

International market links and volatility transmission

Valentina Corradi
Warwick University

Walter Distaso
Imperial College

Marcelo Fernandes
Queen Mary University of London

QASS conference on Financial Econometrics and Realized Volatility (June 2009)

Outline of the talk

1. motivation
2. testing for volatility spillovers
3. going as nonparametric as possible
4. evidence of international market links
5. concluding remarks

Motivation: International market links

King and Wadhvani (RFS 1990): volatility as the main driver

decline/rise in
volatility \Rightarrow decline/rise in
correlation \Rightarrow weaker/stronger int'l
market links

driving force contagion stemming from attempts of rational agents to infer from price changes in other markets

volatility transmission channel... a common shock increases the perceived variance of any common shock and thus of the correlation

How to uncover volatility transmission?

GARCH approach completely dominates the literature...

multivariate modeling

Engle and Ng (JF 1988)
Hamao, Masulis and Ng (RFS 1990)
Engle, Ito and Lin (Ecta 1990)
King, Sentana and Wadhvani (Ecta 1994)
Lin, Engle and Ito (RFS 1994)
Karolyi (JBES 1995)
Wongswan (RFS 2006)

cross-correlation analysis

Cheung and Ng (JoE 1996)
Hong (JoE 2001)
Pantelidis and Pittis (EL 2004)
Sensier and van Dijk (REStat 2004)
van Dijk, Osborne and Sensier (EL 2005)

GARCH approach: Issues and drawbacks

filtration

discrete time versus continuous time
→ just a matter of preference?

solution

start with a continuous-time process, but...
then move to discrete-time analysis

volatility process

measurable versus stochastic volatility
→ **market incompleteness**

specification

parametric versus nonparametric
→ **misspecification risks**, especially if controlling for
market microstructure noise and jumps

transmission channel

linear versus nonlinear
→ perhaps even more important, **pointwise?**

Going as nonparametric as possible

- first step** estimate the daily integrated variance using some realized measure
- second step** test whether the conditional density of the daily integrated variance does actually satisfy the density restriction implied by conditional independence
- complications** accounting for the first-step estimation error in the asymptotic distribution of the test statistic within a sufficiently general setting so as to accommodate jumps and microstructure noise

Issues in the realized approach

$$\text{quadratic variation} \approx \text{integrated variance} + \text{jump component} + \text{microstructure noise}$$

presence of jumps realized variance versus multi-power variation

microstructure noise multi-scale and realized kernel approaches
'optimal' sampling frequency

complication rate of convergence depends on the specific realized measure that we employ

Issues in testing noncausality in variance

$$\mathbb{H}_0 : f_{Y|\mathbf{X}^{(p)}}(y | \mathbf{X}_t^{(p)}) = f_{Y|\mathbf{X}^{(q)}}(y | \mathbf{X}_t^{(q)}) \quad \text{a.s.}$$

- data persistence** integrated variance is not really Markov
→ noncausality versus conditional independence
→ options-implied volatility helps!!
- time difference** contemporaneous effects
- density estimation** local linear smoothing × kernel smoothing
→ dimensionality issues
- test statistic** integrated square relative distance
→ facilitates asymptotic derivations
→ alleviates sensitiveness to bandwidths

Test statistic based on local linear smoothing

$$\hat{\Lambda}_T^* \equiv \sum_{t=1}^T \left[\frac{\hat{f}_{Y|\mathbf{X}^{(p)}}(Y_t | \mathbf{X}_t^{(p)}) - \hat{f}_{Y|\mathbf{X}^{(q)}}(Y_t | \mathbf{X}_t^{(q)})}{\hat{f}_{Y|\mathbf{X}^{(q)}}(Y_t | \mathbf{X}_t^{(q)})} \right]^2 \pi(y_t, \mathbf{x}_t^{(p)})$$

assumptions

- A1** kernel conditions \longrightarrow smoothness, boundedness, order
- A2** density conditions \longrightarrow smoothness, boundedness
- A3** weighting scheme \longrightarrow continuity, integrability, compactness
- A4** weak dependence \longrightarrow β -mixing with $\beta_\tau \equiv O(\rho^\tau)$

Asymptotic result in the local-linear context

Theorem 1: Under Assumptions A1 to A4 and bandwidth conditions,

$$\widehat{\Lambda}_T = \frac{h_p^{p/2} b^{1/2} \widehat{\Lambda}_T^* - h_p^{-p/2} b^{-1/2} \widehat{\mu}_{1,T} - h_p^{p/2} h_q^{-q} b^{-1/2} \widehat{\mu}_{2,T} + 2 h_p^{p/2-q} b^{-1/2} \widehat{\mu}_{3,T}}{\widehat{\Omega}_T} \xrightarrow{d} N(0, 1)$$

under the null of conditional independence.

remark: bandwidth conditions require $b = O(T^{-1/5})$, $h_1 = o(T^{-1/5})$ and $h_2 = o(T^{-9/50})$ for **second-order kernels**, whereas $b = O(T^{-1/9})$, $h_1 = o(T^{-17/81})$, $h_2 = o(T^{-17/90})$ and $h_3 = o(T^{-17/99})$ for **fourth-order kernels**

- ▶ **bit of undersmoothing**
- ▶ **dimensionality constraints**

Asymptotic result in the standard kernel context

Theorem 2: Under Assumptions A1 to A4 and bandwidth conditions

$$\bar{\Lambda}_T = \frac{h_p^{p/2} b^{1/2} \bar{\Lambda}_T^* - h_p^{-p/2} b^{-1/2} \bar{\mu}_{1,T} - h_p^{p/2} h_q^{-q} b^{-1/2} \bar{\mu}_{2,T} + 2 h_p^{p/2-q} b^{-1/2} \bar{\mu}_{3,T}}{\widehat{\Omega}_T} \xrightarrow{d} N(0, 1).$$

remark: bandwidths are such that $b = O(T^{-1/9})$ and $h_d = o(T^{-1/m_d})$, with $\frac{17}{15}d < m_d \leq \frac{9}{17}(16 + d)$ for fourth-order kernels and $d \in \{p, q\}$

- ▶ **as before, bit of undersmoothing**
- ▶ **but no dimensionality constraints**

Summary of the asymptotic results

- $(p = 1, q = 0)$ extends Ait-Sahalia, Fan and Peng (JASA 2008) in that we control for the nonparametric estimation of the lower-dimensional density
 - $(p = 2, q = 1)$ extends to the local-linear smoothing context Amaro de Matos and Fernandes (JoE 2007)
 - $(p = 3, q \leq 2)$ local linear smoothing with higher-order kernels
 - $(p > 3)$ local linear smoothing does not work and hence one must apply kernel-based estimation
- realized approach \sim no asymptotic impact under weak regularity conditions as long as M grows at a given faster rate than T

Monte Carlo simulations

empirical versus nominal size independent CIR price processes
→ standard in finance
→ integrated variance \sim ARMA(1,1)

sample sizes $M = 144, 288, 576$ (first-step measurement error)
 $T = 200, 400$ (second-step approximation)

implementation second-order Gaussian kernel
adjusted rule-of-thumb bandwidths
scaling factors $(\kappa_b, \kappa_h) \in \{1, 2.5\} \times \{1, 2.5, 5\}$
trimming given by multivariate standard normal

Bootstrap-based critical values

issues nonparametric null rules out parametric and wild bootstraps
quadratic variation does not follow a Markov process
usual nonparametric bootstrap fails due to degeneracy

solution variation of the standard moon bootstrap
→ obviously inefficient, though extremely simple
→ works reasonably well in finite samples

algorithm sample \mathcal{T} out of T daily realized measures by blocks
bandwidths shrink to zero as $\mathcal{T} \rightarrow \infty$

↓ ↓ ↓
as opposed to parametric/wild bootstrap,
bias in the original and bootstrap statistics
do not cancel out

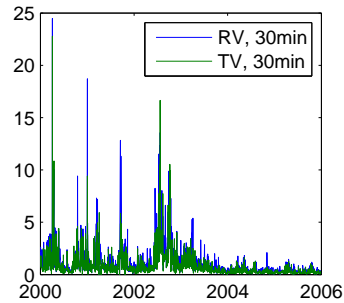
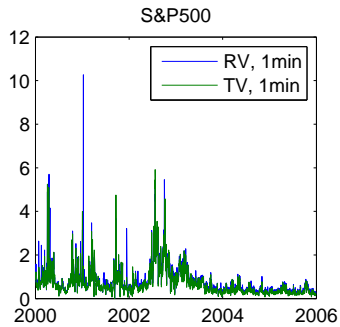
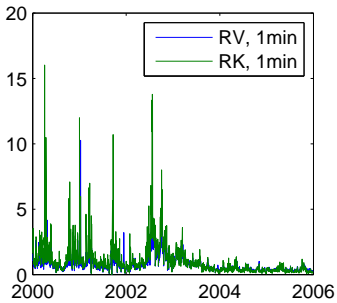
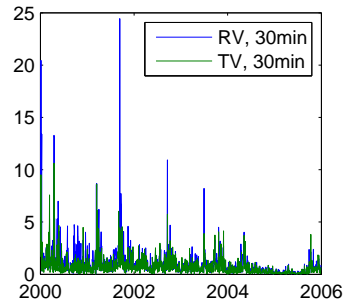
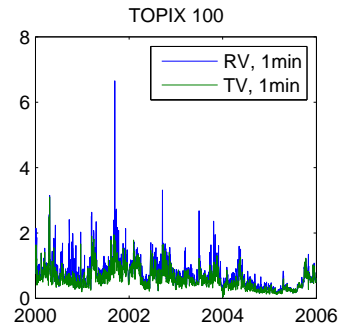
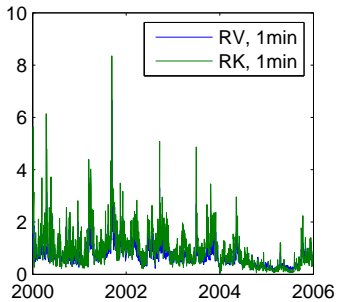
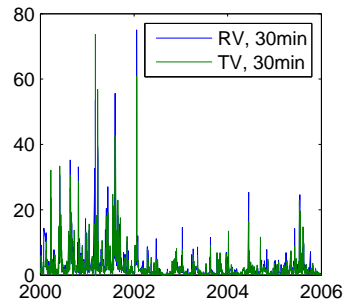
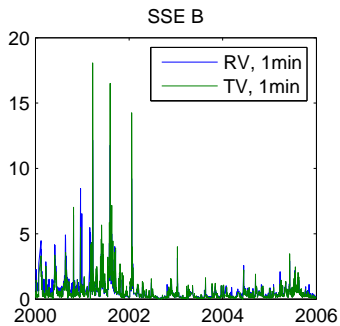
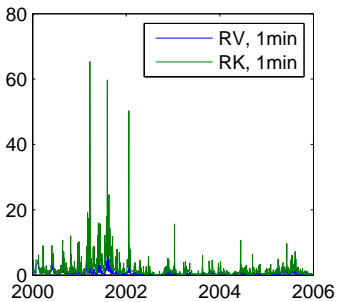
T = 200

(κ_b, κ_h)	$M = 144$		$M = 288$		$M = 576$	
	5%	10%	5%	10%	5%	10%
(1, 1)	0.04	0.06	0.03	0.05	0.03	0.06
(2.5, 1)	0.01	0.03	0.02	0.04	0.02	0.03
(5, 1)	0.01	0.02	0.01	0.03	0.01	0.03
(1, 2.5)	0.01	0.02	0.02	0.03	0.02	0.03
(2.5, 2.5)	0.01	0.03	0.02	0.04	0.02	0.03
(5, 2.5)	0.02	0.04	0.02	0.04	0.02	0.05
(1, 5)	0.06	0.10	0.07	0.10	0.07	0.09
(2.5, 5)	0.12	0.17	0.13	0.19	0.13	0.18
(5, 5)	0.15	0.20	0.17	0.24	0.17	0.22

Volatility transmission between China, Japan and US

previous literature	mainly about Japan, UK, and US
motivation	China is also a big player now no access to LSE transactions data
stock markets	SSE B Share index (USD) Topix 100 index (JPY) S&P 500 index (USD)
sample period	January 3, 2000 to December 30, 2005
source	Reuters database (www.sirca.org)
preliminary results	China indeed seems to matter, especially if controlling for jumps and microstructure noise

	S&P 500	Topix 100	SSE B share
sampling frequency: 1 minute			
mean	-0.0001	-0.0003	-0.0004
standard deviation	0.0448	0.0531	0.0525
minimum	-1.9020	-1.4095	-1.5255
maximum	1.5562	1.0710	2.3179
skewness	-0.1149	0.0429	0.9108
kurtosis	34.4874	21.4390	58.9127
zero returns	3.58%	5.57%	19.39%
sampling frequency: 30 minutes			
mean	-0.0014	-0.0084	-0.0098
standard deviation	0.2910	0.3170	0.5516
minimum	-3.3035	-4.8155	-6.4782
maximum	3.9838	3.5572	5.0368
skewness	0.0459	-0.2314	0.0450
kurtosis	13.1125	14.6988	15.3793
zero returns	1.72%	1.04%	2.51%



Interpretation of realized measures

realized variance
using 1-minute and
5-minute returns

tripower variation
using 1-minute and
5-minute returns

quadratic
variation

\approx

integrated
variance

+

jump
component

+

microstructure
noise

tripower variation
using 15-minute
and 30-minute
returns

realized variance using
15-minute and 30-minute
returns as well as two-scale
and realized kernel
approaches

	RV	TV	TS	RK
Topix 100 index				
1 minute	0.038	0.020	0.050	0.008
5 minutes	0.160	0.224	0.252	0.124
15 minutes	0.010	0.116		
30 minutes	0.014	0.084		
Topix 100 index + VIX index				
1 minute	0.032	0.052	0.234	0.196
5 minutes	0.182	0.208	0.252	0.184
15 minutes	0.036	0.136		
30 minutes	0.046	0.098		
SSE B share index				
1 minute	0.480	0.116	0.028	0.026
5 minutes	0.842	0.250	0.034	0.190
15 minutes	0.010	0.408		
30 minutes	0.008	0.274		
SSE B share index + VIX index				
1 minute	0.546	0.578	0.250	0.216
5 minutes	0.258	0.236	0.094	0.210
15 minutes	0.030	0.104		
30 minutes	0.208	0.106		

	RV	TV	TS	RK
Topix 100 index				
1 minute	0.002	0.004	0.042	0.052
5 minutes	0.068	0.056	0.368	0.156
15 minutes	0.100	0.182		
30 minutes	0.158	0.240		
Topix 100 index + S&P 500 index				
1 minute	0.020	0.016	0.948	0.380
5 minutes	0.950	0.268	0.202	0.156
15 minutes	0.070	0.428		
30 minutes	0.114	0.724		
SSE B share index				
1 minute	0.074	0.128	0.082	0.064
5 minutes	0.066	0.044	0.254	0.110
15 minutes	0.088	0.170		
30 minutes	0.146	0.098		
SSE B share index + S&P 500 index				
1 minute	0.864	0.792	0.780	0.832
5 minutes	0.788	0.610	0.072	0.728
15 minutes	0.050	0.268		
30 minutes	0.082	0.042		

	RV	TV	TS	RK
Panel A: Transmission to Topix 100 index				
S&P 500 index				
1 minute	0.004	0.016	0.108	0.032
5 minutes	0.046	0.124	0.074	0.052
15 minutes	0.016	0.144		
30 minutes	0.014	0.180		
SSE B share index				
1 minute	0.010	0.022	0.152	0.028
5 minutes	0.160	0.126	0.426	0.026
15 minutes	0.204	0.996		
30 minutes	0.282	0.076		
Panel B: Transmission to SSE B share index				
S&P 500 index				
1 minute	0.238	0.122	0.480	0.144
5 minutes	0.132	0.358	0.122	0.284
15 minutes	0.948	0.274		
30 minutes	0.908	0.774		
Topix 100 index				
1 minute	0.010	0.028	0.370	0.248
5 minutes	0.330	0.138	0.410	0.374
15 minutes	0.288	0.054		
30 minutes	0.756	0.828		

Hourly volatility transmission

We report the outcome of the bootstrap test for conditional independence using the following hourly realized measures based on 1-minute returns: realized variance (RV), tripower variation (TV), two-scale realized variance (TS), and realized kernel (RK). We first standardize the logarithm of the data by their mean and standard deviation and then estimate the conditional densities by means of local linear smoothing with Gaussian-type kernels and scaling factors set to $\kappa_b = \kappa_h = 5/2$. As per the trimming function, we employ a standard multivariate normal density. To obtain critical values, we construct $B = 500$ bootstrap artificial samples of size $\mathcal{T} = \lfloor T^{.65} \rfloor$ by resampling blocks of $\lfloor \mathcal{T}^{1/4} \rfloor$ daily observations.

	RV	TV	TS	RK
Panel A: Transmission to the S&P 500 index				
Topix 100 index	0.070	0.092	0.098	0.078
SSE B share index	0.290	0.528	0.686	0.784
Panel B: Transmission to the Topix 100 index				
S&P 500 index	0.178	0.082	0.116	0.130
SSE B share index	0.114	0.082	0.046	0.132
Panel C: Transmission to the SSE B share index				
S&P 500 index	0.592	0.996	0.510	0.906
Topix 100 index	0.154	0.130	0.070	0.358

Summary of empirical results

- ▶ primary channel of bidirectional transmission between **China** and **Japan** consists of **volatility spillovers**
- ▶ **China** affects the **S&P 500 index** and the **VIX index** mainly through **price jumps**, whereas we observe no transmission running from **US** to **China**
- ▶ transmission between **Japan** and **US** is mainly through **price jumps**, though there is also some weak evidence of **volatility spillovers** from **Japan** to **US**

robustness analysis

different realized measures, including or not lunch breaks

reaction time → no link between China and US

volatility jumps from China/US to Japan

Concluding remarks

▶ theoretical contribution

- ▷ dimensionality issues in testing for conditional independence
- ▷ how to account for the first-step estimation error

▶ international market links

- ▷ different channels of transmission within quadratic variation
- ▷ China spillovers to Japan/US are stronger than vice-versa
- ▷ links matter in that the VIX index prices their effects

▶ future research

- ▷ noncausality in jumps (without testing for jumps!!)
- ▷ applications confirm the interpretation of our results
link between S&P 500 index and VIX index
intra- and inter-sectorial transmission