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Interconnectedness and Contagion Effects in International Financial Instruments Markets

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ABSTRACT

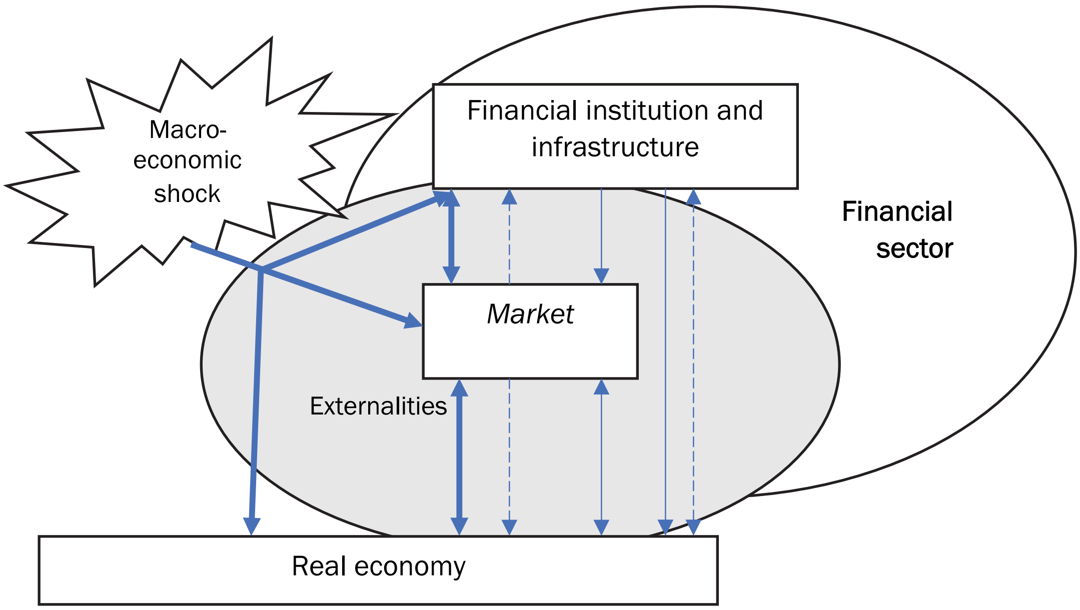
The aim of the research is to define possible contagion level of capital market resulting from shocks in main international stocks and bonds markets on basis of the assessment of market interconnectedness. Global Vector Autoregressive model was built up for securities markets in China, Euro area, Japan and the U.S. Using generalised impulse response functions scenarios of influence of shocks in market and estimate of contagion level in selected time horizon are simulated.

INTRODUCTION

Financial instruments market is an open economics subsystem that is sensitive to negative shock of exogenous (macroeconomic shocks and negative developments in financial institutions activities and infrastructure) and endogenous (for instance unwinding of price spirals on the basis of irrational exuberance (Shiller, 2000), market manipulations etc.) origin, which can lead to implementation of systemic risk in the market (fig. 1).

Macroeconomic shock as a systemic event can have negative influence directly at market capability to perform its typical functions or implicitly through contagion by means of channels of other constituents of financial sector or institutions of real sector of economy. For instance, macroeconomic shock can deteriorate financial soundness of financial institutions (channel of finance sector), what is to reflect at drop in prices of securities in market and this can cause problems with functioning of companies of real sector of economy that will also reflect in market price of their financial instruments. If macroshock directly leads to price turbulences of financial instruments through the information channel, then the market itself could act as a subject spreading contagion both on financial institutions and on the real sector of economy, in particular through the need to reevaluate assets in securities to the negative side, by means of reducing possibilities for funding (increasing risk premia for financial instruments) etc.

Figure 1. Systemic risk materialization



Source: *Own elaboration*

Another direction of systemic risk impact in financial instruments markets is its contagion upon occurrence of systemic event in the activities of financial institutions or infrastructure. For example, materialization of idiosyncratic risk concerning separate financial institution (in particular, its default) on the basis of negative externalities (interconnectedness with other institution on the basis of corporative co-ownership, using of complementary or similar activity strategies etc.) could be extended to other financial agents (domino effect). It will reflect in their market prices.

Despite this, stress situations induce market participants to *fire sales* of existing financial instruments, what will enhance stress in the market, and this in its turn could lead to negative influence on real sector of economy, i.e. market here could again perform as a transmission contagion channel. Financial institutions can extend stress to subjects of real economy sector without any market assistance – for instance, through rising requirements to credits.

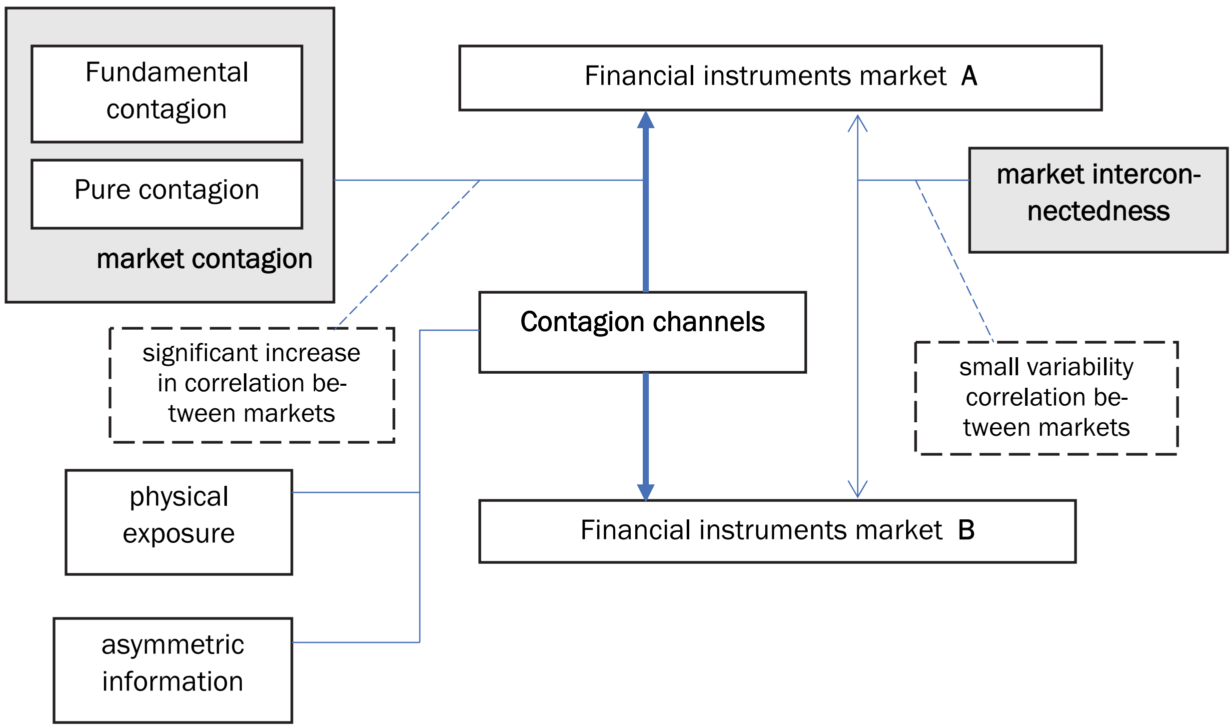
Misbalances unwinding in market *per se* (“booms” and “bubbles”) is an endogenous cause of systemic events incurrence, which can be further extended in cross-sectoral (through contagion of other components of financial system and real sector of economy) and in cross-border measure (causing instability in financial markets of other countries).

Thus, contagion is a main mechanism of instability development both in the financial instruments markets and in wider economy.

Development of relevant measures of macroprudential character to constituents of financial system (markets, institutions, infrastructure), which implementation grounds needs clear quantification of interconnectedness and contagion of financial instruments markets, is an important task of regulatory bodies in order to avoid or at least to soften substantial negative influence of contagion on the level of market dysfunctionality.

That is why the *aim of the research* is to define possible contagion level of capital market resulting from shocks in main international stocks and bonds markets on basis of the assessment of market interconnectedness.

Figure 2. Contagion in The Financial Instruments Market



Source: *Own elaboration*

Many methods of quantitative measurement of contagion were developed during the last years. They can be grouped in the following way (taking to account material of report ECB(2005):

(1) calculation of correlation indicator between markets and its modifications. In this regard work King and Wadhwani (1990) is the seminal research in this direction. It measures contagion as substantial increase of correlation between assets profitability in different markets. Conditional correlation proposed by Forbes and Rigobon (2002, pp. 11–12) is the most famous modification:

$$\rho^{*} = \rho\sqrt{\frac{1+\delta}{1+\delta\rho^{2}}} \qquad (1)$$

where ρ^{*} is the conditional correlation coefficient, ρ is the unconditional correlation coefficient, and δ is the relative increase in the variance of stock market returns.

(2) measurement of conditional probabilities, e.i. whether the probability of instability in certain country increase if there is market instability in the other country. This approach was proposed by

Eichengreen, Rose, & Wyplosz (1996) applying probit-model for probability assessment of currency crisis development. This methodology was mostly applied to identify fundamental contagion. Cappiello, Manganelli and Gerard (2005) have used quantile regressions to assess conditional probabilities of crisis in stock market.

(3) testing of contagion availability on the basis of changes of co-integration vector between financial instruments markets. For instance, Gilmore and McManus (2002) have applied co-integration vectors to assess interconnectedness between securities markets of Central European countries (Poland, Czech Republic, Slovakia and Hungary) and the developed countries (Germany, USA).

(4) application of extreme value theory, i.e. identification of contagion on the basis of availability of similar extreme prices dynamics or other indicators of financial instruments markets. For instance, Longin and Solnik (2001) have conducted estimation of correlation of extreme incomes of stock indexes (for five developed countries), which exceed certain limits (chosen levels – from 1% to 10% of the average value). Chan-Lau, Mathielson and Yao (1998) explored contagion effects in growing and dropping developed and emerging markets in a period from December 12, 1987 up to October 25, 2001, through applying indicators from the theory of extreme value, that are based on asymptotic qualities of joint distribution tails. Development of extreme value theory concerning the contagion research is based on application of copula. Taking into account absence of normal distribution in the dynamics of indicators of financial instruments markets this methodology gets a growing number of followers (Rodriguez, 2007; Durante and Jaworski, 2010).

(5) network analysis – in virtue of analysis of relations (with availability of data visualization) of certain market with others enables defining of its importance level for the finance and economic system of separate region or in global dimension. Besides the established network allows to define directions and speed of instability extension between markets. According to the provided methodology every market is node, which is linked to other markets. A number of incoming and outcoming connections defines a market centrality level, which also depends on the centrality level of neighboring markets. Starting from well-known work (Allen and Gale, 2000) analysis of networks in the finance sphere is actively applied mostly to bank institutions activities (in particular their interconnectedness on the inter-bank market). Network analysis is applied far rarer in researches of finance instruments market, for instance, Nobi, Lee, Kim and Lee (2014) in the virtue of analysis of correlations of global stock indexes and stock index of South Korea (KOSPI) have built relevant correlation network.

(6) Vector Auto Regressions (VAR). This model was proposed by Sims (1980) and is characterized in comparison to earlier developed econometric models by the following peculiarities: (1) absence *a priori* of variables division for exogenous and endogenous; (2) absence of zero conditions; (3) absence of economics theory that would compose basis for the model (Kusideł, 2000, p. 10).

At modern stage VAR models are quite popular in the sphere of finance instruments (Samarakoon, 2011; (Gross and Kok, 2013; Claeys and Vašíček, 2014; Diebold and Yilmaz, 2009; Beirne and Gieck, 2012) and allow defining interconnectedness and contagion between markets in the basis of construction of econometric models with substantial number of equations (in different dimensions depending from quantity of variables, markets or countries) that include mutual influence both current and past value of variables (with a set number of lags). Despite this, a level of shocks influence and instability duration and can be modeled with help of VAR. It is useful for developers of relevant monetary or macroprudential politics, as well as for experts of private institutions of the finance sector for simulation of scenarios and prognoses. This method will be further used to research assessment of systemic risk influence on the financial instruments market.

2. METHODOLOGY AND DATA

Model of global auto regression foresees building up of set of VARX equations (each of which can reflect interconnectedness of variables concerning certain country), for which construction country-specific variables (endogenous) and its lags for every country are being used, foreign-specific variables (weakly exogenous) and its lags, which value is defined as weighted average variables of all countries included in the model.

Interconnectedness and possible contagion is measured on the basis of impulse-response function which predicts influence of unexpected shock from one country to another. These tests are less conservative than those based on correlation coefficients as they generally do not adjust for the heteroskedasticity in returns (Forbes, 2012, p. 7-8).

Using work Pesaran, Schuermann and Weiner (2002, p. 4) model for separate country (group of countries) VARX(p_i,q_i) appears as follows:

$$x_{it} = a_{i0} + a_{i1}t + \Phi_i x_{i,t-1} + \Lambda_{i0} x_{it}^* + \Lambda_{i1} x_{i,t-1}^* + \varepsilon_{it},$$

$$t = 1,2,\ldots,T \; i = 1,2,\ldots N \tag{2}$$

$$x_{it} = \begin{pmatrix} s_{it} \\ b_{it} \end{pmatrix}, \; for\, i = 1,2,\ldots N, \; x_{it}^* = \begin{pmatrix} s_{it}^* \\ b_{it}^* \end{pmatrix}, \; for\, i = 1,2,\ldots N \tag{3}$$

$$s_{it}^* = \sum_{j=0}^{N} w_{ij} s_{ij}\,,\; b_{it}^* = \sum_{j=0}^{N} w_{ij} b_{ij}\,,\; \sum_{j=0}^{N} w_{ij} = 1, \tag{4}$$

where Φ_i – is a $k_i \times k_i$ matrix of lagged coefficients, Λ_{i0} and Λ_{i1} – is a $k_i \times k_i^*$ matrix of coefficients associated with the foreign-specific variables, x_{it} – is a $k_i \times 1$ vector country-specific variables, x_{it}^* – is a $k_i \times 1$ vector of foreign variables specific to country *i*, *N* – number of countries, *T* – number of time periods, ε_{it} – is a $k_i \times 1$ vector of idiosyncratic shocks, that serially uncorrelated with a zero mean and a non-singular covariance matrix $\sum_{ii} = (\sigma_{ii,\ell s})$, where $\sigma_{ii,\ell s} = \mathrm{cov}(\varepsilon_{i\ell t}, \varepsilon_{ist})$, w_{ij} – is the share of country *j* in the trade (exports + imports) of country *i*, p_i – lag order for country-specific variables, q_i – lag order for foreign-specific variables.

In our model x_{it} will include stock market return (s) and change 10-year maturity government bonds yield (*b*):

$$s_{it} = \ln(Close_{it} / Close_{it-1}),$$

$$b_{it} = r_{it} - r_{it-1},$$

We assume that these variables are observed at monthly frequencies.

Model will be built up for securities markets in China, Euro area, Japan and the U.S.

Verification of models relevance for certain countries, solution of global model and obtaining other data on model properties was conducted in the environment of program products *MatLab* and *Excel*, using *GVAR Toolbox*, developed by Smith and Galesi (2014).

Statistic data on stock indexes values (EURO STOXX 50 for euro area, Nikkei 225 for Japan, Dow Jones Industrial Average for U.S. and Shanghai Stock Exchange Composite (SSE) for China) was obtained from Internet portal Investing.com, data on yield of 10-years government bonds – from Internet portal Investing.com and European Central Bank for Eurozone, data on volumes of mutual trade between countries – from IMF (Direction of Trade Statistics), data on GDP by purchasing power parity – from statistical information storage World Bank (World Development Indicators). Calculation includes monthly variables indicators from 2005 up to 2016.

2.1 The main findings of the study

While using GVAR model the following is important stages of activities: (1) unit root tests for stationary autoregressive processes (test ADF) and (2) lag order selection on the basis of criterion Akaike.

According to the data in tab.1 all variables (country-specific and foreign specific) have ADF-test value lower then critical value, and it confirms hypothesis on stationarity of dataset.

Table 1. ADF-statistics for country-specific and foreign-specific variables

Country	s_t	b_t	s^*_t	b^*_t
China	-4.18	-6.37	-4.27	-9.11
Euro area	-4.53	-9.08	-4.04	-7.55
Japan	-7.71	-9.58	-3.99	-7.15
U.S.	-4.37	-9.19	-4.01	-6.72
Critical value	*-3.45*	*-3.45*	*-3.45*	*-3.45*

Source: *Own elaboration.*

Lag order for models on each country is defined on the basis of informational criterion Akaike (AIC) and the model with the highest AIC value is chosen (table 2).

Despite this models were tested for residual serial correlation, which was performed on the basis of the F-version of the familiar Lagrange Multiplier (LM) statistic. If calculated statistics is lower than critical value, then hypothesis on residual correlation availability can be turned down (tab.2).

Table 2. Lag order and residual serial correlation testing for VARX (*p,q*)

Country	*p*	*q*	*AIC*	Testing for residual serial correlation		
				Critical value	*s*	*b*
China	1	1	195.48	2.44245	1.61	1.02
Euro area	2	1	316.89	2.44359	0.72	1.46
Japan	1	1	373.66	2.44245	0.69	1.54
U.S.	1	1	319.39	2.44245	0.31	0.76

Source: *Own elaboration.*

Weak exogeneity of foreign-specific variables is one of the presumptions of VARX (*p,q)* models usage. A test of weak exogeneity for the foreign-specific variables is conducted along the lines described in Johansen (1992) and Harbo, Johansen, Nielsen, & Rahbek (1998). This involves a test of the joint significance of the estimated error correction terms in auxiliary equations for the foreign-specific variables, x^*_{it} (Smith & Galesi, 2014).

Test results confirm this presumption (if statistics is lower than critical value, then hypothesis on weak exogeneity absence is turned down) for variables of all countries (tab. 3).

Table 3. Results of weak exogeneity test

Country	Critical value F-statistics (*p*= *0,05*)	s^*_t	b^*_t
China	3.064761	1.58	1.27
Euro area	3.065839	1.05	1.71
Japan	3.064761	0.12	0.19
U.S.	3.064761	0.92	1.55

Source: *Own elaboration.*

Calculated coefficients of determination evidence of acceptable level of explanation of dependent variables – return of stock indexes and government bonds yields (tab. 4).

Table 4. Autoregressive models statistics

Country	Variable	R^2	AIC	SBC
China	s	0.54	151.27	143.91
	b	0.47	46.02	38.67
Euro area	s	0.68	252.78	242.48
	b	0.76	70.11	59.81
Japan	s	0.62	225.04	217.69
	b	0.63	152.96	145.60
U.S.	s	0.71	295.67	288.32
	b	0.70	29.06	21.71

R^2 – coefficient of determination, *AIC* – Akaike information criterion, *SBC* – Schwartz Bayesian criterion

Thus, the coefficient of determination fluctuates around 0.47 (for bonds market in China) up to 0.76 (for bonds market in Euro area). Average value of the coefficient of determination is 0.7.

Aggregate influence of stocks market (or government bonds market) over relevant market of certain country is reflected by elasticity coefficients (tab. 5).

Table 5. Contemporaneous effects of foreign-specific variables on their country-specific counterparts in VARX(p,q) models

Country	*s*	*b*
China	0.849*** (6.46)	0.115 (1.81)
Euro area	0.585*** (10.68)	0.887*** (13.30)
Japan	0.535*** (9.13)	0.281*** (7.78)
U.S.	0.461*** (13.36)	1.155*** (11.03)

t-ratio in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

These coefficients empower to carry out estimation of international interconnectedness of domestic financial instruments market of a specific country. For instance, Chinese stock market will raise by 0.85% if stock markets of the entire selection raise by 1% (*ceteris paribus)*. Elasticity coefficient for stock market is the biggest in China, and for bonds market – in the U.S. Weak interconnectedness with international markets is observed in Asian bonds markets (China – 0.12; Japan – 0.28).

Coefficients of average pairwise cross-section correlations of market of certain country with markets of other countries, obtained on the basis of GVAR modeling, as well show similarity of markets dynamics (tab. 6). Average pairwise cross-section correlations of stock markets is 0.55, and this indicator is somewhat lower in bonds markets – 0.37. The highest average pairwise cross-section correlations with international stock markets is indicative for Euro area – about 0.62, and for debts security markets in the U.S. – almost 0.5.

Table 6. Average pairwise cross-section correlations in the financial instruments markets

Country	Cross-section correlation	Residuals correlation	Country	Cross-section correlations	Residuals correlation
Stock market			**Bond market**		
China	0.38	-0.51	China	0.15	-0.40
Euro area	0.62	0.10	Euro area	0.44	-0.08
Japan	0.58	0.09	Japan	0.38	0.01
U.S.	0.61	0.04	U.S.	0.49	-0.05
Average sample correlation	0.55	-0.07	Average sample correlation	0.37	-0.13

Source: *Own elaboration.*

One of the important presumptions of GVAR modeling it is necessary that idiosyncratic shocks of certain country (residuals – ε_{it}) were weakly correlated – $\operatorname{cov}(x_{it}^*, \varepsilon_{it}) \to 0, \; with\, N \to \infty$ (di Mario & Pesaran, 2013, p. 24). Data provided in tab. 6 on correlation of residuals demonstrate their mainly low values what responds to presumption of GVAR model.

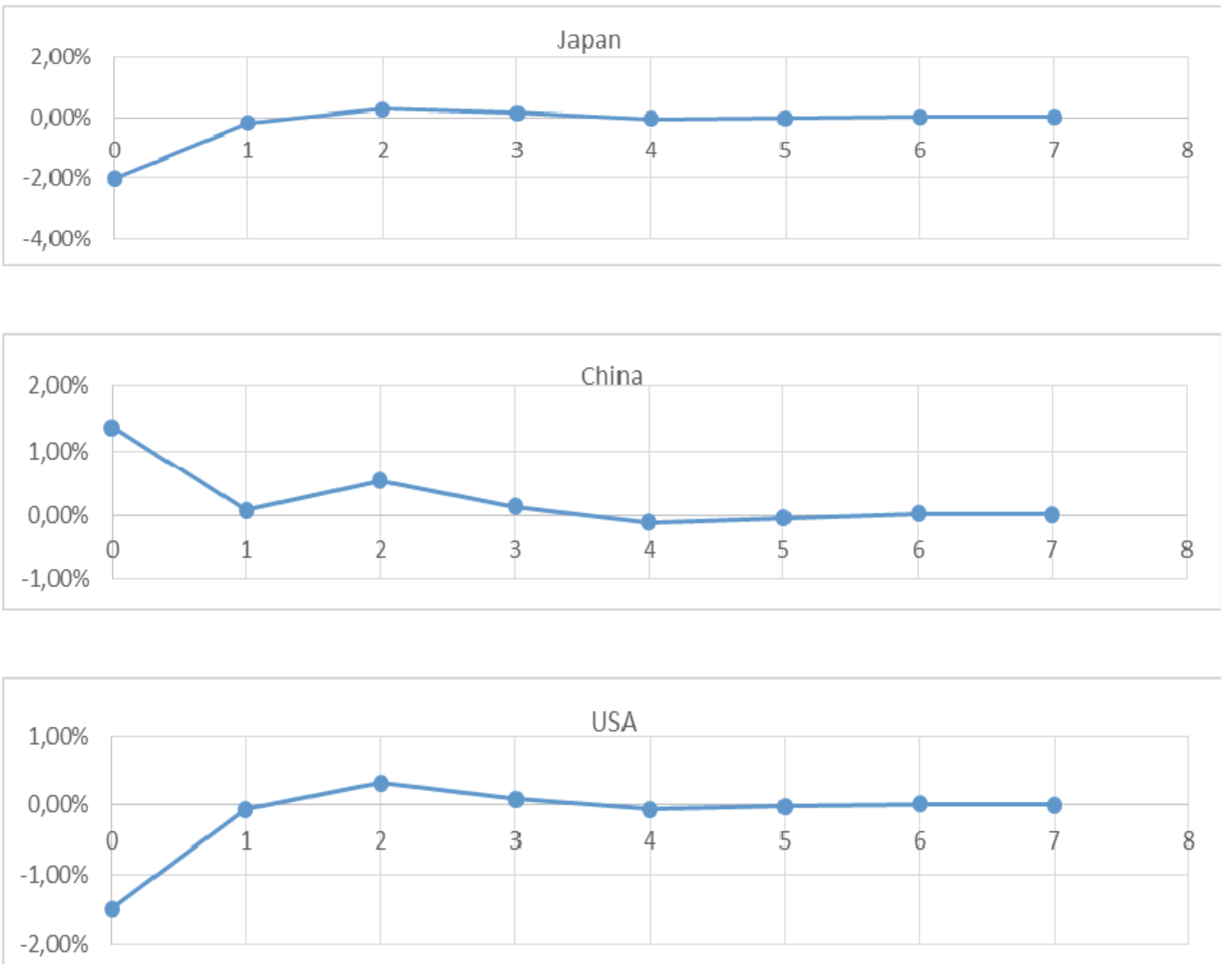
The developed GVAR model allows to predict change in return of stock indexes and government bonds yield of the countries included in sample, as well as by using generalised impulse response functions (GIRFs), that are described in Smith and Galesi (2014), to simulate scenarios of influence of global shocks in market and estimate contagion level in selected time horizon.

Build from estimated residuals of individual models for certain countries covariance matrixes were applied to implement GIRFs. Role of certain country on the basis of partition in selection according to GDP at purchasing power parity was applied to identify global shocks.

Simulation of shocks on the basis of return drop (in a size of one standard error)) in stock indexes in Euro area, Japan, the U.S. and China was conducted.

Shock in Euro area stock market will cause drop in stock markets of Japan (-2.03%) and the U.S. (-1.49%) already this month, however stock market of China will react with growth (+1.36%) and only after 4-5 month of European shock marginal drop of stock index at Shanghai Stock Exchange is possible. Complete damping of shock influence at international markets will take place in 7 months (fig. 3).

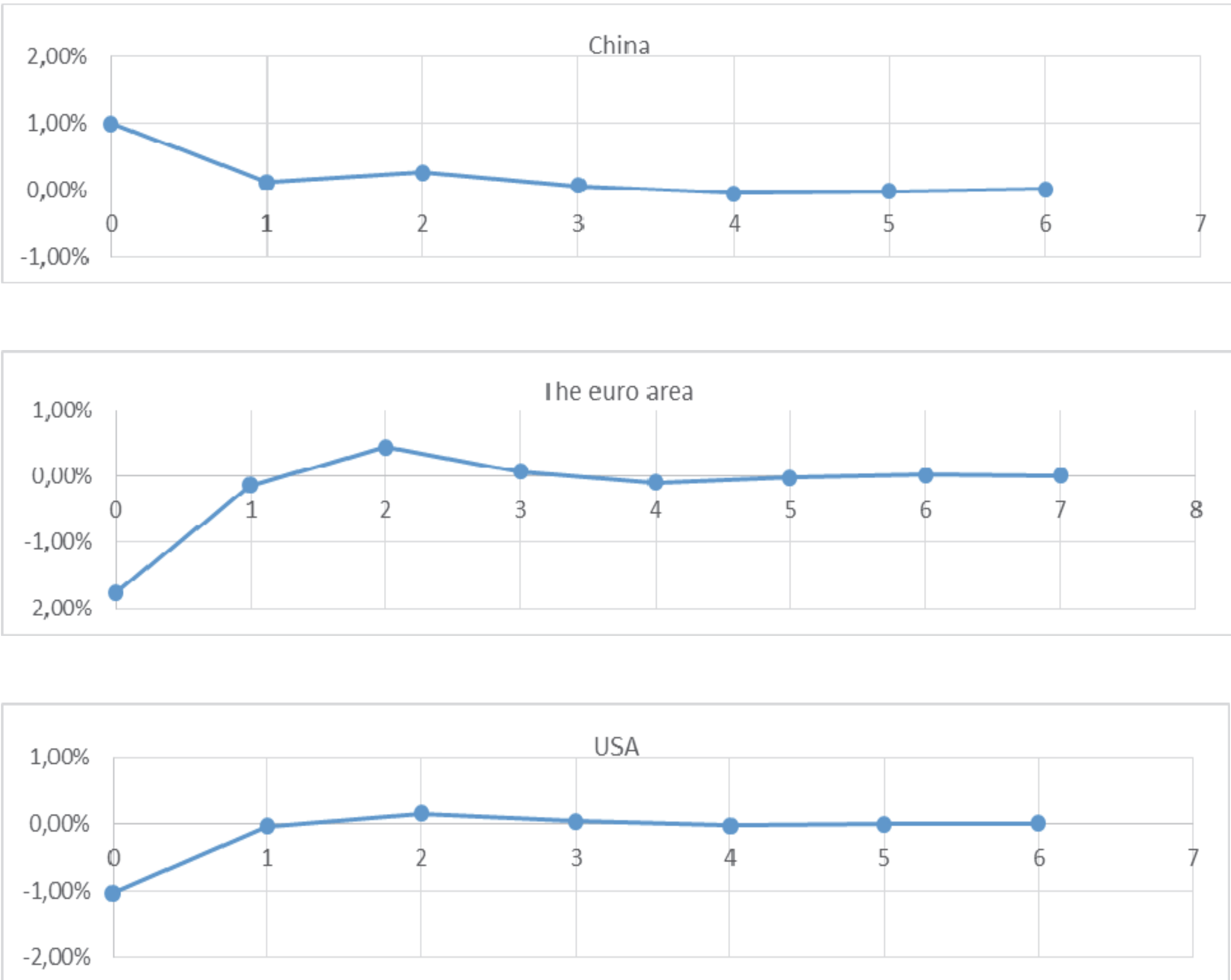
Figure 3. Stock Markets Reaction to Stock Market Shock in Euro area



Source: *Own elaboration.*

Similarly to the previous simulation monthly drop of Nikkei 225 index in the amount of one standard error (fig.4) will lead to drop in Euro area stock markets (1.76%) and the U.S. (-1.04%) and growth of China stock market by almost 1% per month of buildup of negative market situation in Japan. Complete attenuation of shock influence at international markets will take place in 5-6 month (fig. 4).

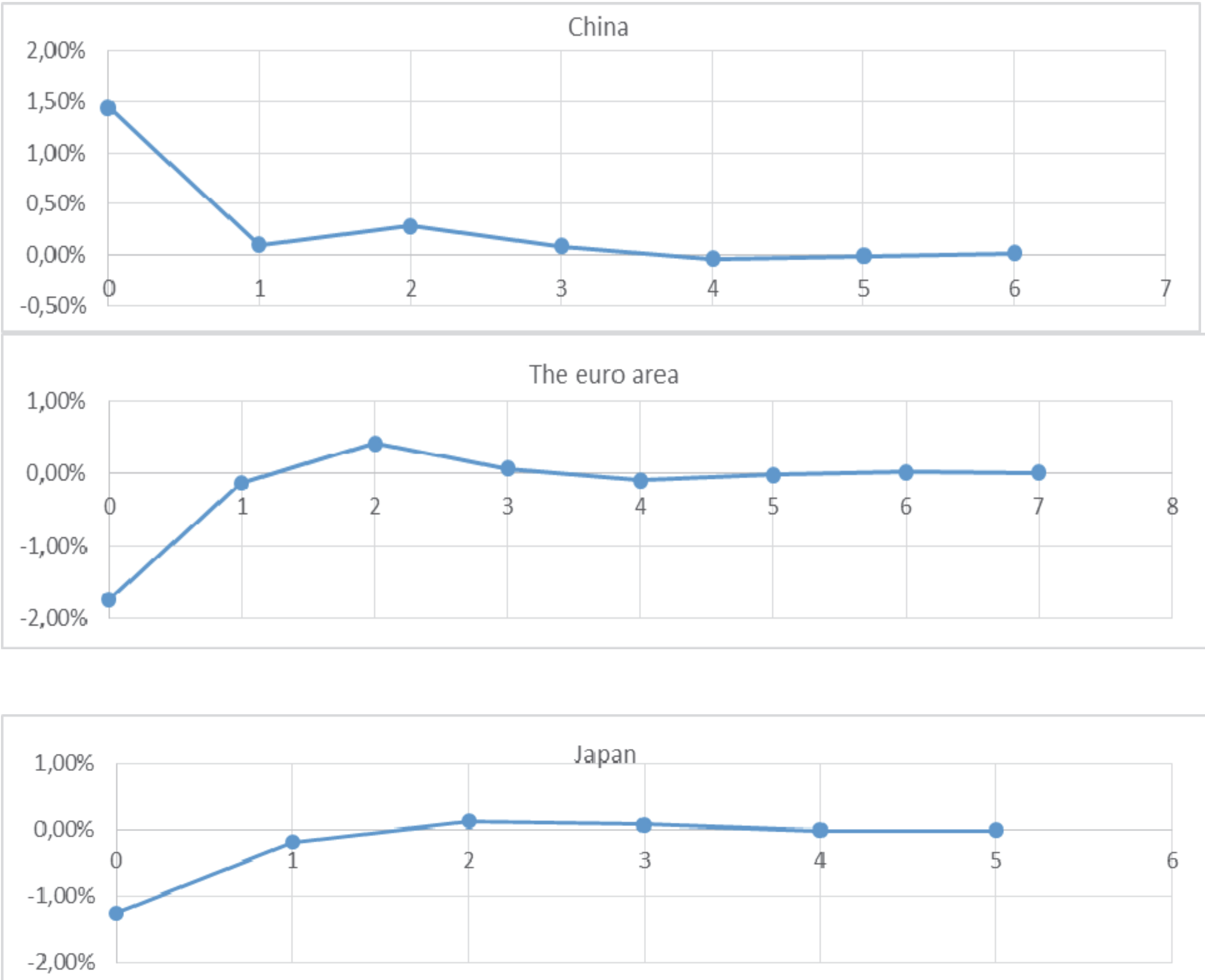
Figure 4. Stock market reaction on the stock market shock in Japan



Source: *Own elaboration.*

Chinese market will grow again in cases of disturbances at the American market, and the rest of markets will react with stock indexes drop (fig. 5).

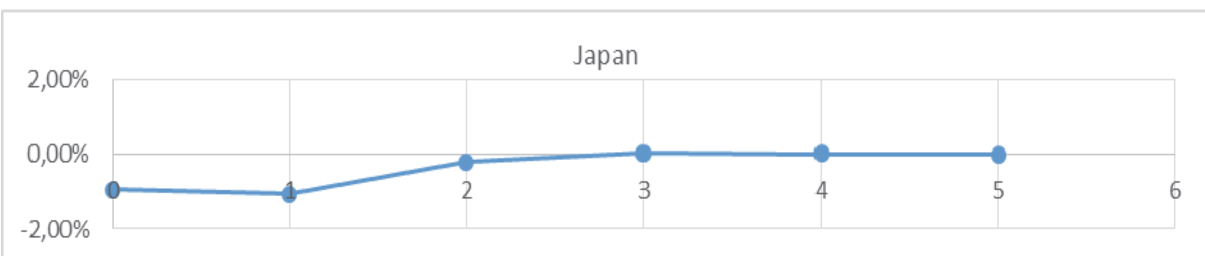
Figure 5. Stock market reaction on the stock market shock in the U.S.

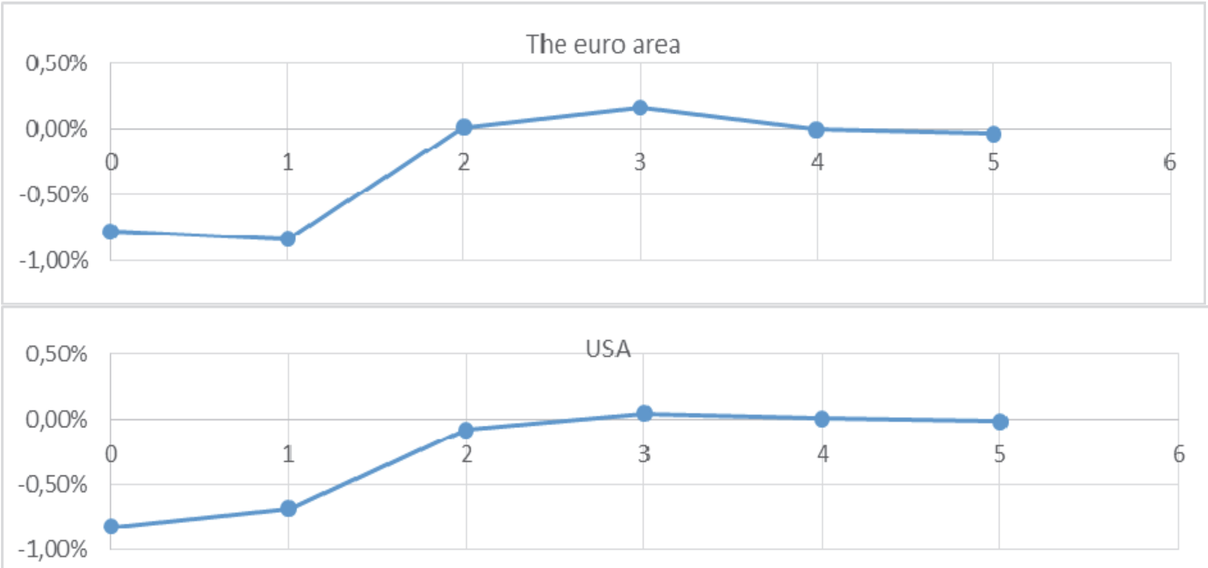


Source: *Own elaboration.*

However, all markets will feel negative influence in case of shock in China stock market (fig. 6). First of all such reaction will be connected with significant drop of stock exchange in Shanghai – by 8.66% (the Chinese market is more volatile, and thus one standard error has higher value).

Figure 6. Stock market reaction on the stock market shock in China





Source: *Own elaboration.*

Reaction of bond markets to idiosyncratic shocks in some international markets is substantially weaker (tab. 7).

Table 7. Bond market reaction (yield change, %) on stock market shocks

Country	*Period after shocks (months)*			
	0	1	2	3
Shock in China	-0.037	-0.021	-0.011	-0.003
Euro area	-0.001	-0.025	-0.009	0.002
Japan	-0.006	-0.008	0.003	0.000
U.S.	-0.015	-0.038	-0.015	0.000
Shock in the euro area	0.00001	-0.018	-0.004	0.007
China	0.016	-0.002	-0.002	0.003
Japan	-0.003	-0.005	0.001	0.002
U.S.	-0.017	-0.026	0.005	0.009
Shock in Japan	-0.010	-0.006	0.001	0.001
China	0.008	-0.002	-0.002	0.001
Euro area	-0.001	-0.011	0.002	0.003
U.S.	-0.011	-0.018	0.002	0.004
Shock in the U.S.	-0.013	-0.039	0.002	0.004
China	0.018	-0.003	-0.005	0.001
Euro area	-0.014	-0.015	0.000	0.004
Japan	-0.001	-0.006	0.000	0.001

Source: *Own elaboration.*

Thus, in the first month after shock in China stock market, maximal cross-border reaction totaled at 0.038% drop in the U.S. 10-year bonds yield and maximal cross-sector reaction within one country – yield drop by 0.039% in the U.S. bonds during the next month after Dow Jones index drop.

CONCLUSIONS

On the grounds of the conducted research of assessment of interconnectedness and possible market contagion level during shocks in stock markets (using GVAR model) the following may be affirmed (1) absence of cross-border and cross-sectoral contagion of bonds markets in case of idiosyncratic shock at stocks market of leading international markets; (2) availability of mutual negative reaction in stock markets of the U.S., Japan and Euro area in case of negative shock in one of those markets, which demonstrates significant possibility of mutual contagion; (3) absence of negative reaction of China's stock market (in the month their occurrence) to the shocks in other international stock markets of the sample, i.e. the Chinese stock market has low probability of trans-border contagion, however (4) negative shock in China stock market will have negative outcomes for other stock markets; (5) durability of markets reaction to cross-border shocks is not critical and their influence disappears completely in 5-7 months in stock market and in 2-3 months in bond markets.

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