Aaltonen, J. and R. Östermark: "Multiple-input rolling Granger-causality between the Finnish stock return and global factor representing portfolios". Presented at the 5th Annual Conference of the Multinational Finance Society, Helsinki, Finland, June 24-27, 1998.

Contact addresses:

Lic.sc (econ) Jaana Aaltonen
e-mail: jaana.aaltonen@abo.fi

Professor Ralf Östermark
ralf.ostermark@abo.fi

Åbo Akademi University
Department of Business Administration
Henriksgatan 7
FIN-20500 ÅBO
Finland
Tel:+358-2-2654669
Fax:+358-2-2654806

Abstract

The interdependence of international asset pricing is one of the key topics of modern finance. In this research domain, a specific category is composed of studies focusing on the interrelations between relatively thin or incompletely developed stock markets and the leading capital markets of the world. In this paper we study the Granger causality between a representative set of global asset returns and a thin Nordic financial market within a recursive framework. The database is initially subjected to factor analysis, where three global factors are identified: a European, an American and an Asian. Next, Granger causality between these factors and the Finnish stock market is studied. The results reveal that - in most cases - the global factors are relevant and have an incremental impact on the Finnish stock return. The timeliness hypothesis is accepted for the American factor but not for the Asian and European. The global factors show interesting interrelations in the rolling Granger framework.

Keywords: Rolling Granger causality, global asset returns.

1. Introduction

The interdependence of international asset pricing is one of the key topics of modern finance (cf., e.g., Masih and Masih, 1997, Blackman et al., 1994, Malkamäki et al., 1991). Empirical evidence indicates an increasing comovement of international capital markets (cf., e.g., Malliaris and Urrutia, 1992, Bos et al., 1995). In this research domain, a specific category is composed of studies focusing on the interrelationships between relatively thin or incompletely developed stock markets and the leading capital markets of the world. For example, Masih and Masih [1997] examined the patterns of dynamic linkages among national stock prices of four newly industrializing Asian countries - Taiwan, South Korea, Singapore, and Hong Kong - in models incorporating the established markets of Japan, USA, UK, and Germany. Another example is the increased attention paid to the interrelationships between the Scandinavian financial markets and the leading economies of the world (cf. e.g., Martikainen et al. [1994] and Mathur and Subrahmanyam [1991, Malkamäki [1993])]. For example, Malkamäki et al. [1993] investigated the lead-lag structures and causality patterns of the Scandinavian stock markets relative to world wide returns. They found that the Swedish market was the leader of the four, while the other three appeared to have no significant influence on the other markets. The presence of a US influence on Finnish stock returns was documented in Östermark and Aoki [1995] and of a Japanese impact in Östermark [1998]. Multivariate causality in consecutive subperiods was examined using the same database as in Östermark [1997]. It should be noted that, as evidenced by Martikainen et al. [1991], the relationship between the Finnish and US stock markets seems to be weaker than between the Finnish and the Swedish stock markets.

The present study is a continuation of the empirical research on the relationship between the Finnish and global asset returns. We will focus on the Granger causality between the Finnish market return and some factors representing global asset returns. The research issue is twofold. Firstly, three core hypotheses describing the features of the global return generating mechanism are developed and tested, using the well-known Granger framework. Secondly, the dynamics of Granger causality is analyzed within the Rolling Granger framework introduced by Smith et al. [1993]. This framework has been extensively applied by Östermark and Aaltonen [1998] and Aaltonen and Östermark [1997].

The study is organized as follows. In the next chapter, the methodology of the paper is presented: the Granger causality framework, a set of relevant unit root tests and the diagnostic tests applied to check the statistical properties of the residuals are discussed. In chapter 3 we present the global returns database and in chapter 4 the test setting. The empirical tests and the statistical properties of the residuals are examined in chapter 5. Chapter 6 concludes.

2. Methodology

2.1. Univariate Granger-causality

A time series $<x_t>$ causes another time series $<y_t>$ in the Granger sense if present y can be predicted better by using past values of x than by not doing so, considering also other relevant information, including past values of y. Formally, y is caused by x, if (cf., e. g. Pehkonen, 1991)

$$\sigma^2(y_t | \mathrm{y}) > \sigma^2(y_t | \mathrm{y}, \mathrm{x}) \qquad (2.1)$$

$$\text{where } \mathrm{y} = \{y_{t-1}, y_{t-2}, \ldots, y_{t-r}\}$$
$$\mathrm{x} = \{x_{t-1}, x_{t-2}, \ldots, x_{t-s}\}$$

$\sigma^2(y_t | \mathrm{y})$ and $\sigma^2(y_t | \mathrm{y}, \mathrm{x})$ represent the minimum predictive error variance of y_t obtained by regressing y_t respectively on y and (y, x).

In mathematical terms, x is said to cause y, provided some β_j is nonzero in the full regression equation (2.2a):

$$y_t = \delta_0 + \sum_{i=1}^{r} \alpha_i y_{t-i} + \sum_{j=1}^{s} \beta_j x_{t-j} + \varepsilon_t . \qquad (2.2a)$$

The relevance of x is indicated when comparing the error in (2.2a) to that of the reduced equation

$$y_t = \delta_0 + \sum_{i=1}^{r} \alpha_i y_{t-i} + \varepsilon \qquad (2.2b)$$

The error terms are compared formally in the following F-statistic:

$$F = \frac{(SSE_r - SSE_f)/s}{SSE_f / (T - r - s - 1)} \qquad (2.3)$$

where SSE_r, SSE_f = residual sum of squares of the reduced (2.2b) and full (2.2a) models respectively

T = total number of observations

r = number of lags for the y-variable

s = number of lags for the x-variable

F has an asymptotic F-distribution with s and T-r-s-1 degrees of freedom.

In this study, a rolling Granger causality test is employed. With this method, possible changes (structural breaks) in the causality pattern can be detected. Initially, Granger causality is estimated for the first 100 observations in the database, i.e., with a window length of 100. Then, the first observation is dropped from the sample and a new one is added to the end, after which the relationship is reestimated. The procedure is repeated throughout the sample. A similar procedure was applied in Smith et al. [1993] to test for the causality between four major equity markets.

2.1.1. Determining the Optimal Lag Structure

Studies by Guilkey and Salemi [1982], Geweke [1984], and Kang [1985] have indicated that Granger causality tests are sensitive - often critically so - to the choice of lag length. (cf. Thornton and Batten [1985], Jones [1989], and Kang [1989]).

The optimal lag-length is here defined by a two-step procedure based on minimizing Akaike's [1969] final prediction error (FPE) criterion, as suggested by Hsiao [1981]. We begin by determining the optimal lag of *Y*. We estimate the auto-regression equation (2.2b) with $r = 1,...,5$ and compute the sum of squared residuals for each regression. The optimal lag is selected by minimizing FPE, defined as

$$\text{FPE}(r) = \frac{T + r + 1}{T - r - 1} * \frac{SSR_r}{T} \tag{2.4}$$

Let r^* denote the lag that minimizes FPE(r). The optimal lag for the exogenous variable x is then determined by running the bivariate regressions (2.2a) with the lag for y fixed at r^* and lags $s = 1,...,5$ for x, and calculating the FPEs for each lag as follows:

$$\text{FPE}(r^*, s) = \frac{T + r^* + s + 1}{T - r^* - s - 1} \tag{2.5}$$

The optimal lag structure (r^*, s^*) is determined separately for each iteration in the rolling Granger regressions.

2.1.2. Testing for Stationarity and Co-integration

Since the return series are defined as first differences of the natural logarithms, we first test for stationarity of the logarithmic index series using the Augmented Dickey-Fuller (ADF) -statistic. The presence of a unit root in a time series indicates non-stationarity (cf. Engle and Granger [1987]). The test statistic is based on the following ADF-regression:

$$\Delta y_t = \delta + \alpha y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \varepsilon_t , \tag{2.6}$$

where Δ is the difference operator, the residual term ε_t is assumed to be Gaussian white noise and the number of lagged terms p is chosen such that the errors are uncorrelated (cf. Dickey and Fuller, 1979, SHAZAM, 1993. The critical values for the t-statistic are tabulated in Fuller, 1976). The null hypothesis H_0 is that $\alpha = 0$, i.e., there exists a unit root and the time series is non-stationary. If the logarithmic index is non-stationary, but the first difference of the series, i.e. returns are stationary, the prices are said to be integrated of order one, denoted $I(1)$. We test for stationarity of the total data series (752 observations) using three different tests: A standard augmented Dickey-Fuller (ADF)-test, the Phillips-Perron [1988] test, and a refined DF-GLS$^\tau$ test due to Elliott et al. [1992].

Phillips and Perron [1988] suggested some non-parametric corrections to the conventional test statistics which eliminate the nuisance parameter dependencies asymptotically. (For the exact formula, see Phillips and Perron, 1988.) The Dickey-Fuller critical values can still be directly used.

The third stationarity test is a modified Dickey-Fuller test called DF-GLS test due to Elliott et al. [1992]. The DF-GLS$^\tau$ test that allows for a linear time trend applies the ADF-regression (2.6)

$$\Delta y_t^\tau = a_0 \; y_{t-1}^\tau + \sum_{j=1}^{p} a_j \Delta y_{t-j}^\tau + u_t \tag{2.7}$$

where y_t^τ, is the locally detrended data process given by

$$y_t^\tau = y_t - z_t \tilde{\beta} . \tag{2.8}$$

In (2.8), $z_t = (1,t)$ and $\tilde{\beta}$ is the regression coefficient of $\tilde{y}$ on $\tilde{z}$, for which

$$\tilde{y}_t = (y_1 , (1 - \bar{\alpha} L) y_2 ,..., (1 - \bar{\alpha} L) y_T)' \text{ and}$$
$$\tilde{z}_t = (z_1 , (1 - \bar{\alpha} L) z_2 ,..., (1 - \bar{\alpha} L) z_T)' .$$

Elliott et al. [1992] analyzed a sequence of Neyman-Pearson tests of the unit root null hypothesis against the local alternative $\bar{\alpha} = 1 + \bar{c} / T$. The DF-GLS$^\tau$ test statistic is given by the conventional t-statistic, with the null ($a_0 = 0$) tested against the alternative ($a_0 < 0$). Elliott et al. [1992] recommend that the parameter $\bar{c}$ be set equal to -13.5. A detailed description of the DF-GLS test is presented in Cheung and Lau [1995].

2.1.3. Diagnostic Testing of the Residuals

We test for the statistical properties of the residuals in each full regression model (2.2a) using five tests (cf. Hendry and Doornik [1996]).

1. Error Autocorrelation Test

Test equation: $\varepsilon_t = \beta_0 + \sum_{i=1}^{k-1} \beta_i x_i + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i} + e_t$

Hypotheses: H_0: $\alpha_1 = ... = \alpha_p = 0$ vs. H_1: At least one $\alpha_i \neq 0$, $i = 1,...,p$.

Statistic: $F_c = \frac{R^2 / p}{(1 - R^2)/(n - k - p)} - F_{p,n-k-p}$

2. ARCH-test

Test equation: $\varepsilon_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + e_t$

Hypotheses: H_0: $\alpha_1 = ... = \alpha_p = 0$ vs. H_1: At least one $\alpha_i \neq 0$, $i = 1,...,p$.

Statistic: $F_c = \frac{R^2 / p}{(1 - R^2)/(n - k - p - 1)} - F_{p,n-k-p-1}$

3. Normality test

Statistic: $\chi^2 = n * \left(\frac{S^2}{6} + \frac{(K - 3)^2}{24} \right) - \chi_2^2$

where n = sample size, S = skewness, K = kurtosis

4. Heteroskedasticity

Test equation: $u_t = \beta_0 + \sum_{i=1}^{k-1} \beta_i x_i + \sum_{i=1}^{p} \alpha_i u_{t-i} + \varepsilon_t$

Hypotheses: H_0: $\alpha_1 = ... = \alpha_p = 0$ vs. H_1: At least one $\alpha_i \neq 0$, $i = 1,...,p$.

Statistic: $F_c = \frac{R^2 / p}{(1 - R^2)/(n - k - p)} - F_{p,n-k-p}$

5. The RESET-test

The RESET test (Regression Specification test) due to Ramsey [1969] tests the null of correct model specification against the alternative that powers of the endogenous variable (actually its predictions) have been omitted from the model.

3. Data

Our database consists of daily market indices of 15 stock exchanges all around the world between February 1, 1994 and December 31, 1996 (752 observations). The statistical properties of the return series are presented in tables (3.1) - (3.2).

Most of the return series are non-normal, leptocurtic, autocorrelated, and heteroskedastic. At the 1% level normality is accepted for Paris and Stockholm. London, Paris, Sidney, Tokyo and Oslo exhibit no autocorrelation in their market returns. Furthermore, Paris and Sidney are homoskedastic.

The three unit root tests support the nonstationarity hypothesis for most exchanges. When including a trend, nonstationarity is rejected for more than half of the exchanges by the Dickey-Fuller or Phillips-Perron test in at least one of the null hypotheses. The evidence is contradictory because none of the tests indicates stationarity simultaneously for any exhange index. In fact, the DF-GLS$^{\tau}$ test indicates nonstationarity for the index of all exchanges at the 10% level. We therefore interpret the results as an indication of unit roots in all index series. The return series are unequivocally $I(0)$.

Table 3.1: Descriptive statistics for the return series

Index	Country	Mean	Standard Deviation	Excess Kurtosis	Skewness	K-S Z[1)]	Kiefer-Salmon[2)]
Helsinki FOX	FIN	0.0414	1.2787	3.0709	-0.3893	1.366**	314.489***
Standard & Poors 500	USA	0.0578	0.6275	2.1094	-0.4457	1.908***	164.318***
Frankfurt Dax	GER	0.0375	0.8865	1.9170	-0.5354	1.675***	151.074***
Hong Kong Hang Seng	HKG	0.0171	1.3230	3.2695	-0.3723	2.332***	352.319***
London Financial Times 100	GBR	0.0223	0.6876	0.4758	-0.2934	1.688***	17.883***
Mexico IPC Stock	MEX	0.0249	1.8055	3.7909	0.1894	2.228***	454.791***
Paris CAC 40	FRA	-0.0009	0.9944	0.3630	-0.0128	1.284*	4.149
Singapore Straits	SIN	-0.0077	0.8845	3.3404	-0.2349	1.664***	356.54***
Sydney Australian All Ordinary	AUS	0.0054	0.7598	2.4380	-0.0065	1.491**	186.244***
Tokyo Nikkei	JPN	-0.0071	1.1049	3.1011	0.0983	1.551***	302.538***
Toronto Stock Exchange 300	CAN	0.0340	0.5724	2.7965	-0.6175	2.103***	292.835***
Zürich Swiss	SWI	0.0308	0.6983	2.5180	-0.3131	1.948***	210.957***
Stockholm General Index	SWE	0.0551	0.8429	0.3512	-0.1264	0.544	5.866*
Oslo General Index	NOR	0.0466	0.7584	3.7367	-0.0623	1.542***	437.999***
Copenhagen General Index	DEN	0.0197	0.7190	1.2979	-0.2966	1.502**	63.812***
Critical values: 10%						1.2238	4.605
5%						1.3581	5.991
1%						1.5174	9.210

Index	Country	LB6[3)]	LB12[3)]	QLB6[4)]	QLB12[4)]	LM[5)]
Helsinki FOX	FIN	13.846**	33.988***	104.114***	195.247***	47.258***
Standard & Poors 500	USA	13.410**	15.830	30.310***	35.272***	0.674
Frankfurt Dax	GER	12.725**	21.098**	25.492***	32.710***	8.934***
Hong Kong Hang Seng	HKG	10.786*	14.415	37.183***	62.609***	4.636**
London Financial Times 100	GBR	8.635	15.002	26.885***	56.014***	0.309
Mexico IPC Stock	MEX	14.862**	22.611**	100.299***	133.869***	51.591***
Paris CAC 40	FRA	2.844	10.624	8.800	17.269	0.604
Singapore Straits	SIN	17.153***	18.620*	55.544***	72.723***	21.834***
Sydney Australian All Ordinary	AUS	6.154	13.565	3.801	4.703	0.175
Tokyo Nikkei	JPN	5.961	14.996	20.704***	34.533***	9.988***
Toronto Stock Exchange 300	CAN	30.561***	36.321***	34.562***	37.999***	5.747**
Zürich Swiss	SWI	14.858**	30.097***	59.791***	69.304***	3.767*
Stockholm General Index	SWE	14.107**	28.377***	15.857**	25.905**	4.667**
Oslo General Index	NOR	9.778	17.167	58.034***	61.784***	44.472***
Copenhagen General Index	DEN	14.107**	28.377***	20.606***	25.532**	0.702
Critical values: 10%		10.645	18.549	10.645	18.549	2.706
5%		12.592	21.026	12.592	21.026	3.841
1%		16.812	26.217	16.812	26.217	6.635

1) One-sample Kolmogorov-Smirnov test for normality (cf. Neave [1981], pp. 26-27)

2) Kiefer-Salmon test for normality: KS = $(T/6)*sk^2 + (T/24)*ku^2$ χ^2_2, T = number of observations (752)

3) Ljung-Box-Pierce test for autocorrelations: $LB[J] = T(T+2)\sum_{j=1}^{J} \frac{1}{T-j} r_j^2 \sim \chi^2_J$

4) Ljung-Box-Pierce test for autocorrelations on squared series

5) Lagrange Multiplier -test for ARCH(1) $\sim \chi^2_1$

Table 3.2: Unit root tests for the global returns database.

(1) Undifferenced variables (Logarithmic indexes)

	Without trend				With trend						DF-GLS$^{\tau}$ H_0: $\alpha_0 = 0$ (critical value at α = 10%: 1.96)		
	H_0: $\alpha = 0$ (critical value at α = 10%: -2.57)		H_0: $\delta = \alpha = 0$ (critical value at α = 10%: 3.78)		H_0: $\alpha = 0$ (critical value at α = 10%: -3.13)		H_0: $\delta = \alpha = \lambda = 0$ (critical value at α = 10%: 4.03)		H_0: $\alpha = \lambda = 0$ (critical value at α = 10%: 5.34)				
	Dickey-Fuller	Phillips-Perron	Dickey-Fuller	Phillips-Perron	Dickey-Fuller	Phillips-Perron	Dickey-Fuller	Phillips-Perron	Dickey-Fuller	Phillips-Perron	$p = 1$	$p = 2$	$p = 3$
FIN	-1.2518	-0.9454	1.2555	0.8130	-2.4579	-2.3777	2.4275	2.3633	3.1668	3.1964	-1.2964	-1.3419	-1.3327
USA	0.8446	0.7515	4.6961	3.8615	-3.0588	-3.3670	6.9022	6.9932	5.9519	6.9762	-0.0263	-0.0725	0.0081
GER	0.0887	0.2975	0.8665	0.9297	-1.9579	-2.0437	2.5055	2.8074	2.8900	3.3803	-0.5601	-0.5836	-0.5995
HKG	-0.1374	-0.8725	0.2693	0.4343	-2.5525	-3.1711	3.9602	5.1632	5.6766	7.6837	0.0828	-0.0019	-0.0087
GBR	0.1054	0.0712	0.6241	0.4504	-3.8744	-3.9315	6.4560	6.8594	9.0509	9.8074	0.1951	0.1247	0.1762
MEX	-1.1766	-1.0611	0.7483	0.6263	-2.3081	-2.2124	2.1858	2.1009	3.2222	3.0877	-0.3961	-0.3822	-0.3402
FRA	-2.0996	-2.0724	2.2045	2.1477	-2.3609	-2.3322	3.1619	3.1615	4.7426	4.7419	-0.2853	-0.3159	-0.3104
SIN	-1.9559	-2.7040	1.9131	3.6812	-1.9539	-2.6747	1.2740	2.4567	1.9106	3.6609	-1.5122	-1.4763	-1.4050
AUS	-0.4661	-1.1700	0.3065	0.7044	-2.4291	-3.1079	3.0712	4.5186	4.4068	6.7551	-0.0177	0.0005	-0.0279
JPN	-1.4293	-1.6145	1.0246	1.3179	-1.5153	-1.7293	0.7762	1.0333	1.1612	1.5354	-0.7633	-0.8163	-0.7872
CAN	0.6617	0.9639	1.1340	1.5762	-2.5405	-2.4518	4.3464	4.8092	5.5927	6.0849	-0.1746	-0.1658	-0.2020
SWI	0.7582	0.4279	1.6217	0.810	-3.0400	-3.3133	6.0036	6.1522	7.6461	8.4356	0.4059	0.3741	0.4271
SWE	1.0085	0.9515	2.3312	1.9760	-2.5237	-2.7802	4.6660	5.0199	5.1551	6.0486	-0.2785	-0.3274	-0.3114
NOR	0.4888	0.8292	1.1251	1.6429	-2.8627	-2.5582	4.5030	4.5543	5.7347	5.5208	-0.1650	-0.2056	-0.2232
DEN	0.0498	0.2277	0.2035	0.2787	-2.2893	-2.1321	4.6346	4.6682	6.7462	6.7427	0.0135	0.0223	0.0225

(2) Differenced variables (Return series)

	Without trend				With trend						DF-GLS$^{\tau}$ H_0: $\alpha_0 = 0$ (critical value at α = 10%: 1.96)		
	H_0: $\alpha = 0$ (critical value at α = 10%: -2.57)		H_0: $\delta = \alpha = 0$ (critical value at α = 10%: 3.78)		H_0: $\alpha = 0$ (critical value at α = 10%: -3.13)		H_0: $\delta = \alpha = \lambda = 0$ (critical value at α = 10%: 4.03)		H_0: $\alpha = \lambda = 0$ (critical value at α = 10%: 5.34)				
	Dickey-Fuller	Phillips-Perron	Dickey-Fuller	Phillips-Perron	Dickey-Fuller	Phillips-Perron	Dickey-Fuller	Phillips-Perron	Dickey-Fuller	Phillips-Perron	$p = 1$	$p = 2$	$p = 3$
FIN	-4.0999	-26.006	8.4087	338.150	-4.1487	-26.012	5.7413	225.500	8.6079	338.260	-10.723	-8.175	-6.692
USA	-6.4186	-25.110	20.6000	315.140	-6.5710	-25.208	14.4280	211.670	21.6420	317.490	-10.680	-8.811	-7.142
GER	-5.7716	-29.704	16.6880	441.110	-5.8556	-29.895	11.4870	297.810	17.1980	446.720	-12.807	-9.411	-7.270
HKG	-6.2907	-26.732	19.8430	357.330	-6.5270	-26.869	14.3090	240.610	21.4070	360.920	-17.268	-14.496	-13.700
GBR	-7.3386	-27.410	26.9470	375.610	-7.5510	-27.595	19.0190	253.740	28.5090	380.600	-4.558	-3.476	-2.635
MEX	-5.3057	-24.078	14.0950	289.880	-5.3306	-24.068	9.5094	193.080	14.2450	289.620	-18.186	-15.708	-13.198
FRA	-5.8666	-28.345	17.2330	401.670	-6.0989	-28.604	12.4210	272.650	18.6070	408.980	-6.497	-4.744	-3.658
SIN	-6.3385	-23.683	20.1040	280.350	-6.3349	-23.669	13.3980	186.640	20.0820	279.960	-14.920	-12.271	-10.338
AUS	-5.9895	-26.884	18.0020	361.270	-6.1292	-27.090	12.6120	244.480	18.8520	366.720	-15.124	-11.277	-9.455
JPN	-4.8172	-27.392	11.6280	375.140	-4.8059	-27.376	7.7456	249.800	11.5930	374.690	-10.028	-7.626	-6.006
CAN	-6.1324	-22.486	18.8070	252.820	-6.4555	-22.484	13.8950	168.480	20.8390	252.720	-14.592	-11.286	-9.733
SWI	-5.6761	-25.967	16.1410	337.080	-6.0550	-26.276	12.2750	229.980	18.3800	344.970	-7.177	-5.496	-3.940
SWE	-5.5102	-24.917	15.2010	310.390	-5.8728	-25.049	11.5100	209.040	17.2450	313.560	-6.074	-4.648	-3.603
NOR	-5.4337	-27.298	14.7950	372.650	-5.7721	-27.393	11.1280	250.140	16.6590	375.210	-7.272	-5.289	-4.021
DEN	-6.9329	-24.278	24.0440	294.660	-7.5684	-24.533	19.1140	200.520	28.6600	300.770	-5.936	-4.362	-3.288

Having demonstrated the presence of unit roots in the indexes, we conducted pair-wise co-integration tests between the Finnish stock exchange and the major world markets. No pair-wise co-integration seems to be present in the data (cf. table (3.3)). The result implies that there is no need for an error correction term in the Granger regressions. Theoretically, co-integration is stronger than causality, i.e., the latter can prevail with or without the former. However, co-integration would automatically indicate the presence of causality.

Table 3.3: Co-integration tests between Finland and the other 14 market indices

	No trend in cointegrating regression			Trend in cointegrating regression		
	Dickey-Fuller	Phillps-Perron		Dickey-Fuller	Phillps-Perron	
	t	Z	t	t	Z	t
10%	-3.04	-17.1	-3.04	-3.5	-23.4	-3.5
USA	-2.4880	-10.9210	-2.2396	-2.4849	-11.3080	-2.2887
GER	-2.7075	-9.3254	-2.1390	-3.0952	-11.6320	-2.3743
HKG	-2.5889	-10.8950	-2.4483	-2.6560	-12.1800	-2.4085
GBR	-2.5484	-10.8970	-2.3094	-2.5295	-11.1360	-2.2784
MEX	-2.0232	-7.6084	-1.8264	-2.9024	-12.2950	-2.3983
FRA	-1.7335	-4.6294	-1.3940	-2.5926	-11.7860	-2.3858
SIN	-1.3836	-4.0248	-1.1066	-2.6028	-13.4140	-2.5471
AUS	-2.3364	-8.3548	-2.0830	-2.5313	-11.3020	-2.3021
JPN	-1.3471	-3.2837	-0.9703	-2.4889	-12.4780	-2.4533
CAN	-2.3210	-10.5130	-2.3107	-2.6648	-12.2770	-2.4419
SWI	-2.4560	-9.6494	-2.1299	-2.5271	-11.5780	-2.3244
SWE	-2.4642	-10.4370	-2.2900	-2.4561	-10.1570	-2.3170
NOR	-2.4719	-9.9744	-2.2335	-2.4843	-10.1650	-2.2393
DEN	-2.3533	-8.1466	-2.0983	-2.5497	-11.8060	-2.3821

Next, the global database was subjected to principal components factor analysis. The VARIMAX-rotated factor loadings matrix computed on the return database is presented in table 3.4. The corresponding price series along with the Finnish stock market return are presented in figures (3.1) - (3.4). The factors clearly reflect three continental areas: Asia, Europe, and America. Daily stock returns are effectively governed by the trading activity within the continental time zones.

Table 3.4: Rotated factor loadings matrix for the global database.

Country		FACTOR 1	FACTOR 2	FACTOR 3
SWI	Zürich	**0.772**	0.176	0.091
FRA	Paris	**0.759**	-0.015	0.201
SWE	Stockholm	**0.755**	0.162	0.149
GBR	London	**0.739**	0.031	0.301
GER	Frankfurt	**0.719**	0.357	0.012
NOR	Oslo	**0.662**	0.284	0.042
DEN	Copenhagen	**0.647**	0.295	-0.044
HKG	Hongkong	0.198	**0.781**	0.057
SIN	Singapore	0.073	**0.744**	0.091
AUS	Sydney	0.280	**0.660**	0.088
JPN	Tokyo	0.113	**0.523**	0.010
USA	S&P 500	0.176	-0.029	**0.832**
CAN	Toronto	0.237	0.131	**0.781**
MEX	Mexico	-0.006	0.088	**0.634**

4. Test Setting

In this paper we study the impact of three geographical factors - the European, Asian, and American - on the Finnish market returns in a rolling framework. We expect a thin stock market to be continuously and significantly caused by the global market movements. The time zone differences between the three continents create a continuous information flow, where the stock markets of one continent open approximately the same time as the markets of another continent close. At each time point we have one active continent and two continents closed.

The Finnish market operates within the time zone of the European markets. On the daily level, the most recent European and American information available for the Finnish investors is that of the previous day. The major Asian markets, again close before or slightly after the Finnish market opens. Thus, even on the daily level the Asian market information is available to the Finnish investors most of the trading hours.

Due to the rotation of the earth and the geographical position of the continents, it seems natural to assume that the daily stock market operations within each continent has its specific impact on the global return generating forces. An interesting question is whether the activity within a continent is fully absorbed into the continent in the succeeding time zone. In particular, the following three aspects of information are addressed (cf. figures (4.1) and (4.2)): relevance, incremental importance and timeliness.

Figure 4.1: Relevance of the three continents w.r.t. the Finnish return generating mechanism.

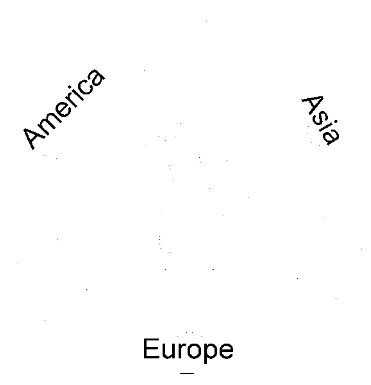
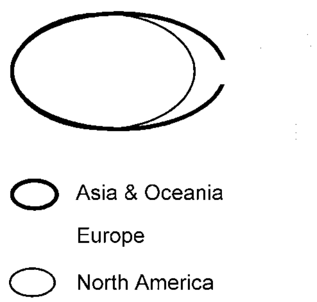


Figure 4.2: Incremental importance and timeliness of the three continents w.r.t. the Finnish return generating mechanism.



We summarize the assumptions in the following research hypotheses:

A. Relevance. All three geographical areas contain relevant information. This assumption is tested by bivariate regression models separately for each continent. A significant causality is expected in each test.

B. Incrementality. New information is added to the total information set in each continent. This assumption is tested separately for each continent by controlling for the previous information set. A significant causality is expected in each test.

C. Timeliness. The old information set is completely absorbed by the current one. This assumption is tested for each continent by controlling for the next information set. We expect no significant causality for the old information sets after controlling for the more recent one.

The hypotheses are operationalized in table 4.1.

Table 4.1: Testing for relevance, incremental importance and timeliness of geographical areas w.r.t. the Finnish return generating mechanism

Hypothesis testing	Expected causality	Explanation
A Relevance		
E -> F	+	Europe is relevant in causing Finnish returns
Am -> F	+	America is relevant in causing Finnish returns
As -> F	+	Asia is relevant in causing Finnish returns
B Incremental information		
Am|E -> F	+	America has incremental information after controlling for the European factor
As|Am -> F	+	Asia has incremental information after controlling for the American factor
E|As -> F	+	Europe has incremental information after controlling for the Asian factor
C Timeliness		
Am|As -> F	~	The American information has been absorbed into the more recent Asian factor
E|Am -> F	~	The European information has been absorbed into the more recent American factor
As|E -> F	~	The Asian information has been absorbed into the more recent European factor

The following symbols are used in the table:

F = the Finnish market return
E = the European factor extracted from the global data base
As = the Asian-Oceanian factor extracted from the global data base
Am = the American factor extracted from the global data base
X -> Y
+ = significant causality
~ = nonexistent causality

5. Empirical Tests

The hypotheses A-C are first tested by running the Granger regressions (2.2a) and (2.2b) - augmented by control variables as implied by table 4.1. - once throughout the whole test period. The dynamics of the observed causalities is then further examined within the rolling framework of Smith et al [1993] using the window length of 100 observations.

5.1. The Relevance Hypothesis

The optimal lag length is determined by the FPE-criterion. As the modern technology allows rapid flow of information, we may expect a low-order optimal lag. Thus, a search interval from one to five days for both the endogenous and exogenous variables was applied. For both the European and Asian factors, the optimal lag is one, whereas for the American one, two lags was found to be optimal. The global market information seems to be reflected in the Finnish market within at most two days. In consequence, lags between one to two days are applied in the subsequent tests. The results for the relevance tests are presented in table 5.1.

Table 5.1: Relevance tests

Hypothesis	Test variable	Test equation / [restriction]	F-value	Significance
E -> F	Europe, previous day	$F_t = \alpha F_{t-1} [+ \beta E_{t-1}] + \varepsilon_t$	0.1231	0.7258
E -> F	Europe, current day	$F_t = \alpha F_{t-1} [+ \beta E_t] + \varepsilon_t$	213.3251	0.0000***
Am -> F	America, previous day	$F_t = \alpha F_{t-1} [+ \beta Am_{t-1}] + \varepsilon_t$	87.7082	0.0000***
Am -> F	America, lag 2	$F_t = \alpha F_{t-1} [+ \beta Am_{t-2}] + \varepsilon_t$	7.5972	0.0060***
As -> F	Asia, current day	$F_t = \alpha F_{t-1} [+ \beta As_t] + \varepsilon_t$	27.0181	0.0000***
As -> F	Asia, previous day	$F_t = \alpha F_{t-1} [+ \beta As_{t-1}] + \varepsilon_t$	8.8440	0.0000***

F_t = The Finnish stock market return
E_t = The European factor return
Am_t = The American factor return
As_t = The Asian factor return

The relevance hypothesis for Europe is, somewhat surprisingly, rejected when using the previous day's observations (t-1). On the other hand, for contemponareous causality (t), a highly significant test statistic is achieved. The Finnish market clearly and immediately reflects general changes in the European market. Note, however, that the European exchanges close one to two hours after the Finnish market. Thus, the daily closing prices include some two hours' information that impossibly can be reflected in the Finnish market. On the other hand, the contemporaneous information emanating from the six hours during which all European markets are jointly operating obviously is relevant.

For the American and Asian markets, significant causality is detected for lags one and two. The evidence is relevant when testing the incrementality and timeliness. For the American factor, the previous day constitutes the latest possible information set with relevance for the Finnish returns.

5.2. The Incremental Information Hypothesis

In testing for the incremental information content of the three continents, the relevant causalities were re-estimated using the previous information set as a control variable. If a significant causality from a continent is maintained even after controlling for the previous information set (cf. figure 4.2), the continent adds some intrinsic value to the global set of information. In the opposite case, the continent may act as a filter, through which the information created otherwise is forwarded to the Finnish market. The test equations and results for the incrementality tests are presented in table 5.2.

Table 5.2: Tests for incremental information

Hypothesis	Test variable	Control variable	Test equation / [restriction]	*F*-value	Significance
E|As -> F	Europe, current day	Asia, current day	$F_t = \alpha F_{t-1} \left[+ \beta E_t \right] + \gamma As_t + \varepsilon_t$	224.2863	0.0000***
E|As -> F	Europe, current day	Asia, previous day	$F_t = \alpha F_{t-1} \left[+ \beta E_t \right] + \gamma As_{t-1} +$	206.7510	0.0000***
Am|E -> F	America, previous day	Europe, previous day	$F_t = \alpha F_{t-1} \left[+ \beta_1 Am_{t-1} \right] + \gamma E_t$	88.3769	0.0000***
As|Am -> F	Asia, previous day	America, lag 2	$F_t = \alpha F_{t-1} \left[+ \beta_1 As_{t-1} \right] + \gamma Am$	4.2221	0.0402**

F_t = The Finnish stock market return
E_t = The European factor return
Am_t = The American factor return
As_t = The Asian factor return

For the European factor, highly significant incremental information value was observed even after controlling for the latest Asian observation. As the previous day Asian factor was significant in the relevance test with respect to the Finnish returns, we replicated the test by using the significant previous day information from the Asian market as the control variable. Practically no impact on the European current day information was observed. The high significance of the European factor may partly be caused by the one to two hours lag between the Finnish and the other European markets.

For the American factor, highly significant incremental causality was observed even after controlling for the latest European information set. As expected, the huge American markets clearly add value to the total set of information reflected in the Finnish market. For the Asian factor, again, the significance observed for the previous day's information in testing for the relevance is weaker when controlling for the previous American information (lag 2). The impact of the American markets seems to be so strong that it is reflected to the Finnish markets both directly and indirectly through the Asian market. The relevance observed for the previous day's Asian information might in fact not be a pure Asian impact, but instead a reflection of the American influence filtered through the American markets.

5.3. The Timeliness Hypothesis

The timeliness hypothesis was tested using the next (newer) information set as a control variable. According to the timeliness hypothesis, the information from one continent should be completely absorbed by that from the next. Thus, no significant causality should exist after controlling for the more recent information set. The test results are presented in table 5.3.

The timeliness hypothesis is accepted for the American factor (E|Am ⁄F). For the Asian and European factors, the timeliness hypothesis is rejected.

Table 5.3: Tests for timeliness of the information

Hypothesis	Test variable	Control variable	Test equation / [restriction]	*F*-value	Significance
E|Am -> F	Europe, previous day	America, previous day	$F_t = \alpha F_{t-1} [+ \beta E_{t-1}] + \gamma Am_{t-}$	0.8265	0.3636
Am|As -> F	America, previous day	Asia, current day	$F_t = \alpha F_{t-1} [+ \beta Am_{t-1}] + \gamma As_t$	61.7365	0.0000***
	America, lag 2	Asia, previous day	$F_t = \alpha F_{t-1} [+ \beta Am_{t-2}] + \gamma As_t$	3.1408	0.0768*
As|E -> F	Asia, previous day	Europe, previous day	$F_t = \alpha F_{t-1} [+ \beta As_{t-1}] + \gamma E_{t-}$	8.7097	0.0033***

F_t = The Finnish stock market return
E_t = The European factor return
Am_t = The American factor return
As_t = The Asian factor return

5.4. The Dynamics of the Causality Pattern

The rolling regressions for the hypotheses A-C are depicted in figures 5.1 - 5.3. In all figures, the time axis shows the ending point of the rolling regressions. For example, the *F*-value for February 1996 corresponds to the period of 100 market days (approximately 4 months) ending at February 1996.

The relative strength of the three hypotheses varies significantly over time. The relevance, incrementality and timeliness of the European information set is significant almost throughout the study period. The relevance, incrementality and timeliness of the Asian factor is notable in the beginning and in the middle of the study period. For the American and European factors, these features are notable most of the study period.

The dynamics of the relevance hypothesis is shown in figures 5.1a-f (cf. table 5.1). There is an interesting common pattern in the behaviour of the global return factors: in all three cases, a clear shift from old to new information is observed. However, also old (yesterday) news have a significant impact on the Finnish returns, especially in the beginning and towards the end of the study period. For the American factor, the shift from old to new information usage occurs somewhat later than for the European. The common shift towards more efficient information processing holds also for the Asian factor.

In figures 5.2a-f we show the dynamics of the incremental information hypotheses (cf. table 5.2). As expected, the significant contemporaneous causality from the European factor prevails over the whole test period. For the American factor, the incremental information pattern closely resembles the relevance pattern, i.e., when the latest American news has significant relevance in causing the Finnish returns, it also has significant incremental value over the older European impact. It is interesting to note that - for a large part of the test period - the European information for the previous day is strong enough to almost annihilate the incremental impact of the latest American information.

Figures 5.3a-f show the evolution of the timeliness hypotheses (cf. table 5.3). For all factors, the timeliness profiles resemble the relevance profiles closely. The timeliness hypothesis is accepted over a larger consecutive time span only for the European factor (figure 5.3f). Yet, in total the evidence suggests that the timeliness hypothesis is mostly rejected for all three factors. Since the intrinsic informational content of each factor persists even after controlling for the newer information, the stock pricing information is not completely absorbed between continents of different time zones. The trading activity within a continental time zone hence contains informational components that are orthogonal to those of the succeeding continent.

5.5. Testing the Statistical Quality of the Regression Models

In order to verify the reliability of the regression models, the key statistical tests presented previously were conducted on the residuals of each regression. The test results are summarized in table (5.4). The table shows that normality of the residuals is rejected in approximately 30-40% of the regressions. The other statistical tests show a considerably lower frequency of rejection. The RESET test, measuring the validity of specification indicates acceptable rejection frequencies at both the 5% and 10% level of significance. The error autocorrelation test indicates moderate rejection frequencies. In no more than seven out of eighteen regression specifications do the rejection frequencies exceed the nominal levels clearly. The ARCH and heteroskedasticity tests exhibit a somewhat higher rejection frequency. At least one of the above statistical tests is rejected frequently mostly because of violations of normality. In summary, rejection of normality appears to be the critical factor among the statistical tests. The statistical quality of the regressions might be somewhat improved by allowing for some type of ARCH-effects. The moderate rejection frequencies suggest, however, that by accounting for ARCH-effects the overall evidence of Granger causality would change only marginally. The verification of this conjecture is left for future research, however.

Table 5.4.: Percentages of iterations with unacceptable residual statistics.

		Error AC		ARCH		Normality		Heterosk		RESET		At least one	
		5%	10%	5%	10%	5%	10%	5%	10%	5%	10%	5%	10%
Relevance													
Europe	E_{t-1}	1.84%	4.45%	14.11%	18.71%	34.97%	38.80%	14.26%	20.86%	7.06%	10.74%	40.34%	51.99%
	E_t	16.72%	26.84%	0.31%	1.69%	36.04%	42.48%	0.31%	1.84%	0.00%	0.61%	45.71%	54.91%
America	Am_{t-2}	7.22%	11.67%	6.91%	15.05%	41.47%	44.24%	8.91%	15.98%	3.84%	6.91%	48.39%	55.30%
	Am_{t-1}	9.51%	15.18%	15.18%	17.33%	41.10%	43.40%	17.33%	17.02%	4.75%	9.36%	51.23%	61.20%
Asia	As_{t-1}	3.07%	5.98%	12.88%	16.41%	42.02%	45.55%	6.75%	12.73%	5.83%	8.74%	46.93%	51.84%
	As_t	2.76%	5.06%	17.33%	21.78%	38.34%	40.80%	21.93%	24.85%	3.83%	9.20%	48.16%	54.91%
Incrementality													
Europe	$E_{t-1}\|As_{t-1}$	10.43%	16.10%	0.46%	2.45%	34.36%	44.48%	0.61%	2.61%	5.67%	13.04%	39.26%	55.21%
	$E_t\|As_t$	7.67%	14.26%	0.15%	2.15%	38.19%	43.56%	0.15%	0.31%	0.00%	0.92%	39.26%	45.40%
America	$Am_{t-2}\|E_{t-2}$	4.14%	9.20%	6.60%	14.72%	38.04%	42.33%	11.81%	18.25%	6.13%	12.88%	48.93%	60.74%
	$Am_{t-1}\|E_{t-1}$	5.21%	8.59%	15.49%	18.25%	34.20%	39.57%	17.02%	16.41%	5.98%	7.98%	43.71%	52.61%
Asia	$As_{t-1}\|Am_{t-2}$	5.38%	10.60%	5.84%	13.21%	40.71%	43.93%	10.29%	10.14%	4.45%	9.37%	49.46%	57.30%
	$As_t\|Am_{t-1}$	5.21%	10.74%	16.26%	17.94%	40.03%	42.94%	17.02%	17.18%	4.29%	5.98%	49.23%	57.21%
Timeliness													
Europe	$E_{t-1}\|Am_{t-1}$	5.21%	8.59%	15.49%	18.25%	34.20%	39.57%	17.02%	16.41%	5.98%	7.98%	43.71%	52.61%
	$E_t\|Am_t$	11.50%	21.78%	0.77%	3.68%	39.11%	44.79%	5.06%	9.36%	3.83%	6.75%	51.84%	65.18%
America	$Am_{t-2}\|As_{t-1}$	5.38%	10.60%	5.84%	13.21%	40.71%	43.93%	10.29%	10.14%	4.45%	9.37%	49.46%	57.30%
	$Am_{t-1}\|As_t$	5.21%	10.74%	16.26%	17.94%	40.03%	42.94%	17.02%	17.18%	4.29%	5.98%	49.23%	57.21%
Asia	$As_{t-1}\|E_{t-1}$	4.75%	9.20%	13.80%	18.25%	35.12%	39.72%	4.14%	6.75%	9.20%	13.80%	39.72%	50.15%
	$A_{st}\|E_t$	10.43%	16.10%	0.46%	2.45%	34.36%	44.48%	0.61%	2.61%	5.67%	13.04%	39.26%	55.21%

6. Conclusion

In the paper we have formulated and tested three hypotheses concerning the impact of global stock return factors on the Finnish return generating mechanism. The study is carried out using the well-known Granger causality framework. The relevance and incrementality hypotheses are corroborated for all continents (America, Europe, Asia). The timeliness hypothesis is accepted for America but not for Europe and Asia, obviously due to the strong information value in the American return factor. The dynamics of the causality patterns - studied within the rolling Granger framework - exhibits features particular to each continent included in the study. This is a reflection of the time-variability of the importance of the geographical continents as driving forces of the global financial markets.

Our study has several implications for future research. Firstly, the study could be extended to cover other Scandinavian markets as well. Furthermore, a comparison between the rather small Nordic stock markets to larger markets such as, e.g., the New York, London or Frankfurt stock markets could reveal interesting relationships. Finally, the three hypotheses tested in this study might be further challenged by extending the set of control information, by for example domestic interest rates, production volume and other macroeconomic variables.

References

Aaltonen, J. and R. Östermark: "A rolling test of Granger causality between the Finnish and Japanese security markets", *Omega*, 25:6, 1997, pp. 635-642.

Akaike, H.: "Fitting autoregression for prediction", *Annals of the Institute of Statistical Mathematics* 21, 1969, pp. 243-247.

Blackman, S., K. Holden, and W. Thomas: "Long-term relationships between international share prices", *Applied Financial Economics* 4, 1994, pp. 297-304.

Bos, T., T. A. Fetherston, T. Martikainen, and J. Perttunen: "The international co-movements of Finnish stocks", *The European Journal of Finance* 1, 1995, pp. 95-111.

Cheung, Yin-Wong and Kon S. Lau: "Lag order and critical values of a modified Dickey-Fuller test", *Oxford Bulletin of Economics and Statistics*, 57:3, 1995, pp. 411-419.

Dickey, D. and W. A. Fuller: "Distribution of the estimates for autoregression time series with a unit root", *Journal of the American Statistical Association*, 74, 1979, pp. 427-431.

Elliott, G, T. J. Rothenberg, and J. H. Stock: "Efficient tests for an autoregressive unit root", National Bureau of Economic Research Technical Working Paper No. 130, 1992.

Engle, R. F. and C. W. J. Granger: "Co-integration and an error correction: representation, estimation, and testing", *Econometrica*, 1987, pp. 251-275 .

Fuller, W. A.: *Introduction to Statistical Time series*, John Wiley, New York, 1976.

Geweke, J.: "Inference and causality in economic time series models", in Z. Griliches and M. D. Intriligator (Eds.): *Handbook of econometrics* 2, North-Holland, Amsterdam, 1984, pp. 1101-1144.

Guilkey, D. K. and M. K. Salemi: "Small sample properties of three tests for Granger-causal ordering in a bivariate stochastic system", *Review of Economics and Statistics* 64, 1982, pp. 668-680.

Hendry, D. F. and J. A. Doornik: "Empirical Econometric Modelling Using PcGive for Windows", International Thomson Business Press. London WC1V 7AA. 1996. ISBN 1-86152-057-3.

Hsiao C (1981) Autoregressive modelling and money-income causality detection", *Journal of Monetary Economics*, 7, January, 85-106.

Jones, J. D.: "A comparison of lag-length selection techniques in tests of Granger causality between money growth and inflation: Evidence for the US, 1959-86", *Applied Economics* 21, 1989, pp. 809-822.

Kang, H.: "The effects of detrending in Granger causality tests", *Journal of Business and Economic Statistics* 3, 1985, pp. 344-349.

Kang, H.: "The optimal lag selection and transfer function analysis in Granger causality tests", *Journal of Economic Dynamics and Control* **13**, 1989, pp. 151-169.

Malkamäki, M., T. Martikainen, and J. Perttunen: "On the riskiness of the world's stock markets", *European Journal of Operational Research* **53**, 1991, 288-296.

Malkamäki, M., T. Martikainen, J. Perttunen, and V. Puttonen: "On the causality and co-movements of Scandinavian stock market returns", *Scandinavian Journal of Management* **9**:1, 1993, pp. 67-76.

Malliaris, A. G. and J. L. Urrutia: "The international crash of October 1987: Causality tests", *Journal of Financial and Quantitative Analysis*, **27**:3, September, 1992, pp. 353-363.

Martikainen, T., J. Perttunen, P. Yli-Olli, and A. Gunasekaran: "Modelling the lead-lag effect between dual-class shares", *International Journal of Systems Science*, **25**:7, 1994, pp. 1205-1211.

Martikainen, T., I. Virtanen, and P. Yli-Olli: "On the international co-movements of capital markets: evidence from two Scandinavian stock markets", in: Khosow Fatumi (Ed.) *International Trade and Finance in the 1990's*. Proceedings of the International Trade and Finance Association, 1991, pp. 995-1009.

Masih, A. M. M. and R. Masih: "A comparative analysis of the propagation of stock market fluctuations in alternative models of dynamic causal linkages", *Applied Financial Economics* **7**, 1997, pp. 59-74.

Mathur, I. and V. Subrahmanyam: "An analysis of the Scandinavian stock indices", *Journal of International Financial Markets, Institutions, and Money*, **1**:1, 1991, pp. 91-114.

Neave, H. R.: *Elementary Statistics Tables*, George Allen & Unwin Ltd, London, 1981.

Östermark, R.: "Modelling cointegrated processes by a vector-valued state space algorithm. Evidence on the impact of Japanese stock prices on the Finnish derivatives market". In Masanao Aoki and Arthur M. Havenner (Eds.): *Applications of Computer Aided Time Series Modelling. Lecture Notes in Statistics 11,* Springer-Verlag, New York, NY, 1997, pp. 141-179.,

Östermark, R.: "Multivariate Granger causality in international asset pricing". Forthcoming in *Applied Financial Economics* **8**, 1998.

Östermark, R. and J. Aaltonen: "Comparison of univariate and multivariate Granger causality in international asset pricing". Forthcoming in *Applied Financial Economics*, 1998.

Östermark, R. and M. Aoki: "State space modelling and spectral analysis of cointegrating vector processes. Evidence from the U.S. and Scandinavian economies", *International Journal of Systems Science* **26**:12, 1995, pp. 2327-2353.

Pehkonen, J.: "Real wages-employment relationship on Finnish manufacturing: A VAR approach", *Applied Economics* **23**, 1991, pp. 1559-1568.

Phillips, P. C. B. and P. Perron: "Testing for a unit root in time series regression", *Biometrika* **75**:2, 1988, pp. 335-346.

Ramsey, J. B.: "Tests for specification error iin classical linear least squares regression analysis", *Journal of the Royal Statistical Society B* **31**, 1969, pp. 350-371.

SHAZAM Econometrics Computer Program, User's reference manual, Version 7.0, McGraw-Hill, Canada, 1993.

Smith, K. L., J. Brocato, and J. E. Rogers: "Regularities in the data between major equity markets: evidence from Granger causality tests", *Applied Financial Economics* **3**, 1993, pp. 55-60.

Thornton, D. L. and D. S. Batten: "Lag-length selection and tests of Granger causality between money and income", *Journal of Money, Credit, and Banking* **17**:2, May, 1985, pp. 163-178.

Figure 3.1: Daily returns on the Finnish general index FOX

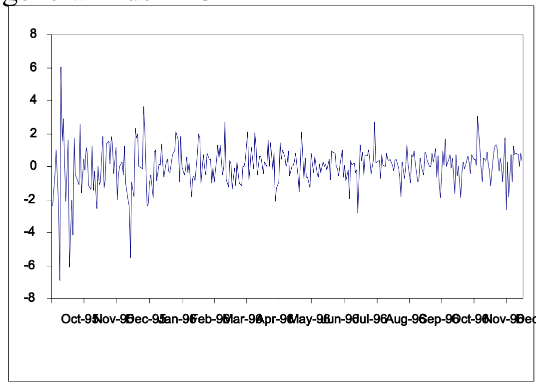


Figure 3.2: Factor 1 - Europe

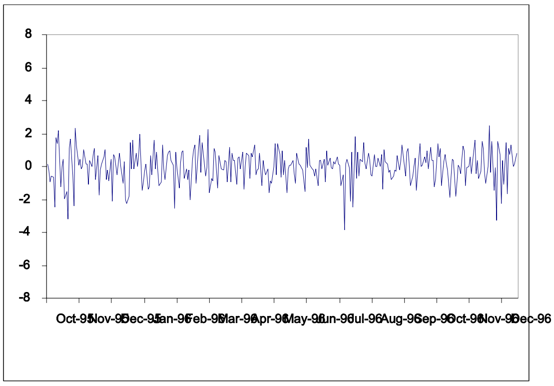


Figure 3.3: Factor 2 - Asia

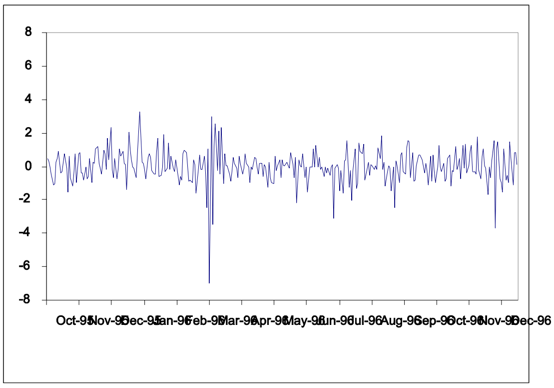


Figure 3.4: Factor 3 - America

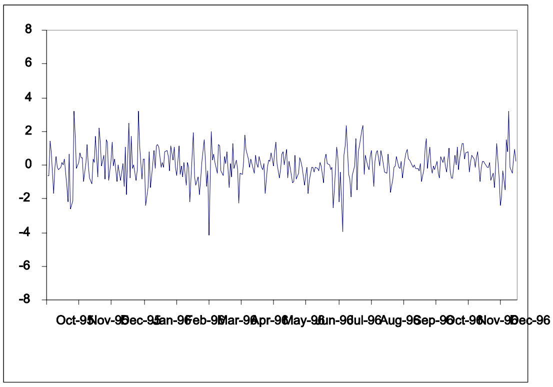
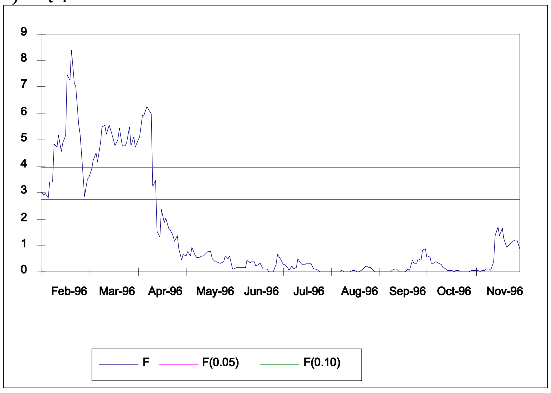
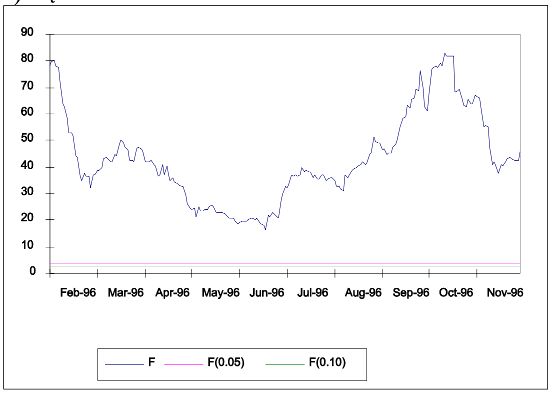


Figure 5.1: Dynamics of the relevance hypothesis measured by rolling Granger causality with window length 100

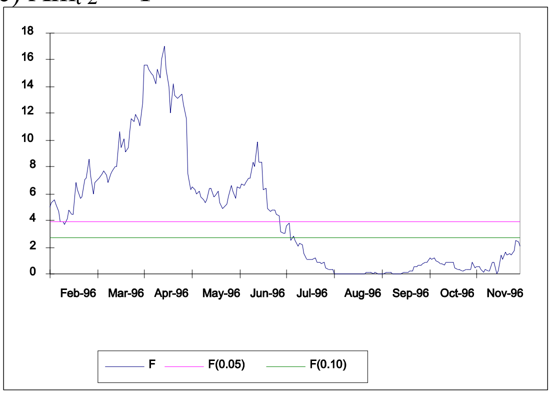
a) E_{t-1} -> F



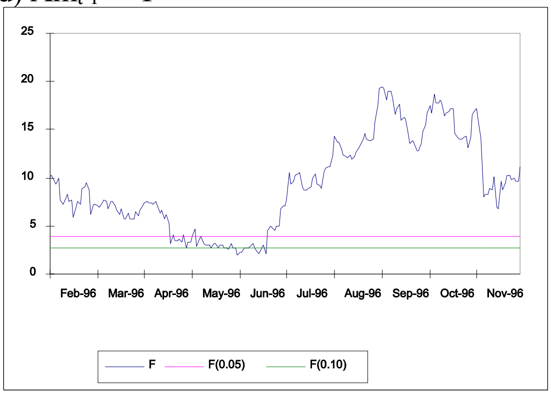
b) E_t -> F



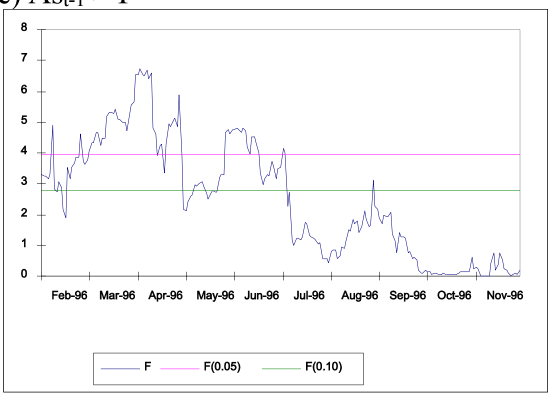
c) Am_{t-2} -> F



d) Am_{t-1} -> F



e) As_{t-1} > F



As_t -> F

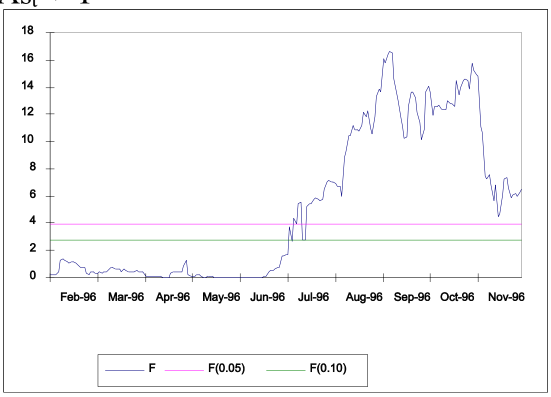
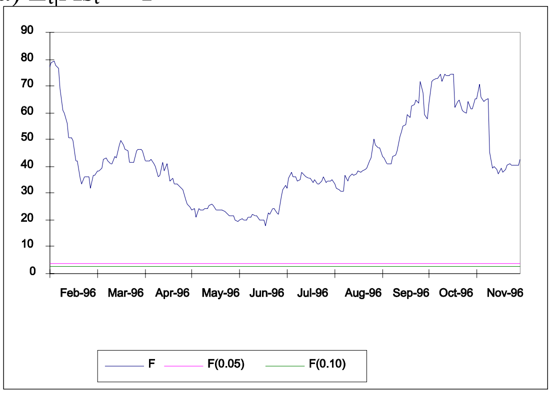
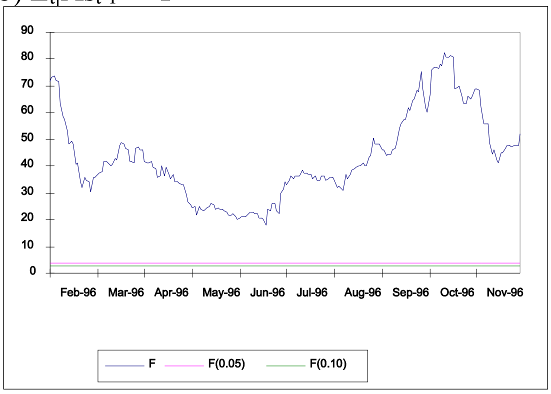


Figure 5.2: Dynamics of the incremental information hypothesis measured by rolling Granger causality with window length 100

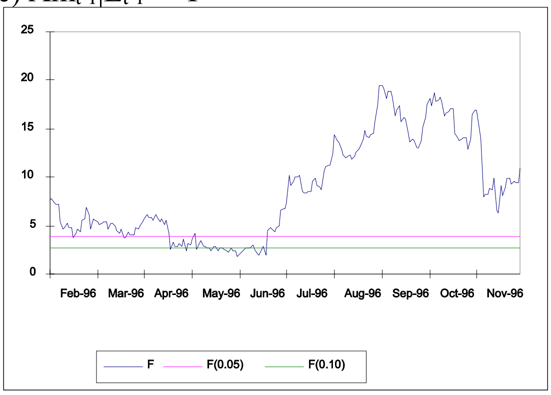
a) $E_t|As_t$ -> F



b) $E_t|As_{t-1}$ -> F



c) $Am_{t-1}|E_{t-1}$ -> F



d) $As_{t-1}|Am_{t-2}$ -> F

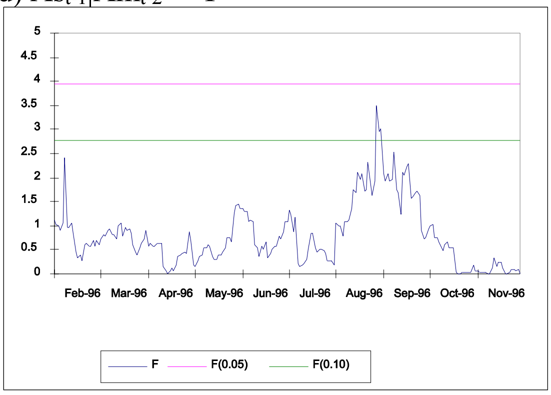
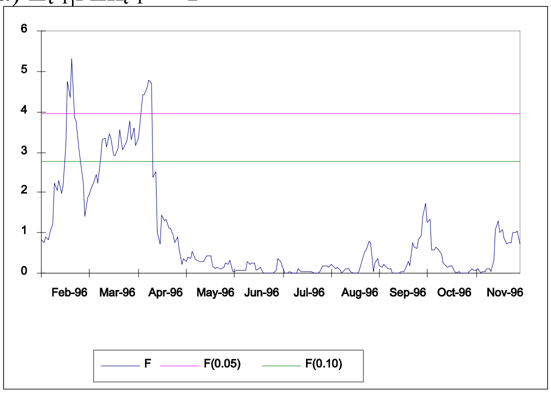
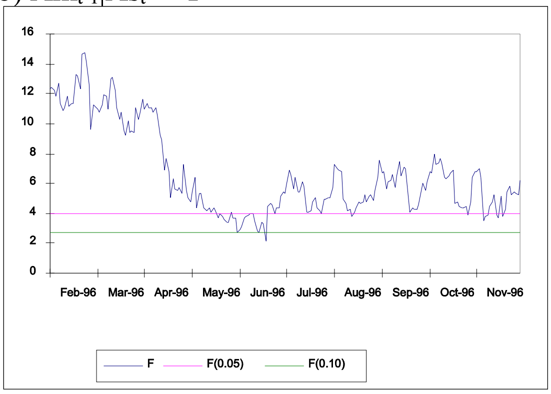


Figure 5.3: Dynamics of the timeliness hypothesis measured by rolling Granger causality with window length 100.

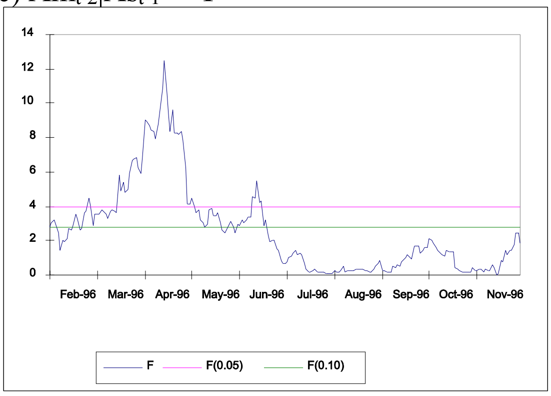
a) $E_{t-1}|Am_{t-1}$ -> F



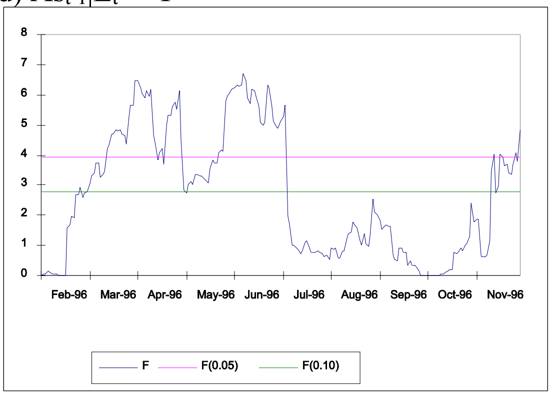
b) $Am_{t-1}|As_t$ -> F



c) $Am_{t-2}|As_{t-1}$ -> F



d) $As_{t-1}|E_t$ -> F



Trading Hours	Local Time		GMT
Helsinki:	9.00 - 14.30*	+2	7.00 - 12.30
Sydney:	8.30 - 12.30 and 14.00 - 16.30	+9	23.30 - 3.30 and 5.00 - 7.30
Tokyo:	9.00 - 11.00 and 12.30 - 15.00	+9	0.00 - 2.00 and 3.30 - 6.00
Toronto:	9.30 - 16.00	-5	14.30 - 21.00

* 1.11.1993 -> 17.00