-1}; \boldsymbol{\theta}\right) = \Pr\left(z_t = s | \mathbf{R}_{t-1}; \boldsymbol{\theta}\right)$.

The global log-likelihood function is given by

$$l(\boldsymbol{\theta}) = \sum_{t=1}^{T} \ln \left[\sum_{s=1}^{N} \Pr(z_t = s | \mathbf{x}_t, \mathbf{R}_{t-1}; \boldsymbol{\theta}) \, g_{st}(r_t | z_t = s, \mathbf{x}_t, \mathbf{R}_{t-1}; \boldsymbol{\theta}) \right]. \tag{6}$$

The prediction probability $\Pr(z_t = s|\mathbf{x}_t, \mathbf{R}_{t-1}; \boldsymbol{\theta})$ can be interpreted as the weight given to the density g_{st} in the time t log-likelihood function. The higher the predicted probability that observation $\mathbf{r}_t$ belongs to regime s, the higher is the weight attached to density g_{st}. Note that the time t log-likelihood function, the denominator in equation (4), can be evaluated as a by-product when iterating through the filter defined by equations (4) and (5).

Since the likelihood surface of a Markov switching model is likely to be multimodal, a non-trivial problem is how to achieve reporting the largest local maximum, especially in a multivariate model with a large number of parameters.[5] One obvious alternative is to restart a conventional local search algorithm with several starting values and then choose the best optimum found. However, with an increasing number of parameters, this will soon became practically infeasible. A more attractive alternative is to use a global search algorithm. We use simulated annealing (SA), a stochastic optimization algorithm in the Markov Chain Monte Carlo (MCMC) family to maximize the log-likelihood function. The important difference between this type of optimizer and a local optimizer is that a global optimizer occasionally goes downhill, and thus is able to escape from truly local maximums. In contrast, a local optimizer never goes downhill, it always moves in the direction of the nearest local maximum. The main drawback of the SA algorithm is that it is quite time consuming.[6] In the simulated annealing optimizations, we approximate the gamma function with Sterling's asymptotic series.[7] To calculate heteroscedasticity robust standard errors, we use the BHHH algorithm in Gauss given the parameter estimates from simulated annealing as starting values.

[5] The multivariate two-regime model contains a total of 80 parameters; 2 transition probabilities, 32 betas, 24 AR-parameters including the intercepts, 20 covariance parameters and 2 degrees of freedom parameters.

[6] With the ever-increasing computational power of standard desktop computers, this drawback is certainly decreasing in importance over time. The processor time required estimating the multivariate two-regime model is about 12 hours on a PIII 800 MHz.

[7] $\Gamma(x) \approx \sqrt{2\pi}\, x^{x-1/2} \exp(-x) \left[1 + 1/(12x) + 1/(288x^2) - 139/(51840x^3) - 571/(2488320x^4) \right.$
$\left. + 163879/(209018880x^5) + 5246819/(75246796800x^6) - 534703531/(902961561600x^7)\right]$.

3 The Data

Monthly nominal returns are calculated as logarithmic differences of stock market indices from Sweden (AGI), Finland (HEX), Denmark (KFX) and Norway (BOX). Returns on the international portfolios are logarithmic differences of stock market indices from the US (S&P), Japan (Nikkei), the UK (FT) and Germany (DAX).[8] The sample period considered is the post war period 1957:6 - 1999:6, a total of 505 observations. All data is obtained from Global Financial Data.[9] Summary statistics of monthly nominal stock returns can be found in Table I.

Table I
Descriptive statistics for monthly returns.

	r_{SWE}	r_{FIN}	r_{DEN}	r_{NOR}	r_{US}	r_{JPN}	r_{UK}	r_{GER}
Mean (% per year)	11.33	11.60	7.23	4.67	7.93	8.36	9.12	7.42
Std (% per year)	17.48	17.09	13.44	19.41	14.44	18.45	19.15	16.27
Skewness	−0.34	0.17	0.08	−0.74	−0.67	−0.52	0.10	−0.56
Kurtosis	5.89	5.44	4.58	8.05	6.19	4.41	12.12	5.76
Min (%)	−24.24	−21.32	−12.20	−35.45	−24.54	−21.35	−30.92	−25.40
	(Sep-90)	(Aug-98)	(Nov-73)	(Oct-87)	(Oct-87)	(Sep-90)	(Oct-87)	(Oct-87)
Max (%)	23.98	20.53	15.11	18.30	15.10	18.29	42.32	13.81
	(Nov-92)	(Oct-92)	(Aug-83)	(Apr-83)	(Oct-74)	(Oct-90)	(Jan-75)	(Feb-88)
Q(12)	20.09	102.62	72.49	32.38	8.31	10.25	23.05	33.33
	[0.065]	[0.000]	[0.000]	[0.001]	[0.760]	[0.594]	[0.027]	[0.001]

Note: Q(12) is the Ljung-Box statistic for 12:th order serial correlation with p-values in parentheses.

We find evidence of excess kurtosis, i.e. kurtosis above three, for all countries. Taken together with the non-zero skewness this is indicative of non-Normal unconditional stock returns. The highest and lowest returns on the Nordic stock markets show no apparent common pattern. The lowest return for Sweden is associated with the Gulf war in the fall of 1990. For Finland, there is a sharp drop in stock price for Nokia, with a large weight in the HEX-index, during August 1998. The lowest return for Denmark in November 1973 and the following very low returns in 1974 could be seen as a reaction to the very strong market in 1972, possibly discounting positive effects of an expected Danish EU membership. For Norway, the lowest return is a consequence of the Wall Street crash in

[8]A nominal stock return is a return from a financial asset that actually belongs to the investment opportunity set. This, of course, motivates the interest in nominal returns found in the Financial Economics literature. We leave an investigation of real returns for future research.

[9]An extensive methodological description of the data can be found at Bryan Taylor, Global Financial Data: `http://www.globalfindata.com`

October 1987. The highest returns for the Nordic countries are more difficult to associate with specific financial or political events, but for Sweden and Finland the high returns in the fall of 1992 followed after the decision of floating exchange rates for the Swedish Krona and the Finnish Markka.

The Ljung-Box tests show that there is significant autocorrelation in the return series, except for the US and Japan. Especially for Finland and Denmark the Q-statistic is very high. A more careful examination of the causes of these high statistics reveal that for Denmark the autocorrelation function is high for lags 1, 2 and 3. For Finland there are high autocorrelations at lags 1, 9 and 10, but these high autocorrelations at the long lags are difficult to understand from an economic point of view.

Table II

Correlation matrix for monthly returns.

	r_{SWE}	r_{FIN}	r_{DEN}	r_{NOR}	r_{US}	r_{JPN}	r_{UK}	r_{GER}
r_{SWE}	1	0.414	0.347	0.398	0.406	0.310	0.392	0.435
r_{FIN}		1	0.262	0.397	0.193	0.260	0.237	0.310
r_{DEN}			1	0.361	0.306	0.242	0.322	0.358
r_{NOR}				1	0.369	0.184	0.339	0.360
r_{US}					1	0.307	0.537	0.396
r_{JPN}						1	0.283	0.307
r_{UK}							1	0.381
r_{GER}								1

As expected, all simple correlations are positive, see Table II. The lowest correlation is between Norway and Japan, 0.184, and the highest between the US and the UK, 0.537. For the Nordic countries, the highest correlation is between Sweden and Finland, 0.414, and the lowest between Finland and Denmark, 0.262.

4 Estimates from the Multivariate Regime-Switching Model

Estimation results for the preferred univariate two-regime models are provided in Appendix C. These models are selected based on standard LR-tests. For Sweden and Finland, AR(1) models are selected, while for Denmark and Norway AR(3) models are preferred.

Table III
Estimates of mean parameters.

	Sweden	Finland	Denmark	Norway
Regime 1				
β_{iUS}	0.210** [0.007]	−0.032 [0.537]	0.025 [0.557]	0.092 [0.268]
β_{iJPN}	0.024 [0.624]	0.076 [0.060]	0.021 [0.518]	−0.020 [0.670]
β_{iUK}	0.076 [0.145]	−0.008 [0.874]	0.098* [0.022]	0.028 [0.579]
β_{iGER}	0.176** [0.001]	0.015 [0.739]	0.043 [0.165]	0.104 [0.096]
α_i	0.257 [0.314]	0.065 [0.725]	0.021 [0.892]	−0.158 [0.484]
ϕ_{i1}	0.042 [0.633]	0.182** [0.005]	0.203** [0.010]	0.215** [0.002]
ϕ_{i2}			0.089 [0.176]	0.039 [0.566]
ϕ_{i3}			0.119* [0.048]	0.038 [0.599]
Regime 2				
β_{iUS}	0.203* [0.042]	−0.083 [0.462]	0.128 [0.075]	0.316 [0.063]
β_{iJPN}	0.167** [0.008]	0.209** [0.006]	0.091* [0.040]	0.038 [0.612]
β_{iUK}	0.246* [0.013]	0.215* [0.015]	0.126 [0.073]	0.320 [0.094]
β_{iGER}	0.261** [0.003]	0.304** [0.001]	0.260** [0.000]	0.284** [0.003]
α_i	0.597 [0.597]	0.928* [0.018]	0.243 [0.243]	−0.071 [0.872]
ϕ_{i1}	0.068 [0.225]	0.264** [0.005]	0.054 [0.374]	0.112 [0.063]
ϕ_{i2}			0.034 [0.544]	−0.004 [0.939]
ϕ_{i3}			0.159** [0.003]	0.119* [0.035]

Notes: ** and * denote parameters statistically significant at the 1% and 5% levels, respectively. Robust p-values are in parentheses.

Ljung-Box tests for up to 12:th-order autocorrelation on the standardized residuals from the multivariate model, calculated as the one-step-ahead prediction errors conditional on the exogenous variables, suggest that there is no remaining autocorrelation for Sweden, Denmark or Norway. However, even if the model removes most of the autocorrelation also for Finland, the Ljung-Box statistic indicates remaining autocorrelation.[10] Hence, the results for Finland should be interpreted with some caution. The preferred AR-specification for each country is then used in the multivariate model.

[10]The Q(12) statistics with p-values in parentheses are 6.12 [0.864], 33.17 [0.001], 12.07 [0.209] and 11.21 [0.261] for Sweden, Finland, Denmark and Norway, respectively.

One characterization of the regimes is given by the fact that the international influence is differing between regimes, see Table III. Obviously, in the second regime, international stock markets affect the Nordic stock markets to a larger extent than in the first regime. The betas are higher in the second regime and also the p-values are in general much lower. This pattern is relatively consistent across the different countries. A formal LR-test also easily rejects that betas are equal in both regimes, see the first test in Table IV. There are probably large cross-country effects between the international stock returns, for example from the US to Japan, the UK and Germany. This will understate or overstate the influence of individual countries and hence the betas should discussed as a group rather than individually. However, it is noticeable that for Sweden, in contrast to the other Nordic countries, two of the betas are highly significant also in the first regime. This implies that the link between the Swedish stock market and international stock markets is relatively strong throughout the whole sample, 1957-1999.

To investigate if the international dependence could be approximated by a link with US only, we estimate a model with r_{USt} as the only exogenous variable. This model is overwhelmingly rejected with a LR-statistic of 128.28 implying a p-value less than 0.001.[11] This suggests that the Nordic stock markets are dependent not only on the US stock market and that the joint influence the Japanese, UK and German stock markets is statistically significant.

Table IV

LR-tests of parameter differences between regimes.

Null hypothesis	χ^2	dgf
Are betas equal across regimes?	79.88 [0.000]	16
Are country-specific volatilities equal across regimes?	69.01 [0.000]	4
Are country-specific correlations equal across regimes	10.44 [0.107]	6

Notes: p-values are in parentheses. dgf = degrees of freedom.

The transition probabilities for both regimes are all well defined with high persistence, see Table V. Given that we currently are in regime s, the expected duration of that regime is given by $1/(1-p_{ss})$, see Kim and Nelson (1999), pages 71-72. These calculations

[11] The estimation results can be found in Appendix D.

indicate that we expect to stay in the first regime about 9 years, while we expect to stay in the second regime for more than 15 years. The inverses of the degrees of freedom parameters are highly significant in both regimes. This gives strong support for the choice of the Student-t distribution instead of the Normal distribution.

Another characterization of the regimes is that country-specific volatility is higher in the second regime, see Table VI. The difference is highly significant, as shown by the second LR-test reported in Table IV.

Table V

Estimates of transition probabilities and degrees of freedom parameters.

	p_{11}	p_{22}	ν^{-1}
Regime 1	0.991** [0.000]		0.116** [0.000]
Regime 2		0.995** [0.000]	0.071** [0.005]

Notes: ** and * denote parameters statistically significant at the 1% and 5% levels, respectively. Robust p-values are in parentheses.

Table VI

Estimates of variance-covariance parameters.

		Sweden	Finland	Denmark	Norway
Regime 1					
σ_i		3.670** [0.000]	2.785** [0.000]	2.274** [0.000]	3.324** [0.000]
ρ_{ij}	Sweden	1	0.114 [0.063]	0.115 [0.071]	0.007 [0.898]
	Finland		1	0.008 [0.899]	0.137* [0.021]
	Denmark			1	0.096 [0.145]
	Norway				1
Regime 2					
σ_i		4.651** [0.000]	5.410** [0.000]	4.011** [0.000]	5.768** [0.000]
ρ_{ij}	Sweden	1	0.298** [0.000]	0.096 [0.196]	0.253** [0.000]
	Finland		1	0.077 [0.268]	0.263** [0.000]
	Denmark			1	0.129 [0.051]
	Norway				1

Notes: ** and * denote parameters statistically significant at the 1% and 5% levels, respectively. Robust p-values are in parentheses.

The smallest numerical difference is for Sweden, with around 25% higher volatility in the second regime, while for Denmark and Norway, the difference is around 75%. Finland is the extreme case with almost 100% higher volatility in the second regime. All country-specific correlations except between Finland and Norway are insignificant in the first regime. In the second regime, country specific correlations are significantly different from zero between Sweden and Finland, Sweden and Norway and again Finland and Norway. However, the last LR-test in Table IV shows that the correlations between the country-specific components are not statistically different in the two regimes. Taken together these two tests imply that covariance between the country-specific components is higher in the second regime, but that this difference is driven only by higher volatility, not by higher correlation.

5 The timing of regimes and economic implications

The smoothed probability of each of the regimes are shown in Figure 1.[12] The first structural break found is around 1969. We term this a structural break since it is the first time nominal returns on the Nordic stock markets show a strong international dependence and a high volatility after the 1950s and 1960s that were characterized by weak international dependence and low volatility. The are probably multiple underlying causes for this change, but it is likely that the increased inflation in the US, created partly by the funding of the Vietnam war, played an important role. This increased inflationary pressure is usually seen as one of the direct forces causing the breakdown of the Bretton-Woods exchange rate agreement in 1971.

The second structural break found is around 1982. This year, international dependence and volatility increase again, after some years of mostly low international dependence and volatility following the first oil crises in 1973-74. Over the years 1982-1999, the Nordic stock markets have not left this state of strong international dependence, high volatility and large covariance with each other. Hence, we may conclude that the financially more deregulated time period is associated with sharply different stock return characteristics compared to the previous more regulated period. Again, there may be multiple underlying causes, but the process of financial liberalization is a strong candidate as one of these causes.

To further discuss these changes we propose a variance decomposition and a covariance

[12]The smoothed probabilities are calculated using the algorithm proposed by Kim (1994).

decomposition based on the theory of mixture models. The total variance of stock returns conditional on past returns, can be decomposed according to

$$Var_{t-1}\left(r_{it}\right) = INT_{it} + DOM_{it} + CROSS_{it} \tag{7}$$

where the cross-term ($CROSS_{it}$) is always very small in magnitude compared to the international component (INT_{it}) and the country-specific component (DOM_{it}).[13] Similarly, the total covariance conditional on past returns can be decomposed according to

$$Cov_{t-1}\left(r_{it}, r_{jt}\right) = INT_{ijt} + DOM_{ijt} + CROSS_{ijt} \tag{8}$$

for $i, j = SWE, FIN, DEN, NOR$. We use the same notation here to indicate that DOM_{ijt} is in contrast to INT_{ijt}. The variance decompositions shown in Figure 2 reveal that the total variance, the international component and the country-specific component are all higher during the deregulated period. In other words, total variance has increased on the Nordic stock markets as a consequence of stronger dependence on international stock markets, i.e. higher betas, and higher country-specific volatility. If the proportional contributions to total variance are calculated another picture emerges. The proportion of total variance explained by the international variance component has increased from around 5% during the regulated time-period to 20%, 25% and 30% after deregulation for Finland, Denmark and Norway, respectively. For Sweden, with a relatively strong international dependence throughout the sample, the corresponding increase is from around 20% to 30%. The mirror image of this is that the proportion of total variance explained by the country-specific component has decreased from 95% (80% for Sweden) prior to deregulation to around 70% for Sweden and Finland and to around 75% and 80% for Denmark and Norway, respectively.

The covariance decompositions shown in Figure 3 reveal a similar, but slightly more complex pattern. For all pairs of Nordic countries, the international contributions to total covariance are much higher during the deregulated period. However, the proportional contributions to total covariance before and after deregulation are very different for different pairs of countries. The two extremes are Sweden-Norway and Finland-Norway. For Sweden-Norway the international contribution to total covariance is almost 100% due to the very low correlation, 0.007, between the country-specific components of returns before deregulation. At the other extreme, for Finland-Norway the international contribution

[13]Details of the variance and covariance decompositions can be found in Appendix B.

is close to zero, mostly a consequence of the relatively high country-specific correlation, 0.137. During deregulation and afterwards, a more homogenous pattern is found. This is a direct consequence of the much larger betas after deregulation. The contribution of the international component to total covariance ranges from around 20% for the covariance between Sweden and Denmark to around 50% for the covariance between Sweden and Finland and between Finland and Norway.

The economic implications of the financial liberalization for a Nordic stock market investor can be discussed in terms of reward to risk and diversification. Even though volatility is clearly higher during the deregulated period, the investor may be compensated for this increased risk by higher expected returns. Further, the possibility of portfolio diversification, either internationally or to the other Nordic stock markets, may decrease portfolio risk without sacrificing expected return. The discussion that focuses on the question of whether financial deregulation has been "good" or "bad" is obviously very complex, but below we make some arguments based on changes in reward to risk and diversification benefits.

The expected return per unit of risk, the reward to risk ratio, conditional on past returns can be written

$$RR_{it} = \frac{E_{t-1}\left[r_{it}\right]}{\sqrt{Var_{t-1}\left(r_{it}\right)}} \tag{9}$$

where the expected returns and variances are calculated as described in Appendix B. The evolution of the reward to risk ratios over time can be found in Figure 4. The average ratios are 0.189, 0.165, 0.152 and 0.053% of return per unit of standard deviation for Sweden, Finland, Denmark and Norway, respectively. Even though volatility (the denominator) has increased as shown above, there is no downward trend in the ratios during the process of deregulation or afterwards. If anything, the reward to risk ratios seem to be higher on average after 1982, at least for Sweden and Finland. Hence, in this respect and from the perspective of the Nordic home country investor, we find no adverse effects of the stock market liberalization.

Turning to diversification, we can separate between diversification to other Nordic stock markets and diversification to international stock markets. It is obvious from Figure 5 that correlations between the Nordic stock markets are considerably higher during the deregulated period, even though we could not reject that correlations between the country-specific components have increased over time, see Table IV. In other words, the higher correlations are due to the fact that the betas with international stock returns have increased over time. In principle, these higher correlations should decrease the benefits from diversification both to other Nordic markets and internationally. As previously discussed, the amount of country-specific volatility is significantly higher during the deregulated period, implying increased diversification gains for a Nordic home-market investor, counteracting the higher correlation. This is because one of the main ideas with diversification is to eliminate country-specific risk that does not contribute to expected return.

Hence, we find no adverse effects of stock market liberalization on investment opportunities for Nordic investors. On the contrary, liberalization has made diversification to foreign markets an attractive possibility to improve the return to risk ratio. This is so even if correlation both with other Nordic markets and international markets have increased during the liberalization process and afterwards.

6 Summary and Conclusions

This paper investigates the changing behavior of Nordic stock market returns over time with special reference to the process of financial liberalization. Using a multivariate regime-switching model to endogenously date changes in return behavior, we find that the time-period during liberalization and afterward, i.e. after 1982, is associated with significantly different return characteristics than during the regulated time-period, i.e. before 1970. This does not necessarily imply a causal relation, but we argue that stock market liberalization is a strong candidate for causing these changes. We show that higher expected return, higher volatility and stronger links with international stock markets characterize the deregulated period for all Nordic stock markets. We also find higher correlation between the Nordic stock markets and that this is mostly a consequence of the stronger links with international stock markets, not of higher correlation between country-specific components of returns.

The economic consequences of the changing investment opportunities from the perspective of a Nordic investor are also discussed. We calculate reward to risk ratios, i.e. expected return per unit of volatility risk, for each Nordic stock market, and find that these ratios have not decreased after liberalization. We also argue that because of the much higher country-specific volatility in the deregulated period, the possibility to diversify both to other Nordic countries or internationally provides an attractive opportunity to lower portfolio risk without sacrificing return. Taken together, our investigation supports the argument that stock market liberalization has created excess volatility but also that Nordic investors are more than compensated for this both in terms of expected return and the opportunity to cross-border diversification.

Appendix A

To test for the existence of regimes, we use the Monte-Carlo method discussed in Ang and Bekaert (1999) and Rydén, Teräsvirta and Åsbrink (1998). The main idea is to simulate M data series from a $N-1$-regime model given the parameter estimates and then estimate N-regime models using the M simulated data series and the original data. If the original data is from a N-regime model we expect the likelihood value from the estimation on the original data to be higher than the likelihood values from the estimations on the simulated series. If the likelihood value instead is lower for the original data, this is evidence against the N-regime model. The p-value is calculated as the number of times the likelihood value for a simulated series is higher than for the original data divided by the number of simulated series. These tests are extremely time-consuming and for this reason we restrict the number of simulated series for each test to $M = 100$. We simulate data from a linear model ($N = 1$) and estimate two-regime models using the simulated series. The results show that the null hypothesis of a linear model is strongly rejected for all four Nordic countries.

Appendix B

From the theory of mixture models it follows that

$$E\left[r_t|R_{t-1}\right] = \sum_{s=1}^{N} p_{st} E\left[r_t|z_t = s, R_{t-1}\right]$$

and

$$Var\left(r_t|R_{t-1}\right) = \sum_{s=1}^{N} p_{st}\left[Var\left(r_t|z_t = s, R_{t-1}\right) + \left(E\left[r_t|R_{t-1}\right] - E\left[r_t|z_t = s, R_{t-1}\right]\right)^2\right]$$

where p_{st} are the prediction probabilities from equation (5) and $R_{t-1} = \{r_{t-1}, r_{t-2}, ...\}$. For the two-regime model these expressions simplify to

$$E_{t-1}\left[r_{it}\right] = p_{1t}E_{t-1}\left[r_{it}|z_t = 1\right] + p_{2t}E_{t-1}\left[r_{it}|z_t = 2\right]$$

and

$$\begin{aligned} Var_{t-1}\left(r_{it}\right) &= p_{1t}Var_{t-1}\left(r_{it}|z_t = 1\right) + p_{2t}Var_{t-1}\left(r_{it}|z_t = 2\right) \\ &\quad + p_{1t}p_{2t}\left(E_{t-1}\left[r_{it}|z_t = 1\right] - E_{t-1}\left[r_{it}|z_t = 2\right]\right)^2 \end{aligned}$$

for $i = SWE, FIN, DEN, NOR$ and where $E_{t-1}[\cdot]$ and $Var_{t-1}(\cdot)$ denote that the expectations are taken conditional on past returns. Straight forward calculations then gives the variances as

$$\begin{aligned} Var\left(r_{it}|z_t = 1\right) &= \beta_{iUS}^2 Var_{t-1}\left(r_{USt}\right) + \beta_{iJPN}^2 Var_{t-1}\left(r_{JPNt}\right) \\ &\quad + \beta_{iUK}^2 Var_{t-1}\left(r_{UKt}\right) + \beta_{iUK}^2 Var_{t-1}\left(r_{UKt}\right) \\ &\quad + 2\beta_{iUS}\beta_{iJPN}Cov_{t-1}\left(r_{USt}, r_{JPNt}\right) + 2\beta_{iUS}\beta_{iUK}Cov_{t-1}\left(r_{USt}, r_{UKt}\right) \\ &\quad + 2\beta_{iUS}\beta_{iGER}Cov_{t-1}\left(r_{USt}, r_{GERt}\right) + 2\beta_{iJPN}\beta_{iUK}Cov_{t-1}\left(r_{JPNt}, r_{UKt}\right) \\ &\quad + 2\beta_{iJPN}\beta_{iGER}Cov_{t-1}\left(r_{JPNt}, r_{GERt}\right) + 2\beta_{iUK}\beta_{iGER}Cov_{t-1}\left(r_{UKt}, r_{GERt}\right) \\ &\quad + \sigma_i^2 \end{aligned}$$

where the volatility and the betas are for regime 1. The variances and covariances for the international stock returns are calculated using the sample values. $Var\left(r_{it}|z_t = 2\right)$ is computed analogously. We can now define

$$
\begin{aligned}
INT_{it} &= Var_{t-1}\left[r_{it}\right] - DOM_t - CROSS_t \\
DOM_{it} &= p_{1t}\sigma_{1i}^2 + p_{2t}\sigma_{2i}^2 \\
CROSS_{it} &= p_{1t}p_{2t}\left(E\left[r_{it}|z_t = 1\right] - E\left[r_{it}|z_t = 2\right]\right)^2
\end{aligned}
$$

The covariances for a two-regime model conditional on past returns are

$$
\begin{aligned}
Cov_{t-1}(r_{it}, r_{jt}) &= p_{1t}Cov_{t-1}(r_{it}, r_{jt}|z_t = 1) + p_{2t}Cov_{t-1}(r_{it}, r_{jt}|z_t = 2) \\
&\quad + p_{1t}p_{2t}\left(E\left[r_{it}|z_t = 1\right] - E\left[r_{it}|z_t = 2\right]\right)\Big(E[r_{jt}|z_t = 1] - E[r_{jt}|z_t = 2]\Big)
\end{aligned}
$$

and a corresponding decomposition of covariances can be derived.

Appendix C

Table C1
Estimates of univariate models.

	Sweden	Finland	Denmark	Norway
Regime 1				
p_{11}	0.979** [0.000]	0.979** [0.000]	0.990** [0.000]	0.979** [0.000]
σ	2.901** [0.000]	2.908** [0.000]	2.331** [0.000]	3.159** [0.000]
ν^{-1}	< 0.001 [–]	0.115 [0.065]	0.129* [0.016]	0.152* [0.044]
β_{US}	0.223** [0.001]	−0.015 [0.806]	0.026 [0.550]	0.096 [0.211]
β_{JPN}	−0.014 [0.674]	0.066 [0.099]	0.026 [0.426]	0.007 [0.875]
β_{UK}	0.070 [0.063]	−0.004 [0.937]	0.081* [0.012]	0.022 [0.684]
β_{GER}	0.211* [0.031]	−0.011 [0.831]	0.039 [0.193]	0.117* [0.022]
α	0.584* [0.028]	−0.109 [0.607]	−0.026 [0.859]	−0.084 [0.695]
ϕ_1	−0.038 [0.687]	0.288** [0.001]	0.252** [0.000]	0.121 [0.053]
ϕ_2			0.089 [0.202]	0.153* [0.021]
ϕ_3			0.056 [0.376]	−0.003 [0.956]
Regime 2				
p_{22}	0.978** [0.000]	0.978** [0.000]	0.996** [0.000]	0.986** [0.000]
σ	5.403** [0.000]	5.836** [0.000]	4.665** [0.000]	5.993** [0.000]
ν^{-1}	0.048 [0.460]	0.055 [0.440]	0.096 [0.127]	< 0.001 [–]
β_{US}	0.171 [0.154]	−0.075 [0.667]	0.114 [0.096]	0.420* [0.001]
β_{JPN}	0.237** [0.004]	0.223** [0.006]	0.089 [0.063]	0.006 [0.961]
β_{UK}	0.259* [0.012]	0.293 [0.147]	0.117 [0.058]	0.151 [0.116]
β_{GER}	0.269* [0.029]	0.311** [0.000]	0.247** [0.001]	0.319** [0.000]
α	0.252 [0.502]	1.304** [0.009]	0.238 [0.351]	−0.130 [0.773]
ϕ_1	0.136* [0.037]	0.177* [0.025]	0.073 [0.222]	0.192** [0.000]
ϕ_2			0.040 [0.454]	−0.023 [0.646]
ϕ_3			0.177** [0.001]	0.112* [0.033]

Notes: ** and * denote parameters statistically significant at the 1% and 5% levels, respectively. Robust p-values are in parentheses.

Appendix D

Table D1
Estimates of mean parameters from model with only US link.

	Sweden	Finland	Denmark	Norway
Regime 1				
β_{iUS}	0.283**	−0.016	0.070	0.122
	[0.000]	[0.743]	[0.151]	[0.116]
α_i	0.416	0.125	0.113	−0.115
	[0.103]	[0.553]	[0.464]	[0.579]
ϕ_{i1}	0.100	0.222**	0.224**	0.217**
	[0.235]	[0.001]	[0.006]	[0.002]
ϕ_{i2}			0.090	0.037
			[0.202]	[0.609]
ϕ_{i3}			0.094	0.017
			[0.184]	[0.859]
Regime 2				
β_{iUS}	0.645**	0.383**	0.447**	0.762**
	[0.000]	[0.005]	[0.000]	[0.001]
α_i	0.687	1.067	0.369	−0.005
	[0.205]	[0.121]	[0.281]	[0.997]
ϕ_{i1}	0.061	0.154**	0.046	0.127
	[0.321]	[0.009]	[0.477]	[0.110]
ϕ_{i2}			0.057	−0.014
			[0.296]	[0.796]
ϕ_{i3}			0.175**	0.131*
			[0.001]	[0.021]

Notes: ** and * denote parameters statistically significant at the 1% and 5% levels, respectively. Robust p-values are in parentheses.

Table D2
Estimates of transition probabilities and degrees of freedom parameters from model with only US link.

	p_{11}	p_{22}	ν^{-1}
Regime 1	0.987**		0.107**
	[0.000]		[0.002]
Regime 2		0.990**	0.072**
		[0.000]	[0.006]

Notes: ** and * denote parameters statistically significant at the 1% and 5% levels, respectively. Robust p-values are in parentheses.

Table D3
Estimates of variance-covariance parameters from model with only US link.

		Sweden	Finland	Denmark	Norway
Regime 1					
σ_i		3.818^{**} [0.000]	2.732^{**} [0.000]	2.320^{**} [0.000]	3.324^{**} [0.000]
ρ_{ij}	Sweden	1	0.115 [0.089]	0.142^{*} [0.045]	0.028 [0.705]
	Finland		1	0.004 [0.967]	0.142^{*} [0.022]
	Denmark			1	0.108 [0.149]
	Norway				1
Regime 2					
σ_i		5.040^{**} [0.000]	5.962^{**} [0.000]	4.357^{**} [0.000]	6.151^{**} [0.000]
ρ_{ij}	Sweden	1	0.416^{**} [0.000]	0.235^{**} [0.001]	0.346^{**} [0.000]
	Finland		1	0.205^{**} [0.004]	0.343^{**} [0.000]
	Denmark			1	0.225^{**} [0.000]
	Norway				1

Notes: ** and * denote parameters statistically significant at the 1% and 5% levels, respectively. Robust p-values are in parentheses.

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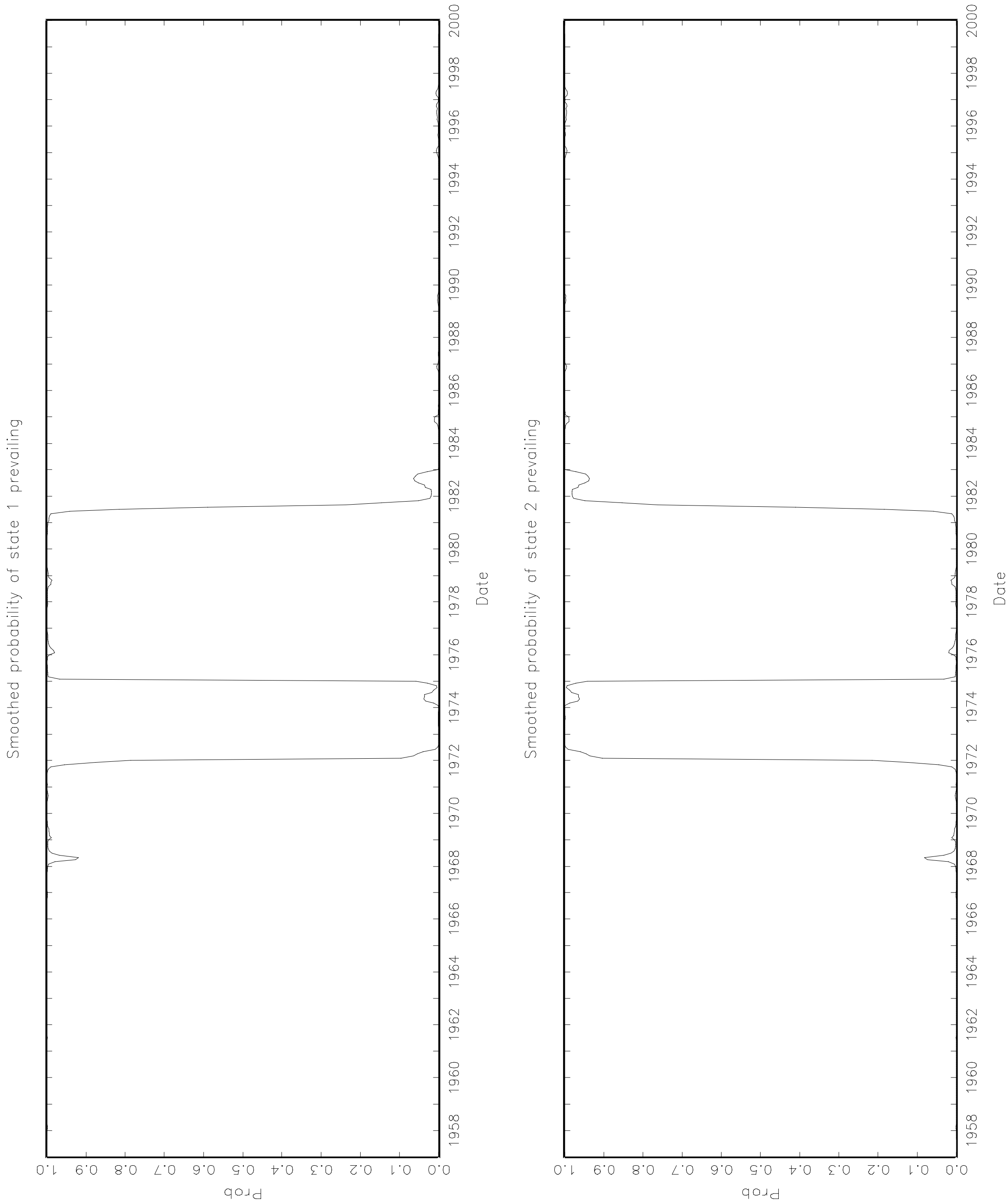

Figure 1: Smoothed probabilities.

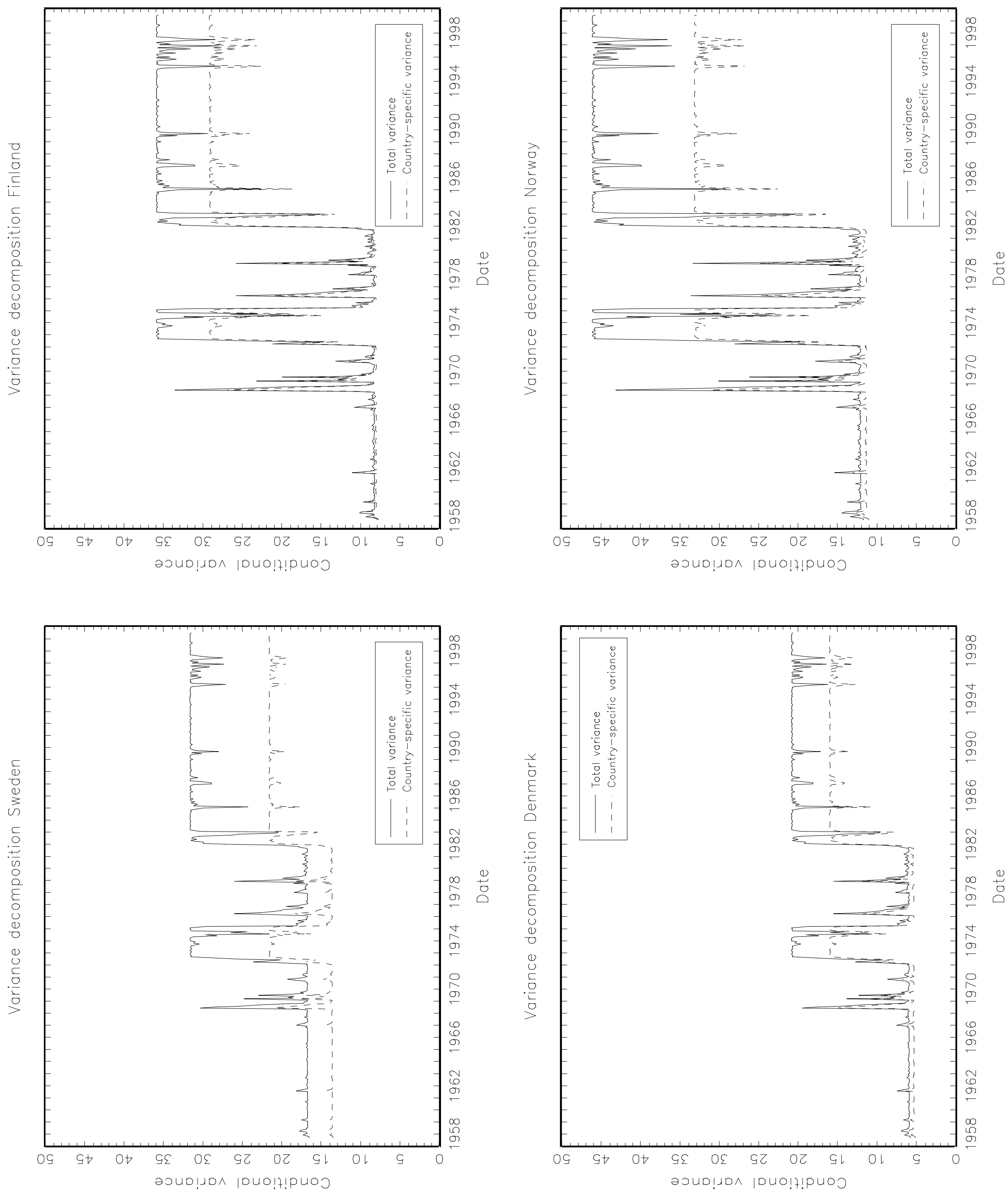

Figure 2: Conditional variance decomposition.

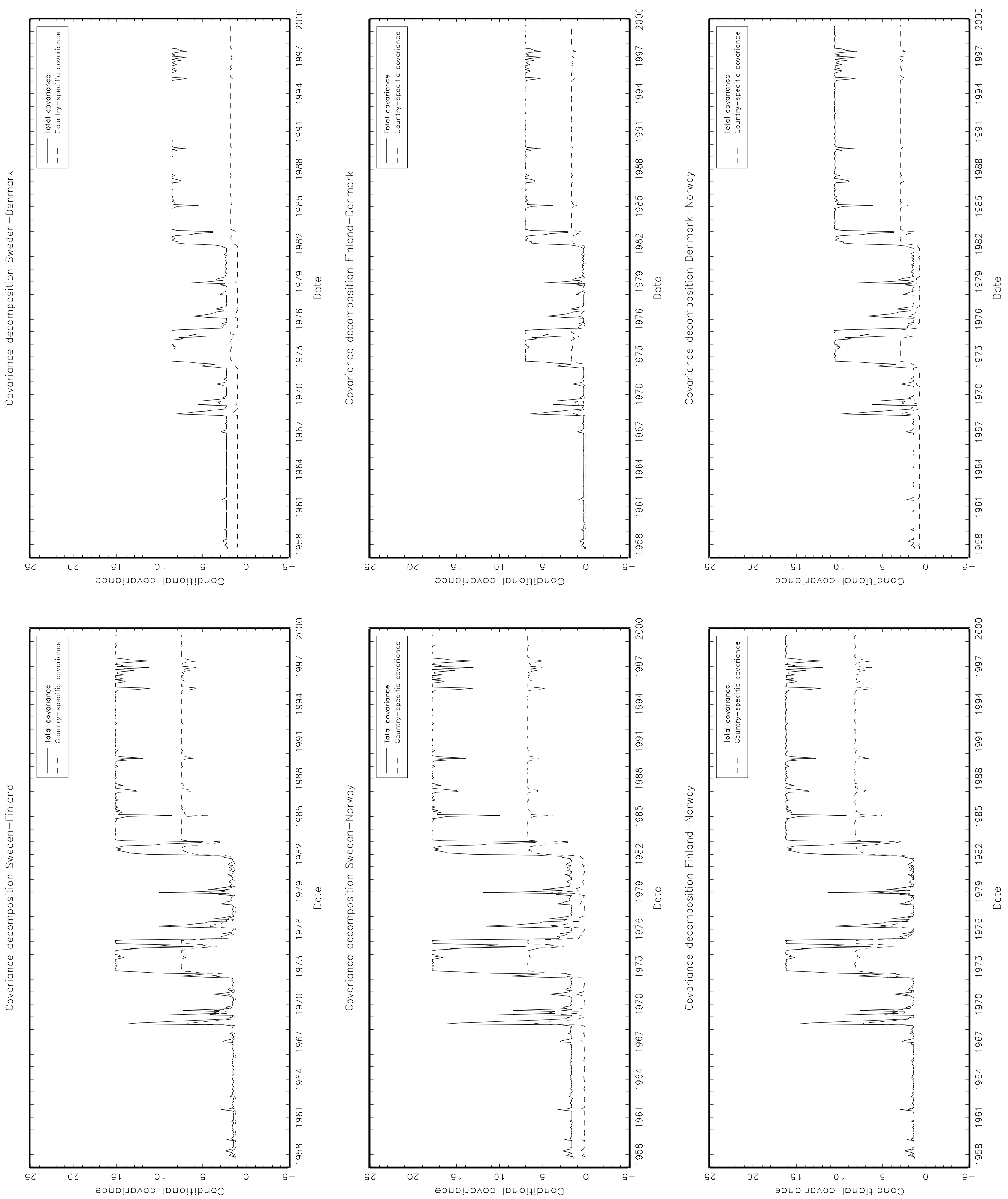

Figure 3: Conditional covariance decomposition.

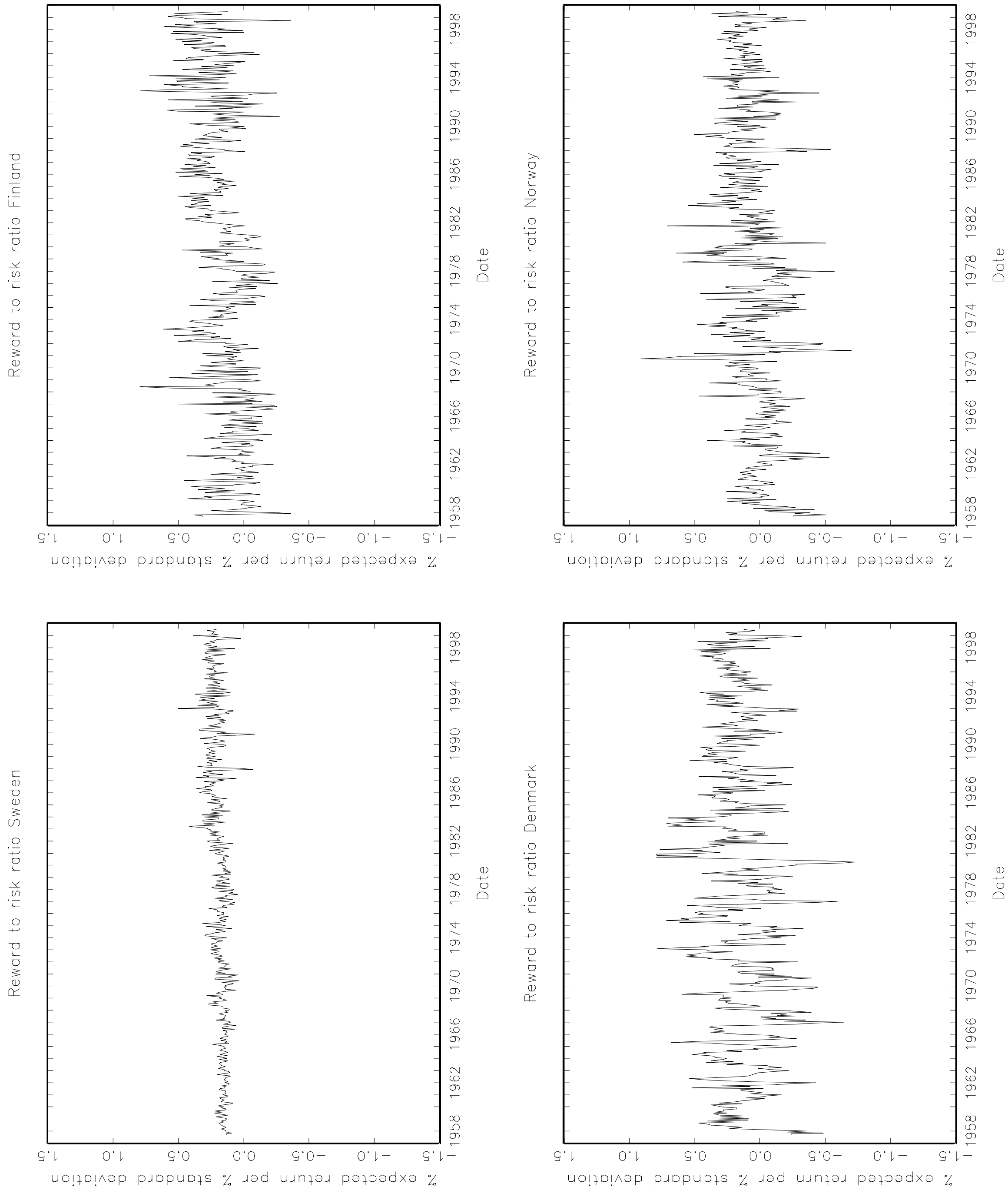

Figure 4: Reward to risk ratios.

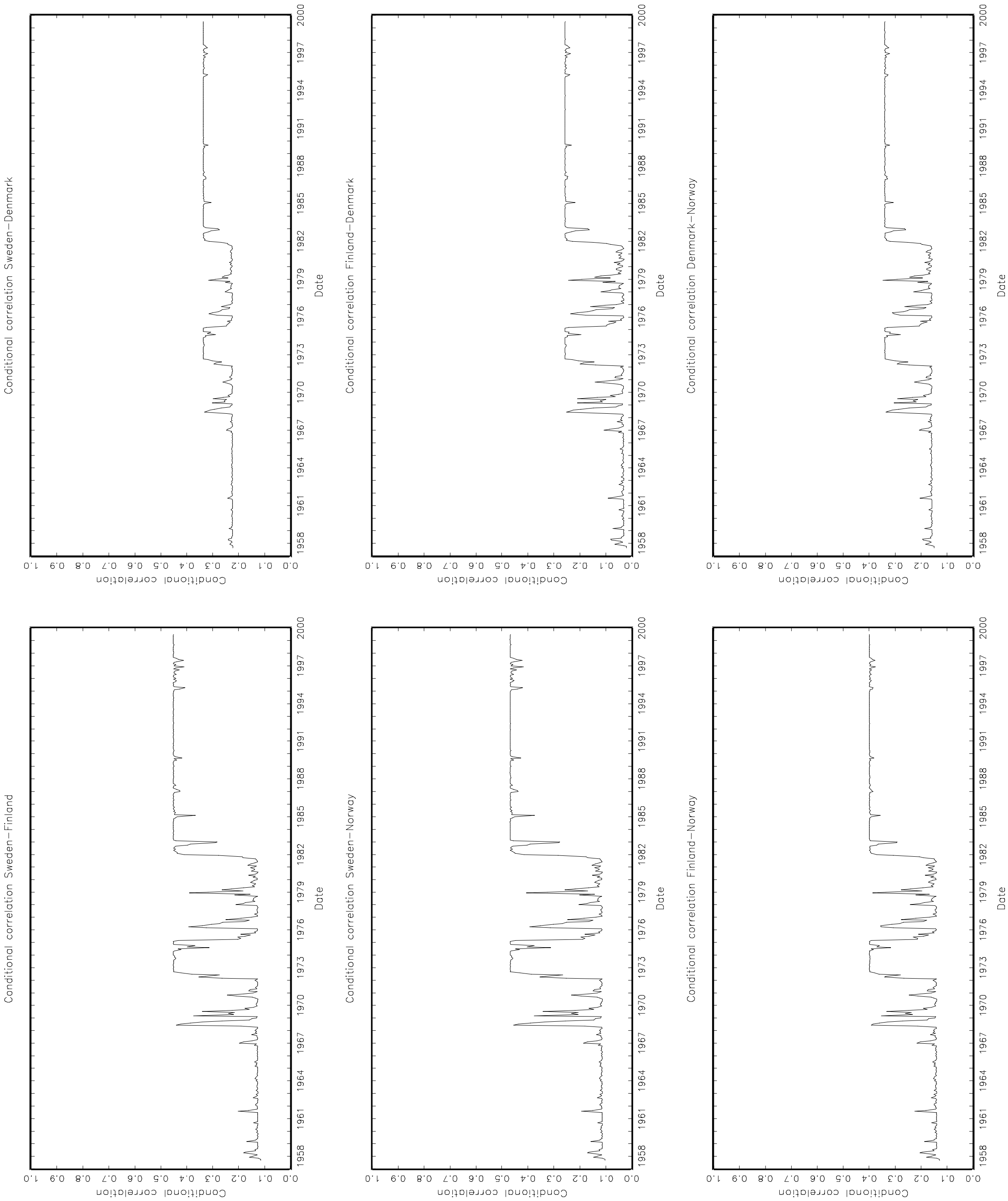

Figure 5: Conditional correlations.