Common Volatility Components in International Stock Markets

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Abstract
This paper analyzes volatility structures and the presence of common volatility components in the stock markets of Asian-Pacific, Europe and North America using close-to-close daily returns in local currencies. The return series are filtered before volatility modeling in order to remove first order autocorrelations. Furthermore, the consequences of nonsynchroneity in the opening hours of the markets around the globe are carefully taken into account. The results indicate that an ARCH-effect is present in all the markets. However, only a few pairs of markets seem to share common volatility. USA is present in most of these pairs. Of the European markets, only France and the small Nordic markets seem to share a common volatility process with USA. It seems that the small markets follow the volatility process generated in US. Furthermore, a common time-varying volatility process seems to be present in Canada and US. In addition, Hong Kong seems to share a common volatility with US. Analysis of weekly data suggests that common volatility is at most a regional feature.

Data of the study
The analysis utilizes daily close-to-close index returns from eleven markets including the stock exchanges in New York, Toronto, Tokyo, Hong Kong, London, Frankfurt, Zurich, Paris, Copenhagen, Stockholm, Oslo and Helsinki. The sample series starts on September 7, 1991 and ends November 10, 1997. The data is obtained from Global Financial Data Base[1]. New York and Toronto floor trading hours have two hours overlap with London, one and half an hour overlap with Paris, Stockholm and Zurich, and half an hour overlap with Oslo and Helsinki. Hong Kong and Tokyo do not overlap with New York, Toronto or the European stock exchanges. The European exchanges are essentially open at the same time.

Table 2. Descriptive statistics for national daily index returns.

Daily index returns in the sample period January 1, 1991 to October 10, 1997 are defined as log-differences $r_t = 100 \times \left(\ln(I_t) - \ln(I_{t-1})\right)$. National holidays are replaced by zero returns. However, days when three or more markets were closed were removed. This reduced the number of trading days from 1762 to 1702.

	Fin	*Swe*	*Nor*	*Den*	*UK*	*Ger*	*Fra*	*Swz*	*USA*	*Can*	*Jpn*	*Hon*
Mean	0.08	0.08	0.06	0.04	0.05	0.07	0.04	0.09	0.06	0.05	-0.01	0.09
Median	0.04	0.04	0.07	0.03	0.03	0.07	0.01	0.11	0.03	0.04	0.00	0.04
Std	1.18	1.06	1.06	0.62	0.69	1.01	1.10	0.92	0.64	0.56	1.11	1.40
Kurtosis	2.67	7.22	9.88	6.99	5.05	8.18	3.01	6.57	3.21	2.88	5.14	4.50
Skewness	0.10	0.49	-0.02	-0.29	0.48	-0.53	-0.05	-0.37	-0.21	-0.39	0.38	-0.42
Minimum	-7.59	-6.53	-9.21	-5.25	-3.66	-9.87	-7.58	-8.40	-3.82	-3.70	-5.38	-8.75
Maximum	6.05	9.01	8.93	3.93	5.70	7.29	6.80	5.65	3.40	2.16	7.28	6.88

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[1] Global Financial Data Base at http://www.globalfindata.com

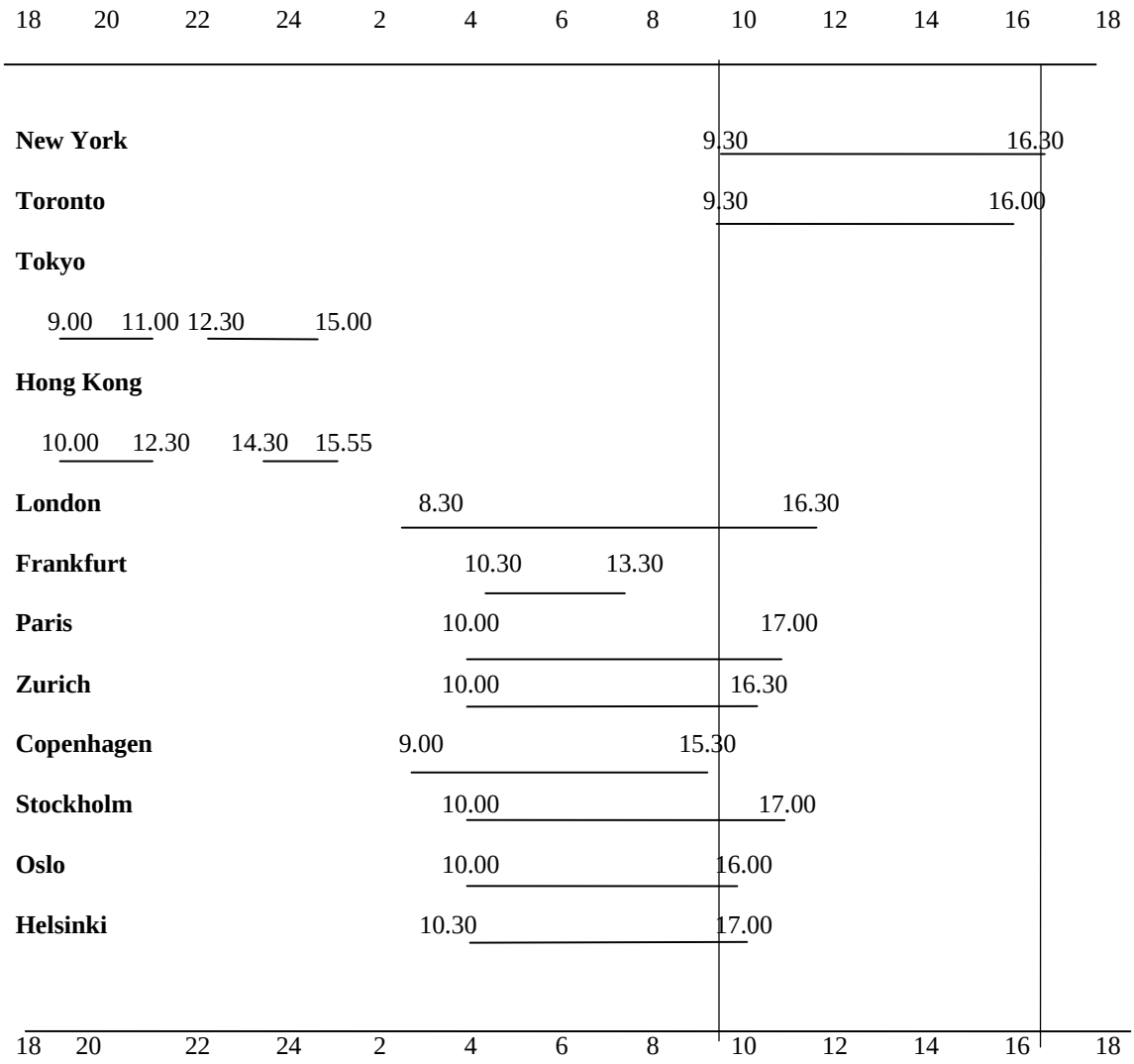

Figure 1. Relative trading hours for twelve stock exchanges.

Descriptive statistics shown in Table 1 indicate the sample period is characterized by a small positive mean daily returns between 0.04–0.06 percentages for USA, Canada, UK, France, Denmark and Norway. Hong Kong, Switzerland, Sweden and Finland have had returns around 0.08 percentage and Japan has had a slight negative average return of –0.01 percentage. Excess kurtosis is obvious in all series. All distributions, except Finland, Norway and France seem to be skewed, too. Sweden, UK and Japan are positively skewed, and the rest (Denmark, Germany, Switzerland, USA, Canada and Hon Kong) are negatively.

Main empirical results

Analyzing common volatility in return innovations on daily basis using close-to close data causes a problem with nonsychroneity of opening hours. If the trading hours do not coincide it may cause dependencies that show spurious information transmission. Because of the close-to-close daily data there is perfect nonsynchroneity between Asian-Pacific and the other markets and an almost perfect nonsynchroneity between European and North American markets. The European markets are trading almost simultaneously. In determining return innovations, we take account of the different trading hours by allowing the same day returns of Asian Pacific and European markets to appear in the North American regression equations. Similarly, we allow the Asian Pacific same day returns to appear

in the European regression equations. The rationale is that the new information processed in the earlier markets are fully available as the latter markets open later on during the same day as the earlier markets are essentially already closed.

We analyze the common volatility pattern in the spirit of Engle and Kozicki (1993) and Engle and Susmel (1993) (see also Arshanapalli, Doukas and Lang 1997). The first step is test for an ARCH-effect in each single series. As autocorrelation in the series will generate autocorrelation in the squared series (volatility entities), we account for the first order correlations using a structural VAR-model. There is strong evidence that Sweden and Norway are cointegrated with a trend in the cointegration space. This effect was also observed in a different (and shorter) data set, see Knif and Pynnonen (1998). Therefore, we removed also this effect from the return series of these two particular individual markets. No other clear evidence of cointegration was found. The fitted structural VAR model contains five lags of all return series of the European markets and the same day return of Japan and Hong Kong. To the regression models for Norway and Sweden the lagged cointegration residual was also added. For Canada and US the same day returns of the European markets were included. For Japan and Hong Kong only lagged returns were used as regressors. In this way we have eliminated the autocorrelation bias in the ARCH-testing.

Table 2. ARCH-tests for daily return innovations.

Return innovations are determined as residuals of an estimated VEC-model. In determining the innovations, differences in trading hours are taken into account by allowing the same day returns of Asian Pacific and European markets to appear in the North American regression equations. Similarly, Asian Pacific same day returns appear in the European regression equations.

	ARCH(5)	p-value
Finland	59.5	0.000
Sweden	94.6	0.000
Norway	126.4	0.000
Denmark	120.0	0.000
UK	44.9	0.000
Germany	33.3	0.000
France	24.6	0.000
Swizerland	83.3	0.000
USA	18.0	0.003
Canada	26.8	0.000
Japan	120.3	0.000
Hong Kong	160.1	0.000

Results of univariate ARCH-tests are reported in Table 2, which indicates that all series series can be inferred to have ARCH-effects. Test results whether the effect is common are reported in Appendix 1. The general result in the common ARCH-effect test is that only few markets seem to share a common time-varying volatility process. USA is present in almost all of these pairs[2]. An interesting feature is that from the European markets, with the exception of France, only the small Nordic markets seem to share a common volatility process with USA. The common volatility process hypothesis is only borderline accepted for Denmark, Norway and Sweden. The results indicate that especially the small markets are sensitive to shocks occurring on the world leading US market. Consequently, instead of talking about a common volatility process, one rather can say that the small markets are following the volatility process determined by the US markets.

In North America, the common time-varying volatility hypothesis is accepted as well between Canada and US. In the Asian-Pacific, also Hong Kong seems to share a common volatility process with US.

All told, these empirical results differ from those of Engle and Susmel (1993) and also from those of Arshanapalli et al. (1997). However, Engle and Susmel used weekly data and Arshanapalli et al. utilized daily data for only one year; 1993. Our data set consists of daily returns covering nearly seven years. Hence, with the increased number of observations smaller deviations from the null hypothesis, common ARCH-feature, is expected to emerge.

[2] Common feature is an equivalence relation. Consequently, all those markets sharing a common time-varying volatility with USA should share a common volatility process with each other. This, however, is not the case in our study nor is it the case in Engle and Susmel (1993) or Arshanapalli *et al.* (1997).

Table 8. ARCH and MARCH tests for weekly return innovations.
Weekly return innovations are aggregated by summing daily innovations. Daily return innovations are determined as residuals of an estimated VEC-model. In determining the daily innovations, differences in trading hours are taken into account by allowing the same day returns of Asian Pacific and European markets to appear in the North American regression equations. Similarly, Asian Pacific same day returns appear in the European regression equations.

	ARCH(4)	p-val	MARCH(4)	p-val	Inf. Set	MARCH(4)	p-val	Inf. Set
Fin	10.5	0.032	21.8	0.151	Fin Swe Nor Den	13.5	0.097	Fin Usa
Swe	5.2	0.268	27.6	0.035	Fin Swe Nor Den	10.4	0.236	Swe Usa
Nor	27.4	0.000	42.5	0.000	Fin Swe Nor Den	34.1	0.000	Nor Usa
Den	6.1	0.194	26.0	0.055	Fin Swe Nor Den	8.5	0.385	Den Usa
Gbr	26.4	0.000	43.4	0.000	Gbr Ger Fra Swz	31.8	0.000	Gbr Usa
Ger	10.4	0.034	34.9	0.004	Gbr Ger Fra Swz	15.3	0.054	Ger Usa
Fra	4.6	0.335	48.9	0.000	Gbr Ger Fra Swz	8.3	0.404	Fra Usa
Swz	13.2	0.010	27.3	0.038	Gbr Ger Fra Swz	14.2	0.078	Swz Usa
Usa	1.2	0.880	4.6	0.801	Usa Can	4.8	0.780	Usa Gbr
Can	5.7	0.220	15.1	0.057	Usa Can	18.1	0.021	Can Gbr
Jpn	39.0	0.000	39.6	0.000	Jpn Hon	40.7	0.000	Jpn Usa
Hon	15.2	0.004	17.2	0.028	Jpn Hon	18.9	0.015	Hon Usa

To make the results better comparable we run weekly analysis as well. The univariate ARCH results reported in Table 3 change to some extends from the daily case, where ARCH-effect was inferred to be present in each series. Now Sweden, Denmark, France, USA and Canada do not show univariate ARCH. Augmenting the univariate information set by other series, ARCH-effect can be inferred to be present additionally in France and possibly in Sweden, Denmark and Canada. Still there is no evidence of ARCH in USA.

These preliminary results suggest that one obvious group for potential common ARCH effect might be the big European markets of Great Britain, Germany, France and Switzerland because, at least after augmenting the information set each series seems to have ARCH effect. A second European group might be the small Nordic countries of Denmark, Finland Norway and Sweden. North America and Pacific Asian areas form their own two natural groups on the basis of geographical reasons.

Using these groupings as the basis, we test the existence of a common ARCH effect between the markets within the groups if either both series have a univatiate ARCH or multivariate ARCH after augmenting the information set by the test pair. Furthermore, we test the existence of an ARCH beyond geographical groups between those series that have multivariate ARCH after augmenting the information set by the test pair. The results are reported in Appendix 2. The results strongly indicate that there is no common volatility process between the small Nordic markets, although the null hypothesis of common volatility between Finland and Norway would be accepted even at a ten percent level. Norway, however, does not share a common volatility process with Great Britain, but Finland does. Consequently because of the equivalence relation property Norway should share a common volatility process with Great Britain as well. Because this is not the case, we can rather infer as in the daily case that these small countries may at most follow the volatility behavior of some of the larger European markets. This partially supports the general result found in the earlier daily analysis.

Among the big European markets, France, Germany, Great Britain and Switzerland, there is strong evidence of a common ARCH feature. In addition, Japan and Hon Kong seem to share a common volatility process, but USA and Canada do not because there is no sign of existence of an ARCH feature at weekly level in the USA series. The cross-continental tests indicate that only Canada and Great Britain might share a common ARCH process.

As a summary the results strongly support the idea found in Engle and Susmel (1993) and Archanapalli et al. (1997), that if there is a common volatility process it tends to be a regional one.

Summary

This paper analyzes volatility structures and the presence of common volatility components in the stock markets of Asian-Pacific, Europe and North America using close-to-close daily returns in local currencies. Before volatility modeling, the series are filtered in order to remove first order autocorrelations that would induce autocorrelation into the squared observations and, hence, spuriousness in the time-varying conditional volatility. Furthermore, the

consequences of nonsynchroneity in the opening hours of the markets around the globe are carefully taken into account.

The results indicate that an ARCH-effect is present in all the markets. However, only a few pairs of markets seem to share common volatility. USA is present in virtually all of these pairs. Of the European markets, only France and the small Nordic markets seem to share a common volatility process with USA. The results indicate that especially the small markets are sensitive to shocks taking place on the world leading US markets. Consequently, the small markets seem to follow the volatility process generated in US. Furthermore, a common time-varying volatility process seems to be present in Canada and US as well as in Hong Kong and US.

No regional common factors were found as in Engle and Susmel (1993) who used weekly data. In order to see the effects of time aggregation, which should smooth daily noise, tests were performed on weekly basis as well. In the time-aggregated data the situation changed quite radically in that the common volatility could be inferred being present especially among European markets. This supports the finding of Engle and Susmel (1993) that if there is common volatility it is at most regional rather than global.

Acknowledgments

This study was done while the second author, Seppo Pynnönen, was a researcher of Academy of Finland, which is gratefully acknowledged. Financial support from Jenny and Antti Wihuri Foundation is also gratefully acknowledged.

References

Arshanapalli, Bala, John Doukas and Larry H.P. Lang (1997). Common volatility in the industrial structure of global capital markets. *Journal of Money and Fiance* 16, 187–209.

Engle, R.F. and S. Kozicki (1993). Testing for common features. *Journal of Business and Economic Statistics* 11, 369–380.

Engle, R.F. and R. Susmel (1993). Common volatility in informational equity markets. *Journal of Business & Economic Statistics* 11, April, No 2, pp. 167–176.

Knif, Johan and Seppo Pynnonen (1997). Local and global price memory of international stock markets. *Proceedings of the University of Vaasa, Discussion Papers* 213. (Submitted for publication)

Appendix 1. Common ARCH-tests for daily return innovations.

Return innovations are determined as residuals of an estimated VEC-model. In determining the innovations, differences in trading hours are taken into account by allowing the same day returns of Asian Pacific and European markets to appear in the North American regression equations. Similarly, Asian Pacific same day returns appear in the European regression equations.

Market	τ	min-Test	p-val
Finland/Sweden	0.48	66.54	0.000
Finland/Norway	-0.05	61.91	0.000
Finland/Denmark	1.08	67.60	0.000
Finland/UK	1.50	54.10	0.000
Finland/Germany	2.04	32.92	0.003
Finland/France	-6.01	33.80	0.002
Finland/Switzerland	1.27	42.72	0.000
Finland/USA	**3.81**	**11.17**	**0.672**
Finland/Canada	4.14	30.26	0.007
Finland/Japan	0.66	47.17	0.000
Finland/Hong Kong	-0.44	52.90	0.000
Sweden/Norway	-0.13	121.04	0.000
Sweden/Denmark	-0.89	124.51	0.000
Sweden/UK	0.46	108.38	0.000
Sweden/Germany	-8.91	37.97	0.001
Sweden/France	-37.82	50.67	0.000
Sweden/Switzerland	1.29	54.89	0.000
Sweden/USA	**10.29**	**23.14**	**0.058**
Sweden/Canada	-4.43	32.77	0.003
Sweden/Japan	0.97	108.61	0.000
Sweden/Hong Kong	-0.52	57.38	0.000
Norway/Denmark	2.17	133.51	0.000
Norway/UK	3.77	68.86	0.000
Norway/Germany	-3.75	37.97	0.001
Norway/France	4.88	29.75	0.008
Norway/Switzerland	1.93	77.99	0.000
Norway/USA	**12.34**	**22.69**	**0.066**
Norway/Canada	**-3.88**	**22.47**	**0.070**
Norway/Japan	-12.70	138.05	0.000
Norway/Hong Kong	-0.76	109.07	0.000
Denmark/UK	-1.31	63.20	0.000
Denmark/Germany	-3.97	36.94	0.001
Denmark/France	-2.14	37.18	0.001
Denmark/Switzerland	0.86	94.92	0.000
Denmark/USA	**-7.46**	**22.77**	**0.064**
Denmark/Canada	-3.37	31.88	0.004
Denmark/Japan	-1.43	113.29	0.000
Denmark/Hong Kong	0.27	137.09	0.000

Market	τ	min-Test	p-val
UK/Germany	1.08	37.56	0.001
UK/France	-5.20	41.13	0.000
UK/Switzerland	1.50	73.44	0.000
UK/USA	-8.79	30.08	0.007
UK/Canada	2.70	29.32	0.009
UK/Japan	-0.36	57.24	0.000
UK/Hong Kong	-0.24	54.82	0.000
Germany/France	1.53	34.84	0.002
Germany/Switzerland	1.07	32.79	0.003
Germany/USA	-0.11	43.65	0.000
Germany/Canada	0.79	47.90	0.000
Germany/Japan	-0.46	38.32	0.000
Germany/Hong Kong	-0.27	33.75	0.002
France/Switzerland	0.43	37.99	0.001
France/USA	**2.14**	**11.03**	**0.683**
France/Canada	2.25	27.30	0.018
France/Japan	-0.26	32.10	0.004
France/Hong Kong	-0.30	24.92	0.035
Switzerland/USA	3.77	27.24	0.018
Switzerland/Canada	31.82	48.10	0.000
Switzerland/Japan	0.61	78.11	0.000
Switzerland/Hong Kong	0.77	141.77	0.000
USA/Canada	**0.67**	**15.20**	**0.365**
USA/Japan	0.13	31.20	0.005
USA/Hong Kong	**-0.19**	**15.51**	**0.344**
Canada/Japan	-0.18	40.22	0.000
Canada/Hong Kong	-0.12	27.35	0.017
Japan/Hong Kong	-0.64	108.47	0.000

Markets for which the common time-varying volatility process hypothesis is accepted are boldface.

Appendix 2. Common ARCH feature tests for weekly returns.

Weekly return innovations are aggregated by summing daily innovations. Daily return innovations are determined as residuals of an estimated VEC-model. In determining the daily innovations, differences in trading hours are taken into account by allowing the same day returns of Asian Pacific and European markets to appear in the North American regression equations. Similarly, Asian Pacific same day returns appear in the European regression equations.

Market pair	MARCH(4) x vs {x, y}		MARCH(4) y vs {x, y}			Min	Min	
x/y	TR2	p-val	TR2	p-val	τ	R2	TR2	p-val
Fin/Nor	14.8	0.064	28.4	0.000	0.16	0.053	17.0	0.109
Fin/Gbr	14.8	0.063	26.0	0.001	-2.02	0.024	7.6	0.751
Fin/Jpn	14.0	0.081	47.8	0.000	-0.21	0.042	13.6	0.256
Nor/Den	31.4	0.000	20.0	0.010	8.13	0.061	20.1	0.044
Nor/Gbr	40.2	0.000	27.1	0.001	-2.01	0.075	24.6	0.010
Nor/Ger	29.1	0.000	18.8	0.016	-1.75	0.017	5.5	0.907
Nor/Jpn	29.3	0.000	45.3	0.000	0.34	0.072	23.9	0.013
Nor/Hon	28.6	0.000	29.6	0.000	-1.15	0.100	33.3	0.000
Gbr/Ger	30.1	0.000	23.7	0.003	-0.75	0.048	15.3	0.169
Gbr/Fra	33.3	0.000	32.2	0.000	-0.64	0.028	9.1	0.614
Gbr/Swz	35.2	0.000	26.5	0.001	-0.82	0.034	11.1	0.434
Gbr/Can	32.4	0.000	18.1	0.021	-0.99	0.029	9.3	0.591
Gbr/Jpn	52.1	0.000	61.1	0.000	0.71	0.062	20.3	0.041
Gbr/Hon	31.1	0.000	27.5	0.001	-0.61	0.069	22.4	0.021
Ger/Fra	14.7	0.064	17.4	0.027	-0.61	0.044	14.1	0.227
Ger/Swz	16.0	0.042	12.4	0.133	-1.30	0.011	3.6	0.979
Fra/Swz	18.2	0.020	16.8	0.032	-0.68	0.047	15.6	0.158
Swz/Hon	20.1	0.010	15.7	0.046	1.94	0.062	20.5	0.039
Can/Jpn	19.5	0.013	41.9	0.000	-0.49	0.057	19.1	0.060
Jpn/Hon	39.6	0.000	17.2	0.028	-1.18	0.047	15.5	0.159