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ECONOMETRIC ANALYSIS OF THE RISK TRANSFER IN CAPITAL MARKETS. THE CASE OF CHINA [1]

The problem of risk transferring is well known in empirical finance. Agents often try to transmit their risk from one market to another when the limit values of their potential losses are being approached or exceeded. The purpose of the paper is to find out whether the Chinese financial markets in the last decade were a source or the result of the risk. Much attention has been paid to the period of the last financial crisis. One of the important findings is that the risk, generated locally, is transmitted via sequent markets to the absorbing one. This process may last up to 40 trading days. To detect whether the risk was transmitted between two markets or not, the Granger causality tests have been applied in connection with the causality in variance as well as causality in risk. Such empirical characteristics as the value at risk and expected shortfall are considered.

Keywords: financial markets, expected shortfall, Granger causality, risk transfer, value at risk.

JEL: C58, G15, O53.

1. INTRODUCTION

The processes observed in the Chinese capital market have attracted the great interest of investors as well as researchers in recent years. Numerous literature has been published including reports (*Preliminary Report…*, 2009), guides (Neftci and Menager-Xu, 2006), scientific analyses (Lim, Habibullah and Hinich, 2009; Osinska and Zdanowicz, 2011) and popular writings (Malkiel and Taylor, 2008). Since the beginning of the 21st century, two important stock exchanges in Shanghai and in Shenzhen have been participating in international competition becoming an important part of the global capital market. In the early 1990s, the Chinese capital market was closed to foreign investors. The restructuring process in China began in 1999 with the reform of nontradable shares. Chinese membership in the WTO

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(since 2001) caused the opening up of the security industry. Foreign securities firms have been allowed to operate directly in B share business and their representative offices in China could become Special Members of Chinese Stock Exchanges. Further steps of opening up are related with the overseas listings of H shares and new regulations concerning public offerings of securities. The Chinese authorities supported eligible companies to list their shares in Hong Kong, Singapore and even in New York or in London. Nowadays shares of the same enterprise are quoted in domestic market and overseas, however, the total number of such cases was only 125 in 2006 (Neftci and Menager-Xu, 2006).

The brisk expansion of the Chinese economy and its financial markets in the last decade was the reason of the analysis of this phenomenon from different viewpoints. Two key questions were put forward by researchers. The first one was about the reasons for the rapid growth rate of the economy with an average 9.3 percent rate of growth for over 20 years. The second question was related to the process of globalization and the impact of the financial crisis of 2007-2009 on the state and development of the Chinese economy. Our research is partially related to the second problem.

In the paper we focus on the risk spread among 18 currencies as well as 33 stock markets represented by the stock indices. We took into consideration the period between 2006 and 2011 and examined relations between pairs of series observed at currency as well as stock markets always taking the time series from China on one side of the relation and the remained series on the other one. Since the last financial crisis began in the USA in 2007, its results were observable at other markets, including Chinese, in mid-2008. Therefore we divided the sample into two sub-samples to show the impact of the financial crisis and its implications on the speed and direction of the risk diffusion.

Hong (2001) and Hong et al. (2009) introduced a new concept of the Granger causality in risk between two time series using the tail probabilities or equivalently, the Value at Risk. It is not very popular yet but some applications can be found (Lee et al., 2009). We propose to extend the scope of application of the test to the Expected Shortfall. The aim of the paper is to test whether the violation of the risk measures in one region causes similar reactions in other regions in the sense of the Granger causality. The answers to the following questions are expected:

1. Is the Chinese market a source or a result of the risk?
2. How fast is the risk spread all over the world?

We concentrated our attention on Chinese financial processes and their relations with those in the rest of the world. We hypothesize that Chinese financial processes can be perceived as the result of the global risk due to the administrative and economic regulations imposed by the authorities. Following the results obtained by Lim et al. (2009) we assumed the informational market efficiency in the long run.

The problem of contagion in the financial markets including China was discussed using various methods in: Pericoli and Sbraccia (2001), Dungey et al. (2003), Wang and Lee (2009), Weber (2010). We chose the Granger causality methodology because it includes the contagion concept by additionally allowing to indicate relations between markets while taking into account three perspectives. The relations that occur between conditional means of the processes under study are expected to last for a longer time than the corresponding relations between conditional variances. On the other hand, the transfer of financial capital shows that the risk is observed all over the world in different periods.

2. THE CHINESE STOCK MARKET – AN OVERVIEW

The Chinese stock market is organized in two well-developed national stock exchanges. These are the Shanghai Stock Exchange and the Shenzhen Stock Exchange. The China Securities Regulatory Commission (CSRC) permits companies' shares to the market that is divided into two parts: the A and B share market. A shares are the common shares issued by companies registered in mainland China and denominated in Chinese currency. B shares are denominated in Chinese yuan but offered and traded in foreign currencies. Since 1992, B shares have been traded on both stock exchanges, in Shanghai they are offered in U.S. dollars and in Shenzhen – H.K. dollars. The third type of Chinese stocks is H share. Those are shares issued by Chinese enterprises and quoted abroad, mainly in Hong Kong but also in the USA. It is important that these three types of shares, denominated in different currencies, coexist in different segments of the market and may be issued by the same enterprises allowing for arbitrage transactions. This is one reason for market inefficiency. Another comes from the asymmetrical information between managers of listed companies and outside investors that in China is a common practice (Wentao, 2006). B and H shares allowed the inclusion of the Chinese stock market into the internationalization process. Before 2001, only foreign investors could operate in the B shares market,

while since 2001, it has been opened for domestic citizens, too (Neftci, Menager-Xu, 2006).

Although the Chinese capital market is still controlled by supervising institutions designated by the government, it serves for companies and money investment just as in the open economies in the world. Controlling the Chinese currency prevents the economy from external shocks however gains from investment abroad denominated mainly in US dollar are transformed into CNY (Chinese Yuan) and invested in the shares quoted in the A market. Further reading on the role of financial market in China can be found, for example, in Chen et al. (2010). In the paper we show the China stock exchange is partially included into the global processes.

The scale of the market development is related to the number of shares and the market capitalization. At the end of 2009, the Shanghai Stock Exchange had a total of 870 listed companies and 1,351 listed securities with CNY 18,465.523 billion market capitalization and 89.6543 million trading accounts.By 30 June 2010, the Shenzhen Stock Exchange was home to 1,012 listed companies, with 485 on the main board, 437 on the SME (Small and Medium Enterprises) board and 90 in the ChiNext market. The total market capitalization was valued at CNY 5.6 trillion (US$828.7 billion).

The dynamics of the Shanghai Stock Exchange (SSE) expressed in terms of the number of accounts in the period 1991-2009 is illustrated in Figure 1.

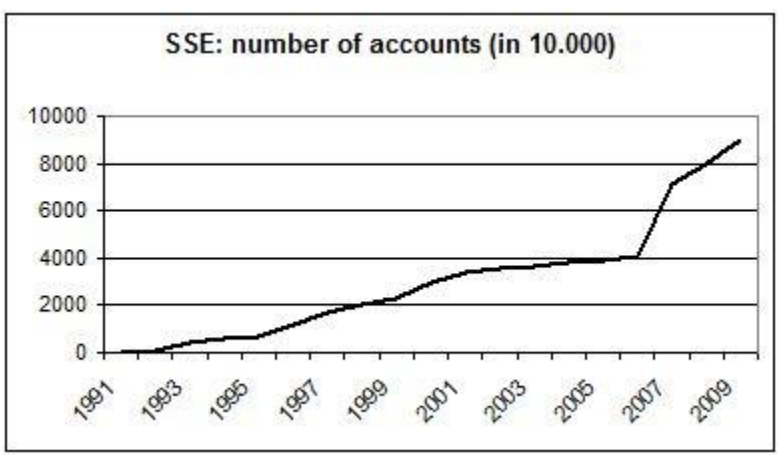

Figure 1. Dynamics of SSE in 1991-2009

Source: data from http://www.sse.com.cn/sseportal/en_us/ps/home.shtml.

The structure of the accounts' ownership in the Shanghai Stock Exchange is illustrated in Figure 2.

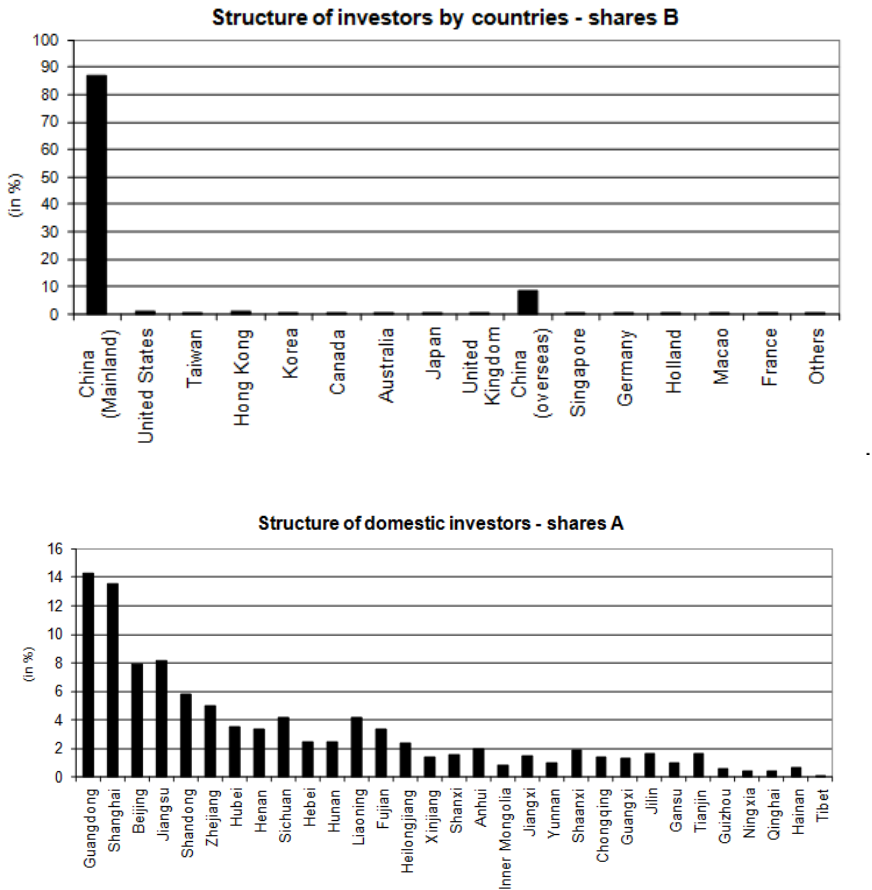

Figure 2. The structure of investors at SSE in 2009

Source: data are downloaded from http://www.sse.com.cn/sseportal/en_us/ps/home.shtml.

It can be seen that the progress of internationalization of the SSE is rather slow because 87 percent of investors' accounts belong to investors from mainland China, 8.5 percent are owned by Chinese overseas investors and 1.13 percent by the citizens of Hong Kong. The next biggest share of 0.87 percent concerns the accounts belonging to investors from the United Stated of America.

3. TESTING FOR THE GRANGER CAUSALITY IN RISK

The concept of the Granger causality was often criticized as depreciating the philosophical concept of causality, but is widely known and popular in econometric literature. In fact, Granger's definition is related with the predictability of one variable using the previous values of another one. Such an approach takes into consideration only one of many characteristics of causal relation, however in practice it is often the unique possibility of measuring interdependencies between variables. This is especially important when causality in conditional variance is considered. The number of factors that cause price volatility in financial markets is big; moreover they change in time and occur only in some periods such as they cannot be observed systematically. Their nature is also very complicated, starting from fundamental causes coming from the company itself, through macroeconomic ones ending at those of a social and psychological background. However the results they cause are very important, observable and spread all over the world. A very similar situation takes place in the case of the Granger causality in risk, where specified risk measures are applied. The causes, which evoke the failure of the risk measures such as value at risk, are rarely of a systematic nature. So if such an increase in risk occurs in one market it is very likely to be moved to another one. This is due to the risk-selling procedure realized by many market participants including banks. Avoiding the risk by closing positions and moving financial capital from one market to another are the main characteristics of such a situation. It changes the liquidity preference in the markets that cannot be avoided without intervention. Such a situation is called the contagion phenomenon (Allen and Gale, 2000).

Despite the above limitations, the original definition of the Granger causality was extended for the conditional variances (Cheung and Ng, 1996) and further for the risk measures (Hong, 2001). This refers to the original Granger's definition in terms of probability, however the meaning did not change.

The Granger causality in risk is defined as follows (Hong, 2001). Let $\{Y_{1t}, Y_{2t}\}$ be a bivariate, not necessarily stationary, stochastic time series. Let $A_{lt} = A_{lt}\left(I_{l(t-1)}\right)$ $l = 1,2$ be the VaR at level $\alpha \in (0;1)$ for Y_{lt} predicted using the information set $I_{l(t-1)} = \{Y_{l(t-1)}, Y_{l(t-2)} \ldots, Y_{l1}\}$ available at time t-1. A_{lt} satisfies $P\left(Y_{lt} < A_{lt} \mid I_{l(t-1)}\right) = \alpha$ for a long position. In the case of the Granger non-causality, the null hypothesis is:

$$H_0: \quad P\left(Y_{1t} < A_{1t} \mid I_{1,(t-1)}\right) = P\left(Y_{1t} < A_{1t} \mid I_{t-1}\right) \text{almost surely} \tag{1}$$

where $I_{t-1} = \left\{I_{1(t-1)}, I_{2(t-1)} \ldots\right\}$ with the alternative

$$H_1: \quad P\left(Y_{1t} < A_{1t} \mid I_{1(t-1)}\right) \neq P\left(Y_{1t} < A_{1t} \mid I_{t-1}\right) \tag{2}$$

Comparing the above definition with the original one we may state that it concentrates only on the violations of VaR's computed for a given portfolio represented by Y_{1t}. So we interpret it as if information about the second portfolio represented by Y_{2t} could help change the probability of breaking the VaR. The definition captures the general characteristics of the Granger causality concept.

The testing idea derived by Hong (2001) and modified by Hong et al. (2009) is based on the cross-spectral density of a bivariate covariance stationary process V_{1t} and V_{2t}, where $V_{lt} = I\left(Y_{lt} < -A_{lt}\right) l = 1,2$ denotes the VaR break indicator. The break indicator takes the value 1 when VaR is exceeded by loss and takes the value 0 otherwise.

The corresponding hypotheses can be transformed into the expected value level:

$$H_0: \quad E\left(V_{1t} \mid I_{1(t-1)}\right) = E\left(V_{1t} \mid I_{t-1}\right) \text{almost surely} \tag{3}$$

$$H_1: \quad E\left(V_{1t} \mid I_{1(t-1)}\right) \neq E\left(V_{1t} \mid I_{t-1}\right). \tag{4}$$

For unidirectional causality, the test statistic takes the form:

$$Q_1(M) = \left[T\sum_{j=1}^{T-1} k^2(j;M)\hat{\rho}(j)^2 - C_{1T}(M)\right] / D_{1T}(M)^{1/2} \tag{5}$$

where:

$$\sum_{j=1}^{T-1} k^2(j;M)\hat{\rho}(j)^2 = 2\pi \int_{-\pi}^{\pi} \left|\hat{f}(\omega) - \hat{f}_l^{\,0}(\omega)\right|^2 d\omega \tag{6}$$

$\hat{f}(\omega)$ and $\hat{f}_i^{\,0}(\omega)$ are both estimators of the cross–spectral densities, the former is the examined cross-spectrum and the latter is the cross-spectrum that corresponds to the null, $C_{1T}(M)$ and $D_{1T}(M)$ are the mean and the variance of the quadratic form, respectively. $k(j/M)$ is the kernel function. In this paper we used Bartlett's kernel.

As was emphasized by Hong et al. (2009) the test statistic does not test exactly the null but its necessary condition that allows for capturing the most important information.

There exists an analog for bidirectional causality concept denoted by $Q_2(M)$.

The VaR concept is not the only one possible to be used for testing. We proposed to use the expected shortfall measure to verify the hypotheses (3)-(4), where the expected shortfall (ES) is defined as:

$$ES_\alpha = -\frac{1}{\alpha}\int_0^\alpha q_p \mathrm{d}p \tag{7}$$

i.e. the average loss under condition that VaR is exceeded (Artzner et al., 1998). The results obtained for the ES should be considered as stronger than those computed for the VaR because the ES denoted the situation when VaR was already exceeded. Then we propose to modify the following. Denote a bivariate covariance stationary process by ES_{1t} and ES_{2t}, where

$ES_{lt} = I(Y_{lt} \mid Y_{lt} < A_{lt})l$ = 1,2 denotes the ES break indicator. The hypotheses to be tested are

$$H_0: \quad E\left(ES_{1t} \mid I_{1(t-1)}\right) = E\left(ES_{1t} \mid I_{t-1}\right) \text{ almost surely} \tag{8}$$

$$H_1: \quad E\left(ES_{1t} \mid I_{1(t-1)}\right) \neq E\left(ES_{1t} \mid I_{t-1}\right). \tag{9}$$

The test statistics as well as its characteristics remain the same because the expected shortfall does not contradict the VaR.

4. EMPIRICAL ANALYSIS

The subject of our research was concentrated on the time series of 33 stock exchange indices from all over the world including the Shanghai Stock Exchange Composite Index and 18 currencies exchange rates against the U.S. dollar including the Chinese yuan. Daily observations from 1 February 2006 to 18 February 2011 were taken into account. They were divided into two groups: before the financial crisis from 1 February 2006 to 31 July 2008 and during and after the crisis from 1 August 2008 to 18 February 2011. Our sample was limited to such a time span due to the availability of the data for all indices and exchange rates. All the data were transformed to logarithmic rates of return $r_t = 100 * (\ln(P_t) - \ln(P_{t-1}))$. The SSE index and the CNY/USD exchange rate observed within the analyzed period are presented in Figure 3.

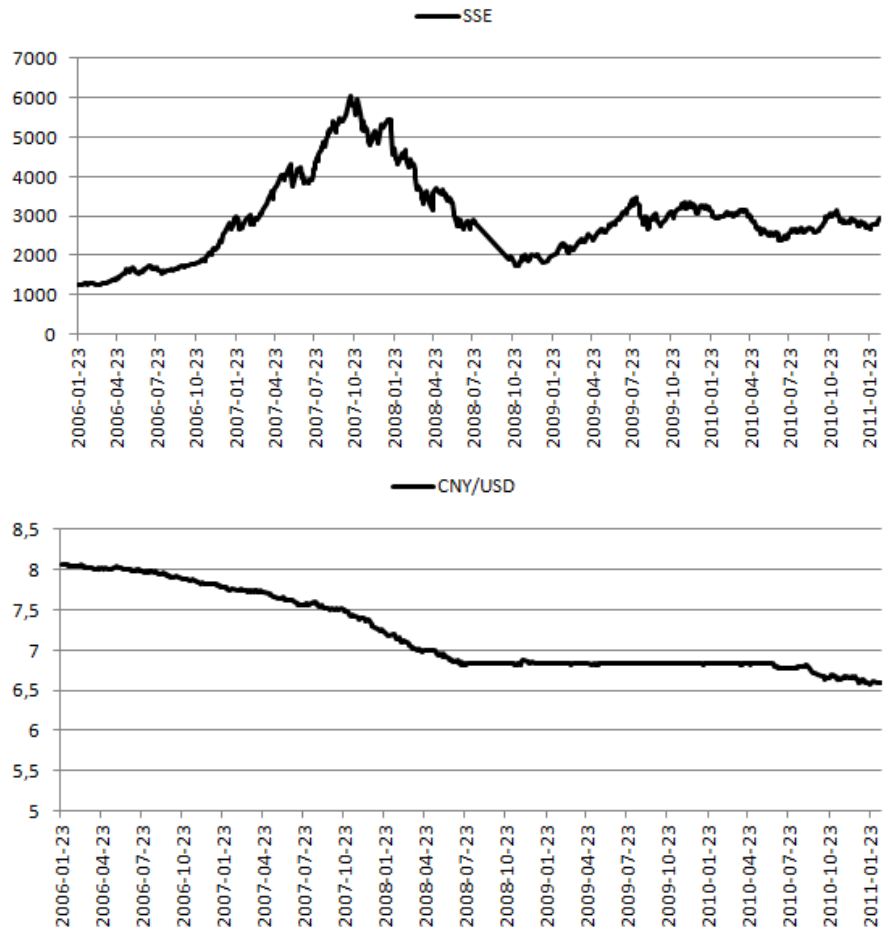

Figure 3. The observations of SSE index and CNY/USD exchange rate from 1 February 2006 to 18 February 2011

Source: data are downloaded from http://www.sse.com.cn/sseportal/en_us/ps/home.shtml.

4.1. The research methodology

We projected our research in a complex way. We tested for the Granger causality in three different aspects. We have defined systematic causality, informational causality and causality in risk. In financial markets systematic causality is not the main one; it covers approximately less than 50 percent of

the observed daily price changes. The informational causality is the most important because it influences the investors' decisions very fast and often many times during the trading day. Causality in risk is related to the previous one but, taking into account the number of violations of the risk measures, it does not occur very often, however its consequences are very strong. First of all, the systematic causality, represented by the conditional expected values of the processes under consideration, was tested. The conditional mean was defined by the autoregressive model with the GARCH error

$$Y_{lt} = \psi_{l0} + \psi_l(L)Y_{lt} + \sqrt{h_{Y_{lt}}}\,\zeta_{lt} \text{ for } l = 1,2, \tag{10}$$

where: ζ_{lt}, l = 1,2 are normally distributed white noises, $\psi_l(L) = \sum_{i=1}^{q} \psi_{li} L^i$, l = 1,2 are polynomial autoregressive operators in the models describing the conditional means of the time series under study, $h_{Y_{lt}}$, l = 1,2 denote conditional variances of the corresponding time series.

In the second step the informational causality, represented by the conditional variance, was tested. The univariate and multivariate GARCH models were used.

The GARCH(1,1) representation of the conditional variances was used:

$$h_{Y_{lt}} = \gamma_{l0} + \gamma_{l1}\xi_{l,t-1}^2 + \delta_{l1}h_{Y_{l,t-1}}, \text{ for } l = 1,2, \tag{11}$$

where: $\xi_{lt} = \sqrt{h_{Y_{lt}}}\,\zeta_{lt}$, l = 1,2. Two error distributions: Gaussian and t-Student were taken into account.

For the multivariate GARCH, the BEKK representation with the same error distributions was assumed (Baba et al., 1990)

$$H_t = C^{*'}C^* + \sum_{k=1}^{K}\sum_{i=1}^{S} D_{ik}^{*'}\varepsilon_{t-i}\varepsilon_{t-i}^{'}D_{ik}^{*} + \sum_{k=1}^{K}\sum_{j=1}^{Q} E_{jk}^{*'}H_{t-j}E_{jk}^{*} \tag{12}$$

where: C^*, D_{ik}^* and E_{ik}^* are $N \times N$ matrices.

In the last step, the causality in risk described in section 3 was examined using both the VaR and ES measures. The details concerning the successive steps of the research are summarized in Table 1.

In each step, the following pair of corresponding hypotheses was used:

H_0: Chinese financial processes do not Granger-cause financial processes in other countries

H_1 : Chinese financial processes do Granger-cause financial processes in other countries.

The opposite direction of causality was also checked. The hypotheses were modified with respect to the tests applied.

Table 1

The successive steps of the Granger causality testing between Chinese financial time series and the rest of the world

Step	Method
Estimating ARMA representation for return series	Maximum Likelihood method
Testing in causality in mean	Pierce and Haugh (1977); PH hereafter
Estimating univariate GARCH models (Gauss, t-Stud)	Maximum Likelihood method
Testing for causality in variance	Cheung and Ng (1996); S hereafter
Estimating bivariate GARCH models (Gauss, t-Stud)	Maximum Likelihood method
Testing for causality in variance	Caporale, Pittis and Spagnolo, (2002); CPS hereafter Hafner and Herwatz (2004); HH hereafter
Estimating VaR using GARCH-t(1,1)	Maximum Likelihood method
Testing causality in risk	Hong et al. (2009)
Estimating expected shortfall using GARCH-t(1,1)	Maximum Likelihood method
Testing causality in risk	Hong et al. (2009)

Source: own study

4.2. Systematic and informational causality in the Granger sense – the results of testing

As was already mentioned above, we considered the Granger causality in the conditional mean as the systematic one, i.e. repeatable in the same situations that occur in the market. This is examined here with the Pierce and Haugh test (1977). A similar relation measured in terms of the conditional variance is called the informational causality. This is due to the fact that the variance clusters after the package of information is published and moreover, the uncertainty increases when the negative information is issued. This kind of relation is verified using Cheung and Ng (for univariate GARCH models) and Caporale et al. (2002) as well as Hafner and Herwatz (2004) (for BEKK models) tests. The testing results were very similar despite the assumption about the error distributions in GARCH models –that is why the results presented below correspond to the Student error distribution. Osinska (2008)

has shown that the Cheung and Ng test is not sensitive for t-Student error distribution unless the number of degrees of freedom is not less than 8.

The test results informing about the relations between the Chinese stock and currency markets and the leading markets from different parts of the world were organized in tables and maps. In Tables 2-5, the results of testing for the Granger causality in the conditional mean and in the conditional variance are presented. The full list of time series used in the research is given in the appendix.

Table 2

Results of causality testing for the relation between CNY/USD and the stock markets (percentage of rejection the null hypothesis at 5% significance level is shown)

Lag\test	Panel A: Granger causality in conditional mean and conditional variance – the whole sample						Panel B: Granger causality in conditional mean and conditional variance – before the crisis						Panel C: Granger causality in conditional mean and conditional variance – during the crisis and after					
	PH1	PH2	PH3	S1	S2	S3	PH1	PH2	PH3	S1	S2	S3	PH1	PH2	PH3	S1	S2	S3
1	6%	12%	18%	35%	6%	29%	12%	48%	64%	39%	15%	42%	18%	0%	56%	6%	0%	3%
2	12%	3%	12%	32%	24%	35%	9%	55%	82%	39%	39%	61%	18%	0%	29%	3%	0%	0%
3	9%	3%	6%	29%	24%	35%	12%	58%	58%	36%	33%	52%	18%	0%	9%	3%	0%	0%
4	3%	9%	6%	26%	32%	35%	6%	52%	61%	36%	58%	64%	12%	0%	6%	3%	0%	0%
5	12%	6%	12%	26%	50%	59%	21%	33%	64%	36%	70%	70%	12%	0%	12%	6%	18%	15%
6	18%	12%	12%	24%	44%	59%	18%	55%	67%	33%	67%	61%	9%	0%	18%	3%	15%	3%
Test	CPS1	CPS2	CPS3	HH1	HH2	HH3	CPS1	CPS2	CPS3	HH1	HH2	HH3	CPS1	CPS2	CPS3	HH1	HH2	HH3
	50%	3%	21%	88%	0%	88%	79%	55%	85%	103%	3%	103%	3%	12%	9%	41%	3%	44%

Notes: H_0: The CNY/USD does not Granger-cause the stock indices – (PH1, S1, CPS1, HH1)

H_0: The stock indices do not Granger-cause the CNY/USD – (PH2, S2, CPS2, HH2)

H_0: Bi-directional causality does not exist – (PH3, S3, CPS3, HH3)

Source: own computations

Table 3

Results of causality testing for the relation between CNY/USD and the currency markets (percentage of rejection the null hypothesis at 5% significance level is shown)

Lag\test	Panel A: Granger causality in conditional mean and conditional variance – the whole sample						Panel B: Granger causality in conditional mean and conditional variance – before the crisis						Panel C: Granger causality in conditional mean and conditional variance – during the crisis and after					
	PH1	PH2	PH3	S1	S2	S3	PH1	PH2	PH3	S1	S2	S3	PH1	PH2	PH3	S1	S2	S3
1	11%	67%	94%	0%	17%	6%	0%	83%	78%	0%	39%	17%	11%	67%	83%	0%	6%	11%
2	11%	67%	94%	0%	11%	6%	0%	83%	78%	0%	28%	17%	6%	61%	83%	0%	6%	11%
3	6%	72%	94%	0%	11%	6%	0%	83%	78%	0%	17%	11%	11%	61%	78%	0%	6%	6%
4	6%	67%	94%	0%	28%	28%	0%	83%	78%	0%	39%	39%	11%	50%	83%	0%	17%	11%
5	11%	56%	89%	0%	39%	22%	0%	78%	78%	0%	44%	39%	11%	50%	83%	0%	22%	22%
6	11%	56%	89%	0%	39%	17%	0%	78%	72%	0%	44%	39%	6%	56%	83%	0%	22%	17%
Test	CPS1	CPS2	CPS3	HH1	HH2	HH3	CPS1	CPS2	CPS3	HH1	HH2	HH3	CPS1	CPS2	CPS3	HH1	HH2	HH3
	6%	11%	17%	11%	0%	11%	28%	56%	67%	72%	0%	72%	22%	44%	56%	22%	0%	22%

Notes: H_0: The CNY/USD does not Granger-cause the currency exchange rates – (PH1, S1, CPS1, HH1)

H_0: The currency exchange rates do not Granger-cause the CNY/USD – (PH2, S2, CPS2, HH2)

H_0: Bi-directional causality does not exist – (PH3, S3, CPS3, HH3)

Source: own computations

The results of the Granger causality analysis differ across the tests applied as well as the number of lags. The general view is that relations in the whole sample were weaker than the same relations in the period since 1 August 2008 – the approximate date of symptoms of the global crisis. A greater uncertainty in the global market implies more frequent movements in the market and more volatility. Two-way Granger causality is most often the case as it consolidates one-way impacts from both sides.

Table 4

Results of causality testing for the relation between Shanghai Stock Exchange and the stock markets (percentage of rejection the null hypothesis at 5% significance level is shown)

Lag\test	Panel A: Granger causality in conditional mean and conditional variance – the whole sample						Panel B: Granger causality in conditional mean and conditional variance – before the crisis						Panel C: Granger causality in conditional mean and conditional variance – during the crisis and after					
	PH1	PH2	PH3	S1	S2	S3	PH1	PH2	PH3	S1	S2	S3	PH1	PH2	PH3	S1	S2	S3
1	33%	58%	100%	55%	39%	97%	12%	64%	100%	52%	24%	97%	33%	45%	100%	12%	15%	79%
2	30%	55%	100%	61%	36%	97%	12%	58%	97%	48%	21%	97%	33%	39%	100%	39%	15%	76%
3	30%	55%	100%	61%	33%	94%	9%	55%	97%	45%	18%	94%	30%	39%	100%	36%	12%	73%
4	30%	64%	100%	58%	27%	91%	3%	61%	97%	45%	18%	94%	27%	42%	100%	24%	12%	67%
5	39%	61%	100%	61%	30%	91%	15%	55%	94%	48%	21%	94%	33%	39%	100%	24%	12%	67%
6	39%	58%	100%	58%	33%	94%	12%	48%	85%	48%	21%	94%	27%	39%	100%	24%	15%	67%
Test	CPS1	CPS2	CPS3	HH1	HH2	HH3	CPS1	CPS2	CPS3	HH1	HH2	HH3	CPS1	CPS2	CPS3	HH1	HH2	HH3
	45%	15%	36%	0%	0%	0%	79%	52%	82%	0%	6%	0%	55%	73%	67%	30%	9%	33%

Notes: H_0: The SSE does not Granger- cause the stock indices – (PH1, S1, CPS1, HH1)

H_0: The stock indices do not Granger- cause the SSE – (PH2, S2, CPS2, HH2)

H_0: Bi-directional causality does not exist – (PH3, S3, CPS3, HH3)

Source: own computations

The exchange rate of CNY against the US dollar had some impact on the stock market while the opposite influence did not occur. CNY is not a global currency. That is why it absorbed external movements concerning both the conditional mean and the conditional variance although it was strongly pegged against the US dollar. As a result, the 'official' exchange rate of CNY/USD decreased. On the other hand, the stock market should be considered as a global one and SSE is one of its elements irrespective of the period considered.

Table 5

Results of causality testing for the relation between Shanghai Stock Exchange and the currency markets (percentage of rejection the null hypothesis at 5% significance level is shown)

Lag\test	Panel A: Granger causality in conditional mean and conditional variance – the whole sample						Panel B: Granger causality in conditional mean and conditional variance – before the crisis						Panel C: Granger causality in conditional mean and conditional variance – during the crisis and after					
	PH1	PH2	PH3	S1	S2	S3	PH1	PH2	PH3	S1	S2	S3	PH1	PH2	PH3	S1	S2	S3
1	26%	42%	84%	16%	11%	53%	12%	64%	100%	52%	24%	97%	21%	53%	95%	16%	11%	21%
2	32%	42%	89%	21%	11%	47%	12%	58%	97%	48%	21%	97%	53%	37%	95%	21%	5%	21%
3	37%	42%	74%	16%	11%	47%	9%	55%	97%	45%	18%	94%	58%	47%	95%	16%	11%	21%
4	37%	42%	79%	16%	11%	37%	3%	61%	97%	45%	18%	94%	53%	47%	95%	11%	16%	21%
5	32%	42%	79%	21%	16%	47%	15%	55%	94%	48%	21%	94%	47%	37%	95%	5%	16%	21%
6	32%	42%	79%	21%	11%	26%	12%	48%	85%	48%	21%	94%	37%	42%	89%	5%	16%	21%
Test	CPS1	CPS2	CPS3	HH1	HH2	HH3	CPS1	CPS2	CPS3	HH1	HH2	HH3	CPS1	CPS2	CPS3	HH1	HH2	HH3
	11%	5%	16%	0%	16%	16%	79%	52%	82%	0%	6%	0%	58%	63%	68%	5%	68%	79%

Notes: H_0: The SSE does not Granger-cause the currency exchange rates – (PH1, S1, CPS1, HH1)

H_0: The currency exchange rates do not Granger-cause the SSE – (PH2, S2, CPS2, HH2)

H_0: Bi-directional causality does not exist – (PH3, S3, CPS3, HH3)

Source: own computations

4.3. Testing for causality in risk

In the last but most important part of the research, we examined the way the risk is transferred from one stock market to another. On the basis of the GARCH models with t-Student error distribution we estimated Value at Risk and Expected Shortfall at 5 percent and 95 percent confidence level. The chosen results for DJIA, HSI and SSE are shown in Figure 4, Figure 5 and Figure 6.

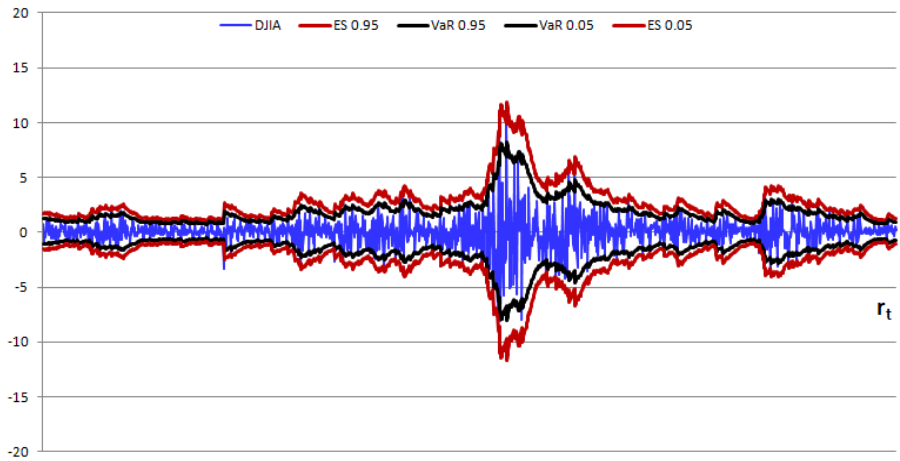

Figure 4. The estimated risk measures for DJIA from 1 February 2006 to18 February 2011

Source: own computations

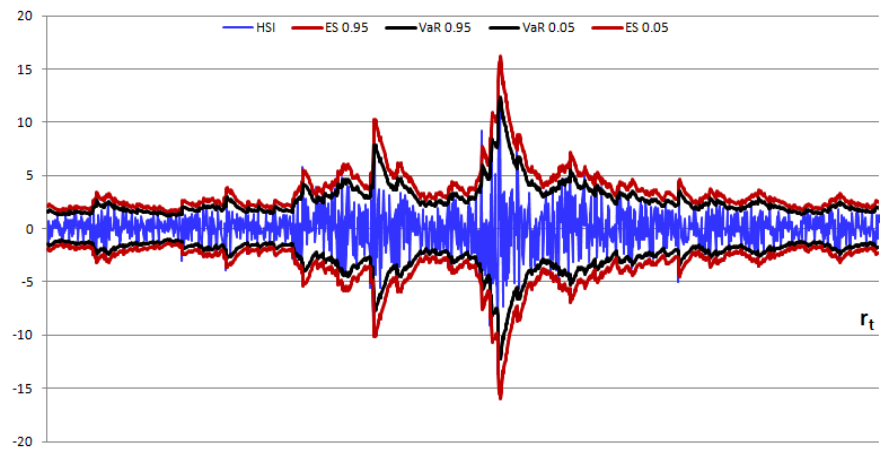

Figure 5. The estimated risk measures for HSI from 1 February 2006 to 18 February 2011

Source: own computations

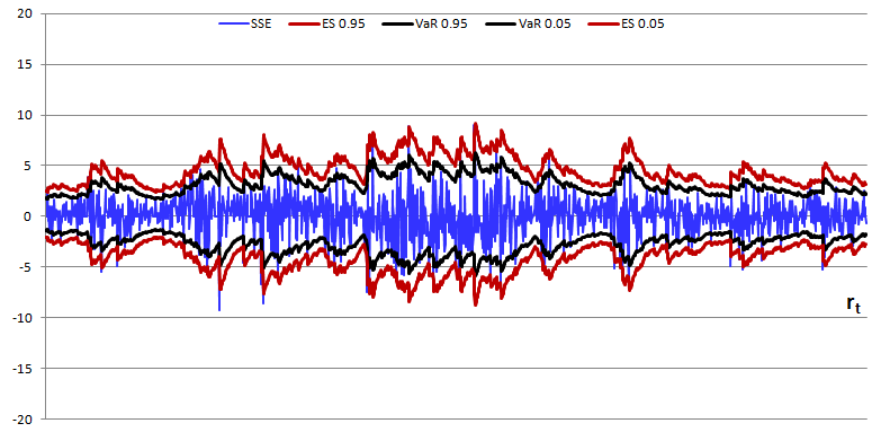

Figure 6. The estimated risk measures for SSE from 1 February 2006 to 18 February 2011
Source: own computations

The dynamics of the risk was similar across the markets although some specific characteristics can be noticed. The range of price changes in the international markets like the NYSE and Hong Kong Stock Exchange was bigger that in the case of the less open and more protected market of the Shanghai Stock Exchange. In the period of the crisis, the changes were bigger than in the other time but the SSE was less sensitive to such changes. It is worth noting that violations of the expected shortfall are less frequent than the VaR breaks. So the results obtained for the ES are much more important for transferring the risk than the results obtained for the VaR. However, both are presented in Tables 6-8. All the results are organized in three panels, with respect to the sample size: the whole sample, the period before the crisis and the period during and after the crisis. In Table 6 the detailed results for testing the Granger causality in risk for HSI and DJIA are shown. One of the important parameters is the lag number M that represents the time delay from the beginning till the end of the risk transfer. The longer the delay, the most often the null hypothesis of the Granger non-causality in risk is rejected. This means that the financial capital moves from one market to another not necessarily in a direct way, so the results of testing for causality in risk cannot only show the direct relations but also the indirect ones.

Table 6

The results of testing for Granger causality in risk for HSI and DJIA (p-values)

Panel A: Granger causality in risk between HSI and DJIA in the whole sample												
Sample: 2-1326	HSI → DJIA				DJIA → HSI				DJIA ←→ HSI			
Risk measure\lag (M)	5	10	20	40	5	10	20	40	5	10	20	40
VaR long	0.00	0.00	0.00	0.00	0.4242	0.0957	0.0752	0.0350	0.00	0.00	0.00	0.,00
VaR short	0.00	0.00	0.00	0.00	0.4213	0.0619	0.0066	0.00	0.00	0.00	0.00	0.00
ES long	0.00	0.00	0.00	0.00	0.3579	0.00	0.2547	0.2457	0.00	0.00	0.00	0.00
ES short	0.5783	0.5760	0.0010	0.00	0.2702	0.0328	0.0033	0.00	0.9055	0.2570	0.0012	0.00
Panel B: Granger causality in risk between HSI and DJIA before the crisis (p-values)												
Sample: 2-658	HSI → DJIA				DJIA → HSI				DJIA ←→ HSI			
Risk measure\lag (M)	5	10	20	40	5	10	20	40	5	10	20	40
VaR long	0.5766	0.6864	0.6024	0.6658	0.5576	0.6419	0.4977	0.3201	0.0370	0.0658	0.1413	0.0425
VaR short	0.3639	0.2662	0.4893	0.8813	0.0010	0.00	0.00	0.0001	0.0003	0.00	0.0001	0.00
ES long	0.2865	0.1244	0.0283	0.3793	0.2865	0.1244	0.6016	0.9427	0.0447	0.0038	0.0079	0.2798
ES short	0.2305	0.1314	0.00	0.00	0.0038	0.0441	0.2763	0.8853	0.1870	0.0034	0.00	0.00
Panel C: Granger causality in risk between HSI and DJIA during the crisis and after (p-values)												
Sample: 659-1326	HSI → DJIA				DJIA → HSI				DJIA ←→ HSI			
Risk measure\lag (M)	5	10	20	40	5	10	20	40	5	10	20	40
VaR long	0.00	0.00	0.00	0,00	0.4242	0.0957	0,0752	0.0350	0,00	0.00	0.00	0.00
VaR short	0.00	0.00	0.00	0,00	0.4213	0.0619	0,0066	0.00	0,00	0.00	0.00	0.00
ES long	0.00	0.00	0.00	0,00	0.3579	0.7266	0,2547	0.2457	0,00	0.00	0.00	0.00
ES short	0.9055	0.5760	0.0010	0,00	0.9055	0.0328	0,0033	0.00	0,4261	0.2570	0.0012	0.00

Source: own computations

The greater the number of intermediaries, the longer delay can be observed. As far as the particular results for HSI and DJIA are concerned, it is important that before the financial crisis the Granger causality in the risk could be observed for 5 percent ES for M=20 and M=40 while during and after the crisis it is commonly accepted. The direction of capital flow is from Hong Kong to the New York Stock Exchange. This refers to both positive (VaR long and ES long) as well as negative impulses. It is also important that the most negative impulses obtained for the ES short are observed only after 20 days, thus it is the period that is necessary for transferring the most

risky capital in both directions from Hong Kong to the USA and from the USA to Hong Kong.

Table 7

The results of testing for Granger causality in risk for SSE index (percentage of rejecting the null hypothesis at 5% significance level is shown)

Panel A: Granger causality in risk between SSE and other stock indices in the whole sample												
	One-way Granger causality								Two-way Granger causality			
Sample: 2-1326	SSE → Indices				Indices → SSE				SSE ←→ Indices			
Risk measure\lag (M)	5	10	20	40	5	10	20	40	5	10	20	40
VaR long	1.9%	1.9%	3.8%	7.5%	5.7%	5.7%	5.7%	7.5%	5.7%	17.0%	20.8%	22.6%
VaR short	52.8%	43.4%	35.8%	28.3%	32.1%	32.1%	22.6%	17.0%	73.6%	7.5%	39.6%	69.8%
ES long	7.5%	5.7%	17.0%	22.6%	13.2%	17.0%	26.4%	34.0%	15.1%	32.1%	41.5%	54.7%
ES short	11.3%	11.3%	11.3%	11.3%	35.8%	32.1%	24.5%	15.1%	45.3%	54.7%	49.1%	47.2%
Panel B: Granger causality in risk between SSE and other stock indices before the crisis												
	One-way Granger causality								Two-way Granger causality			
Sample: 2-658	SSE → Indices				Indices → SSE				SSE ←→ Indices			
Risk measure\lag (M)	5	10	20	40	5	10	20	40	5	10	20	40
VaR long	3.8%	1.9%	3.8%	5.7%	5.7%	3.8%	1.9%	3.8%	17.0%	28.3%	39.6%	32.1%
VaR short	26.4%	28.3%	24.5%	26.4%	15.1%	9.4%	9.4%	7.5%	45.3%	50.9%	52.8%	49.1%
ES long	1.9%	13.2%	66.0%	64.2%	20.8%	28.3%	75.5%	75.5%	84.9%	71.7%	67.9%	73.6%
ES short	22.6%	28.3%	28.3%	18.9%	28.3%	30.2%	26.4%	20.8%	43.4%	54.7%	60.4%	58.5%
Panel C: Granger causality in risk between SSE and other stock indices during the crisis and after												
	One-way Granger causality								Two-way Granger causality			
Sample: 659-1326	SSE → Indices				Indices → SSE				SSE ←→ Indices			
Risk measure\lag (M)	5	10	20	40	5	10	20	40	5	10	20	40
VaR long	20.8%	24.5%	49.1%	75.5%	22.6%	41.5%	54.7%	84.9%	39.6%	58.5%	79.2%	90.6%
VaR short	41.5%	47.2%	52.8%	71.7%	56.6%	60.4%	69.8%	84.9%	71.7%	77.4%	86.8%	90.6%
ES long	56.6%	62.3%	81.1%	83.0%	26.4%	35.8%	49.1%	84.9%	66,0%	79.2%	86.8%	90.6%
ES short	18.9%	22.6%	35.8%	69.8%	39.6%	43.4%	54.7%	71.7%	62,3%	66.0%	77.4%	96.2%

Source: own computations

Table 8

The results of testing for Granger causality in risk for CNY against USD (percentage of rejecting the null hypothesis at 5% significance level is shown)

Panel A: Granger causality in risk between CNY and stock indices in the whole sample												
	One-way Granger causality								Two-way Granger causality			
Sample: 2-1326	CNY → Indices				Indices → CNY				CNY ←→ Indices			
Risk measure\lag (M)	5	10	20	40	5	10	20	40	5	10	20	40
VaR long	3.8%	9.4%	9.4%	3.8%	7.5%	17.0%	24.5%	28.3%	37.7%	39.6%	45.3%	45.3%
VaR short	15.1%	7.5%	3.8%	3.8%	20.8%	15.1%	17.0%	15.1%	73.6%	7.5%	54.7%	75.5%
ES long	5.7%	7.5%	17.0%	18.9%	9.4%	17.,0%	20.8%	20.8%	20.8%	28.3%	39.6%	39.6%
ES short	5.7%	1.9%	3.8%	3.8%	9.4%	7.5%	5.7%	3.8%	50.9%	66.0%	73.6%	75.5%
Panel B: Granger causality in risk between CNY and stock indices before the crisis												
	One-way Granger causality								Two-way Granger causality			
Sample: 2-658	CNY → Indices				Indices → CNY				CNY ←→ Indices			
Risk measure\lag (M)	5	10	20	40	5	10	20	40	5	10	20	40
VaR long	9.4%	9.4%	7.5%	9.4%	15.1%	15.1%	13.2%	18.9%	54.7%	67.9%	69.8%	73.6%
VaR short	3.8%	5.7%	3.8%	7.5%	11.3%	15.1%	11.3%	13.2%	20.8%	17.0%	24.5%	35.8%
ES long	15.1%	18.9%	26.4%	24.5%	18.9%	24.5%	39.6%	26.4%	52.8%	56.6%	56.6%	41.5%
ES short	20.8%	22.6%	32.1%	50.9%	3.8%	5.7%	11.3%	20.8%	54.7%	71.7%	71.7%	69.8%
Panel C: Granger causality in risk between CNY and stock indices during the crisis and after												
	One-way Granger causality								Two-way Granger causality			
Sample: 659-1326	CNY → Indices				Indices → CNY				CNY ←→ Indices			
Risk measure\lag (M)	5	10	20	40	5	10	20	40	5	10	20	40
VaR long	24.5%	34.0%	45.3%	73.6%	26.4%	47.2%	60.4%	79.2%	45.3%	24.5%	34.0%	45.3%
VaR short	15.1%	28.3%	47.2%	67.9%	28.3%	34.0%	50.9%	77.4%	67.9%	15.1%	28.3%	47.2%
ES long	13.2%	28.3%	37.7%	60.4%	9.4%	24.5%	34.0%	54.7%	41.5%	13.2%	28.3%	37.7%
ES short	22.6%	28.3%	49.1%	54.7%	58.5%	54.7%	54.7%	79.2%	56.6%	22.6%	28.3%	49.1%

Source: own computations

Before the crisis the number of markets infected with the risk coming from and to the SSE was smaller than after 1 August, 2008. The direction of contagion was in the greater part from the stock markets to the SSE and obviously bi-directional. In the case of the ES short and for smaller M (M=5 and M=10) the stock markets were the source of risk twice more often than

the stock exchange in Shanghai. On the other hand, positive effects related with ES long were coming from the Chinese stock market. The relations between Chinese currency and the international stock markets have changed over time. Before the financial crisis of 2007-2009, they were rather incidental and concentrated on a small number of markets. During the crisis and later, the scale of transferring the risk became greater. The source of the risk was most frequently external.

Analysis of the results shows that the economic policy of the Chinese government is able to keep away short term shocks (up to 5 days) from the financial market, however, the impact of shocks on the economy is distributed in time (long term 20-40 days).

4.4. The geography of transferring the risk

The results of applying Hong, Liu and Wang test for geographical directions of transferring the risk across international financial markets are illustrated in the map. In Figures 7-8 we showed the process of the risk transfer related to one-way Granger causality from the Chinese stock market as well as the currency. It is interesting to follow how the risk was spread all over the world, which is shown by the directions of arrows. Chinese financial markets were established as the point of our central interest. The results obtained for the measure of the expected shortfall computed at five percent confidence coefficient (short position) at a lag of 5 and 40 days are respectively outlined. It can be noticed (Figure 7) that in the short-term distance, the risk evoked by Chinese financial processes represented by CNY and SSE was transferred mainly to North and South America, Asia and Australia. It was less frequently moved to European financial markets. However, when the opposite direction is considered, the risk induced in Europe and some Asian countries is very quickly moved to China. In the longer period of 40 days (Figure 8) one can observe that the risky capital is transferred to China from the USA, Argentina, Europe, North Africa and Southeast Asia. From China it goes mainly to the USA and Argentina as well as to some European and North African countries and to South Korea. The obtained results are fairly important because the empirical testing for the Granger causality in risk allow finding out the directions of flow of ‘quick’, i.e., most risky capital. In the period of five days, speculative capital exhibits the strongest tendency to escape from risky markets that induces the contagion effect.

5. FINAL REMARKS

The results of the Granger causality in risk can be considered in terms of contagion analysis. They answer the questions put at the beginning of the analysis about the source of the risk and the speed of its diffusion. The results of testing the Granger causality in risk show that in the whole sample period non-expected but positive signals (long position) were weaker than the corresponding negative signals (short position) for both risk measures VaR and ES.

The strongest reaction was within 20 and 40 days periods. For the period of the financial crisis, the impact of mutual reactions was more frequent than in the full sample. Positive signals were spread around slower than the negative ones taking the time lags. However the source of the risk in the global financial world is very difficult to identify. It is rather common that the capital is transferred from one market to another infecting them with panic, increasing volatility and finally causing violations in the VaR or ES. The time of such a contagion is rather long (20 days). This is the evidence that the way of capital circulation is not necessarily simple and direct. On the other hand, the relatively long time delay between spreading the risk shows that the Chinese policy protecting financial markets helps to limit the risk coming from the outside. This can be also confirmed by the fact that in the short-term distance of five days the inflow of speculative capital to China is limited only to some European and Asian markets. Stock and currency markets in China were rather the result than the source of the global risk.

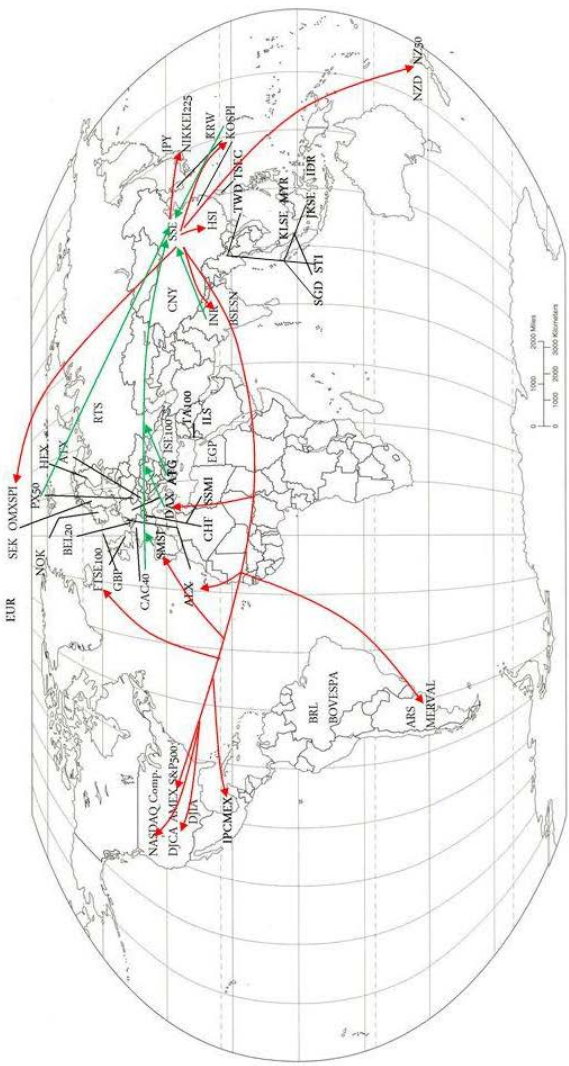

Figure 7. The results of Hong, Liu and Wang test: one-way Granger causality in risk ES(0.05) (lag=5).
Green line indicates that some indices are the Granger-cause in risk for SSE. Red line indicates that SSE is a Granger-cause in risk for some indices.

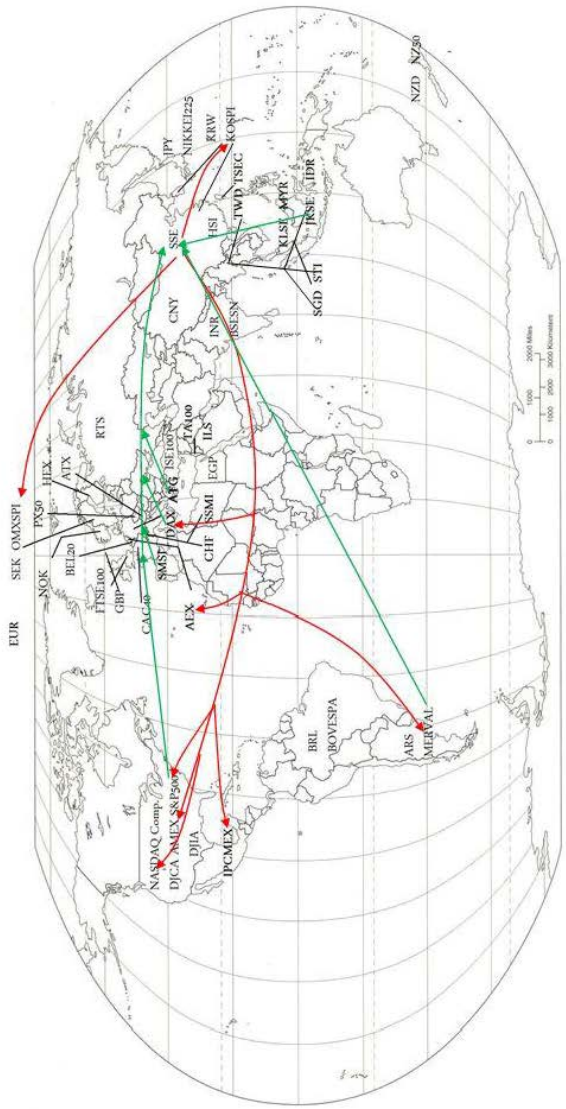

Figure 8. The results of Hong, Liu and Wang test: one-way Granger causality in risk ES(0.05) (lag=40)
Green line indicates that some indices are the Granger-cause in risk for SSE. Red line indicates that SSE is a Grange-cause in risk for some indices.

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APPENDIX

Table
Time series and abbreviations used in the research

Index	Country	Index/Exchange rate	Country	Exchange rate	Country
AEX	Holland	KOSPI	South Korea	USDCHF	Switzerland
AMEX	USA	MERVAL	Argentina	USDCNY	China
ATG	Greece	NIKK225	Japan	USDEGP	Egypt
ATX	Austria	NSDQCOMP	USA	USDEUR	European Union
BEL20	Belgium	NZ50	New Zealand	USDGBP	United Kingdom
BOVESPA	Brazil	OMXSPI	Sweden	USDHKD	Hong Kong
BSESN	India	PX50	Czech Republic	USDIDR	Indonesia
BUX	Hungary	RTS	Russia	USDILS	Israel
CAC40	France	S&P500	USA	USDINR	India
DAX	Germany	SMSI	Spain	USDJPY	Japan
DJCA	USA	SSE	China	USDKRW	South Korea
DJIA	USA	SSMI	Switzerland	USDMYR	Malaysia
FTSE100	United Kingdom	STI	Singapore	USDNOK	Norway
HEX	Finland	TA100	Israel	USDNZD	New Zealand
HIS	China	TWAII	Taiwan	USDSEK	Sweden
IPCMEX	Mexico	USDARS	Argentina	USDSGD	Singapore
ISE100	Turkey	USDBRL	Brazil	USDTWD	Taiwan
JKSE	Indonesia				
KLSE	Malaysia				

Source: own study