Interdependencies between Exchange Rate Volatility and Stock Market Sectors: A Case Study of Poland

Viorica Chirilă
Ciprian Chirilă
"Alexandru Ioan Cuza" University from Iasi,
Faculty of Economics and Business Administration, Romania
vchirila@uaic.ro
chcip@uaic.ro

Abstract

This study analyzes the transmission of foreign exchange market volatility from the stock market sectors and vice versa, in the case of Poland. The methodology used, spillovers indices, offers the possibility of studying volatility spillovers in different market conditions: bear and bull market. The research considers the system determined by the EUR/PLN exchange rate, stock indices of the sectors and WIG 20, which expresses the overall trend of the evolution of the Polish stock market. The results obtained confirm the spillovers effect and also the variation of volatility spillovers over time and significant differences in spillovers in different market conditions. In normal market conditions, the transmission of volatility is lower compared to the situation where the market is faced with new unexpected positive information but also with new unexpected negative information. The results obtained are important for international investors in diversifying portfolios and for hedging investments.

Key words: stock markets sectors, risk, spillovers volatility, QVAR, spillover index
J.E.L. classification: C58, D53, G15, O57

1. Introduction

The relationship between stock and foreign exchange markets is extensively explored in empirical research for several reasons (Kanas, 2000).. One reason is that stock prices and exchange rates are two variables that are linked (Reboredo et al., 2016). According to economic theory, a depreciation (appreciation) of the domestic currency leads to an increase (decrease) in the international competitiveness of domestic firms and a rise (decline) in cash flows, resulting in higher stock prices. When stock prices rise, international investors liquidate their investments to realize profits, and capital is then reallocated to other countries. The selling of stocks causes the domestic currency to depreciate.

Another reason for studying spillovers between stock and foreign exchange markets is that it provides insights for companies that profit from international portfolio investments and develop risk mitigation strategies: credit institutions, insurance companies, and general investment funds. Multinational corporations, also, are interested in hedging their exposure to exchange rate risk.

A third reason, as highlighted by European Central Bank Vice President Luis de Guindos (2019), is the growing concern about the impact of increased international spillovers on financial stability. Consequently, the interconnectedness between stock and foreign exchange markets has become a focal point for policymakers.

This paper aims to study the dynamics of volatility transmission between sectors of the Polish stock market and the foreign exchange market, using transmission indices determined based on quantile VAR methodology, as proposed by Ando et al. (2022), an improved methodology compared to that initially proposed by Diebold and Yilmaz (2012). We developed a model using indices from ten stock sectors, the Polish capital market index, and the EUR-PLN and USD-PLN

exchange rates. The period considered for the analysis includes a sample from March 11, 2011, to March 10, 2023, the entire period of availability of the sectoral indices. The research objectives are: (1) to estimate the average level of transmission between sectors of the Polish stock market and the foreign exchange market under different market conditions; (2) to estimate the dynamics of volatility transmission; and (3) to identify the moments of vulnerability of each of the two markets.

Transmission indices calculated based on quantile VAR, a method proposed by Ando et al. (2022), allow for the study of connectedness between Polish stock market sectors and the foreign exchange market, in three different market conditions: bear, bull, and normal markets. The normal market situation is highlighted by the analysis performed for the median quantile, while the bear market is represented by the lower tail quantile and the bull market by the upper tail quantile

This study extends and complements previous research by offering a novel perspective on volatility transmission between stock and foreign exchange markets. While numerous studies have employed the methodology proposed by Diebold and Yilmaz (2012) and its various extensions, it has not been applied to investigate the transmission of volatility between sectors of the stock market and the foreign exchange market. This methodology enables the dynamic study of the intensity and direction of volatility transmission, allowing for the identification of periods with significant spillovers. The patterns identified in the Polish market can provide valuable insights into the dynamics between the two markets. In the model constructed from EUR/PLN and USD/PLN exchange rates and indices of Polish stock market sectors, the methodology allows for the identification of transmissions between each element of the system and the other individual elements.

Furthermore, there is a lack of recent studies analyzing volatility transmission between Polish stock sectors and foreign exchange markets. While Hung (2021, 2022) examines volatility transmission between the foreign exchange rate and five Central and Eastern European stock markets, including Poland, the study focuses on the overall stock market rather than individual sectors. Similarly, there are few published studies investigating volatility transmission between stock sectors and foreign exchange markets in other countries (Yong Fu et all., 2011; Jayasinghe and Tsui, 2008, Jayasinghe et all. 2014, Mouna and Anis, 2017, Fasanya and Akinwale, 2022).

2. Literature review

The relationship between the exchange rate and local stock markets in BRICS countries, alongside the US stock market return and interest rate differentials, is investigated by Sui and Sun (2016) over both the short and long term. Employing VAR and VECM models, the authors find significant short-term transmission of shocks from the foreign exchange market to the stock market, but no significant reverse transmission. The study does not identify any cointegration relationship, thus confirming the absence of long-term transmission. The transmission effect of shocks is found to be more pronounced during the 2008-2009 financial and economic crisis.

Reboredo et al. (2016) examine the volatility transmission between stock markets and foreign exchange markets in a sample of emerging economies. The study aims to highlight both downside and upside risk spillovers. The results confirm a significant bidirectional relationship between exchange rates and stock markets.

Using GARCH-BEKK, CCC, and DCC models, Hung (2022) investigates the transmission effects between exchange rates and stock markets in Central and Eastern European countries. The results confirm bidirectional transmission for Hungary, Poland, the Czech Republic, and Romania. The intensity of transmission varies before, during, and after the subprime crisis. Moreover, the spillover effect of volatility from stock markets to the foreign exchange market is greater than the reverse effect.

The transmission effect of foreign exchange market volatility on the volatility of stock market sectors is analyzed through the estimation of the bivariate GJR-GARCH model for Japan (Jayasinghe and Tsui 2008). The results confirm a positive exposure to yen volatility for sectors such as hardware and information technology, household goods, automobiles and auto parts, and electrical equipment, and a negative exposure for the construction, oil and gas sectors. Moreover, the results confirm an asymmetric effect of volatility transmission.

Fu et al. (2011) examine the linkages between equity sectors and foreign exchange markets in Japan and the US using a BEKK-GARCH model. The results highlight a unidirectional volatility transmission from the exchange rate to equity market sectors when markets are influenced by news shocks, for most sectors in both Japan and the US. An exception is the US technology sector, which exhibits bidirectional transmission. No significant return transmission between foreign exchange markets and stock markets is identified, confirming the hypothesis that testing transmission in the second moment provides different insights compared to testing in the first moment.

Consequently, the research questions that we pose and seek to address in this study are:

R1: *Does the intensity of information spillover vary under normal, bear and bullish market conditions?*

R2: *What is the net direction and intensity of information spillover between each sector of the stock market and the Exchange market?*

R3: *Which sectors of the Polish stock market are connected the strongest with the changes in the Exchange market?*

3. Research methodology

To investigate the connection between exchange rate volatility and each sector of the Polish stock market, we employ a recently developed methodology by Ando et al. (2022): the quantile connectedness approach, a method developed upon the methodology of Diebold and Yilmaz (2009, 2012, 2014).

This method allows us to study volatility transmission within different quantiles, such that: small and large quantiles highlight characteristics that appear in extreme situations, whether negative or positive (bear and bull markets), and the median quantile allows for the identification of volatility transmission characteristics under normal conditions.

Poland is the only country in Central and Eastern Europe that calculates and publishes stock indices for economic activity sectors, for this reason, we have undertaken a study of this research subject.

The sample period for this study extends from March 11, 2011 (first data available for sectoral indices), to March 10, 2023. The dataset includes 3132 daily observations for each sectoral indices, the EUR/PLN and USD/PLN exchange rates, and the WIG 20 blue-chip index.This period encompasses a range of significant economic events, including the final phase of the European debt crisis (January 2010 - December 2012), oil price shocks and the Brexit period (August 2015 - September 2019), the COVID-19 pandemic (January 2020 - November 2020), and the Russo-Ukrainian War (started in February 24, 2022).

The volatility of equity sectors and exchage rate are determined according to the relation:

$$\left|\ln \frac{P_t}{P_{t-1}}\right|$$

where P_t, P_{t-1} - represent the values of the indices on day t and the previous day, t-1, respectively.

In order to estimate VAR quantiles, the time series data must adhere to the stationarity assumption. Consequently, we will implement the ERS test (Elliott et al., 1996) in conjunction with the conventional ADF (Dickey and Fuller, 1979) and Phillips-Perron (Phillips and Perron, 1988) tests. Our empirical results unequivocally support the hypothesis of stationarity for all series, as evidenced by the absence of unit roots. Given these findings, and due to space constraints, we focus on the ERS test results. The subsequent VAR(p) model estimation, where each volatility is modeled as a function of its own lags and the lags of other volatilities, is facilitated by the stationarity assumption. Based on information criteria, a VAR(1) model is selected for our quantile connectedness analysis. Ando et al.'s (2022) methodology enables the quantification of spillover effects for each quantile. This includes the spillover direction from one volatility to all others (TO), the spillover direction from all volatilities to one (FROM), net directional spillovers (NET), and the total spillover index (TCI).

4. Findings

4.1 Static volatility transmission analysis

Prior to conducting econometric estimations, we examine the statistical properties of the variables under study. Table 1 presents descriptive statistics of the volatility series for sectoral indices, the stock market index, and the two exchange rates. The results obtained confirm the existence of characteristics specific to financial time series: excess kurtosis, known as fat tails, non-normality of the distributions of the studied series, and their stationarity, as confirmed by the Elliott et al. (1996) test. The highest excess kurtosis of the volatility distribution is observed in the food sector, which reached its highest values during the pandemic caused by the COVID 19 virus.

Table no. 1 Indicators of descriptive statistics of risk for the period March 11, 2011 - March 10, 2023

	Mean	Variance	Skewness	Ex.Kurtosis	JB	p value	ERS	p value
USD	0.545	0.256	2.078	7.497	9585	(0.000)	-8.08	(0.000)
EUR	0.306	0.09	2.491	11.660	20975	(0.000)	-12.30	(0.000)
WIG	0.907	0.867	3.168	24.312	82349	(0.000)	-11.75	(0.000)
BK	1.124	1.445	3.390	24.750	85911	(0.000)	-14.47	(0.000)
BM	1.595	2.498	2.252	9.699	14919	(0.000)	-10.64	(0.000)
CHE	1.259	1.543	2.258	9.104	13474	(0.000)	-6.86	(0.000)
CO	0.87	0.787	2.468	10.740	18226	(0.000)	-15.87	(0.000)
DEV	0.743	0.618	3.041	17.389	44273	(0.000)	-16.36	(0.000)
EN	1.230	1.634	2.693	13.635	28039	(0.000)	-11.39	(0.000)
FOOD	1.057	2.161	11.028	264.160	9166947	(0.000)	-14.82	(0.000)
IT	0.821	0.656	2.223	8.129	11199	(0.000)	-9.03	(0.000)
ME	1.059	1.131	2.272	8.864	12943	(0.000)	-10.42	(0.000)
OG	1.259	1.429	1.905	6.211	6926	(0.000)	-10.79	(0.000)

Note: USD, EUR volatility USD/PLN and EUR/PLN exchange rates, WIG - volatility for Polish stock market, BK, BM, CHE, CO, DEV, EN, FOOD, IT, ME, OG - volatility for Polish stock markets sectors
Source: Results obtained by the authors

Table 2 presents the values of the transmission indices in the lower tail quantile (bear market). The highest volatility transmissions are recorded from the own lagged values, as shown on the diagonal, ranging from 14.37% for the volatility of the USD/PLN exchange rate to 19.09% for the volatility of the entire Polish stock market. The transmission of volatility from the USD/PLN exchange rate to the volatility of equity sectors ranges from the lowest value of 5.46% for the developers sector to the highest value of 5.84% for both the basic materials and IT sectors. However, the volatility transmitted by this exchange rate, USD/PLN, is lower overall than the volatility it receives (with the banking sector being the most influential), justifying the conclusion that it is a net receiver of volatility. The volatility of the EUR/PLN exchange rate is also a net receiver of volatility but receives more than the volatility of the USD/PLN exchange rate, as shown by the net value of -9.16% in Table 2. The volatility of the EUR/PLN exchange rate has the highest transmission to the IT sector at 5.54% and the lowest to the food sector at 5.26%.

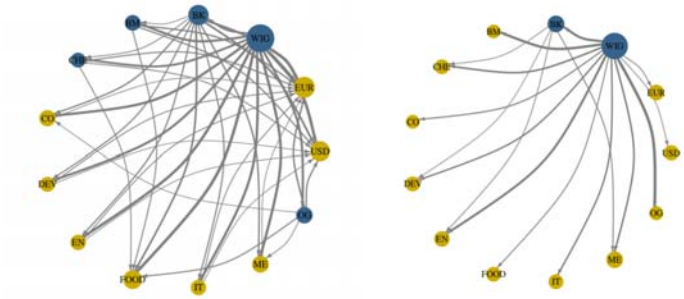
Table no. 2 Risk spillovers estimated on the quantile VAR (q=0.05)

Var	USD	EUR	WIG	BK	BM	CHE	CO	DEV	EN	FD	IT	ME	OG	FROM
USD	**19.09**	11.78	7.06	6.76	6.64	6.16	6.03	5.92	6.12	5.62	6.32	6.04	6.46	80.91
EUR	12.13	**19.6**	6.93	6.84	6.39	6.19	5.93	6.00	5.93	5.51	6.13	5.99	6.43	80.40
WIG	5.31	5.1	**14.37**	11.03	8.58	7.15	6.3	6.63	7.53	5.97	6.78	6.32	8.94	85.63
BK	5.55	5.5	12.07	**15.75**	7.32	7.01	6.28	6.75	7.01	6.08	6.59	6.41	7.67	84.25
BM	5.84	5.49	10.02	7.82	**16.84**	7.16	6.48	6.53	7.03	6.1	6.7	6.44	7.54	83.16
CHE	5.51	5.44	8.48	7.61	7.26	**17.04**	6.93	6.95	7.12	6.48	6.98	6.89	7.30	82.96
CO	5.66	5.43	7.84	7.16	6.9	7.26	**17.97**	7.33	6.54	6.9	7.28	6.73	7.01	82.03
DEV	5.46	5.39	8.08	7.52	6.83	7.13	7.17	**17.58**	6.84	6.85	7.23	7.1	6.83	82.42
EN	5.63	5.33	9.20	7.82	7.36	7.32	6.44	6.85	**17.53**	6.11	6.5	6.6	7.31	82.47
FD	5.49	5.26	7.74	7.21	6.78	7.09	7.17	7.29	6.46	**18.71**	6.7	6.96	7.12	81.29
IT	5.84	5.54	8.31	7.38	7.05	7.2	7.16	7.25	6.54	6.35	**17.67**	6.68	7.05	82.33
ME	5.70	5.52	7.92	7.34	6.9	7.29	6.78	7.3	6.76	6.73	6.8	**18.04**	6.92	81.96
OG	5.61	5.46	10.33	8.09	7.43	7.11	6.54	6.49	6.91	6.37	6.67	6.39	**16.59**	83.41
TO	73.74	71.24	104.01	92.57	85.43	84.08	79.22	81.31	80.78	75.08	80.68	78.55	86.58	
Incl Own	92.82	90.84	118.37	108.33	102.27	101.12	97.19	98.89	98.31	93.78	98.33	96.59	103.17	TCI= 82.56
NET	-7.18	-9.16	18.37	8.33	2.27	1.12	-2.81	-1.11	-1.69	-6.24	-1.67	-3.41	3.17	

Note: USD, EUR volatility USD/PLN and EUR/PLN exchange rates, WIG - volatility for Polish stock market, BK, BM, CHE, CO, DEV, EN, FOOD, IT, ME, OG - volatility for Polish stock markets sectors
Source: Results obtained by the authors

Figure 1a presents the results of the volatility transmission in the extreme lower quantile of the constructed system. It highlights net volatility transmitters with darker circles (for: overall stock market volatility, chemicals, basic materials, banks, and oil & gas) and net volatility receivers with lighter circles (EUR/PLN and USD/PLN exchange rates, media, IT, food, energy, developers, and construction sectors).

Figure no. 1. Net pairwise directional connectedness network at a)extreme quantile and b) median quantile



a) extreme low quatile *q=0.05* b) median quantile *q=0.50*

Source: Results obtained by the authors

In the median quantile, corresponding to a normal market, the volatility transmissions from exchange rates to Polish equity sectors (as shown in Table 3) are significantly reduced, with values ranging between 1.15% and 2.09%. This confirms the results obtained in other studies that volatility transmissions are much more intense under extreme market conditions. Although the foreign exchange market remains a net receiver of volatility in this situation, the results are lower (5.05% and 5.91% compared to 7.18% and 9.16% in a bear market). Additionally, according to Figure 1b, in the constructed system there are only two major volatility transmitters: the overall stock market and the banking sector.

Table no. 3 Risk spillovers estimated on the quantile VAR (q=0.50)

Var	USD	EUR	WIG	BK	BM	CHE	CO	DEV	EN	FD	IT	ME	OG	FROM
USD	**58.43**	18.01	3.40	2.66	2.86	1.82	2.06	1.43	1.79	1.64	2.23	1.39	2.30	41.57
EUR	18.78	**59.72**	3.12	2.93	2.11	1.89	1.86	1.45	1.59	1.55	1.56	1.49	1.96	40.28
WIG	2.02	1.62	**30.87**	16.71	8.54	5.14	3.94	4.12	6.09	3.55	4.43	3.32	9.64	69.13
BK	1.74	1.79	20.55	**37.96**	5.24	4.42	3.53	3.87	4.66	3.27	3.72	3.22	6.01	62.04
BM	2.09	1.68	12.68	6.26	**45.79**	4.51	3.72	3.51	4.44	3.17	3.78	3.00	5.37	54.21
CHE	1.55	1.74	8.07	5.77	5.01	**46.66**	4.98	4.59	4.54	3.86	4.77	3.81	4.65	53.34
CO	1.55	1.41	6.02	4.32	3.80	4.78	**53.21**	4.86	3.12	4.91	4.74	3.47	3.81	46.79
DEV	1.38	1.29	6.72	5.16	3.99	4.37	4.75	**51.93**	3.84	4.34	4.67	3.69	3.87	48.07
EN	1.59	1.27	9.83	6.11	4.80	4.87	3.26	3.88	**50.35**	3.12	3.08	3.13	4.72	49.65
FD	1.34	1.42	5.30	4.21	3.85	4.22	4.96	4.58	2.93	**56.27**	3.39	3.88	3.66	43.73
IT	1.77	1.45	7.04	4.87	4.25	4.74	5.24	4.45	3.20	3.28	**53.00**	2.90	3.82	47.00
ME	1.15	1.22	6.06	4.95	3.58	4.58	3.91	4.44	3.74	4.19	3.36	**55.50**	3.31	44.50
OG	1.57	1.47	14.27	6.97	5.37	4.31	3.67	3.24	4.06	3.34	3.57	2.80	**45.38**	54.62
TO	36.52	34.37	103.04	70.90	53.42	49.64	45.89	44.42	44.00	40.22	43.30	36.09	53.11	654.93
Incl Own	94.95	94.09	133.91	108.87	99.21	96.30	99.11	96.35	94.34	96.49	96.29	91.59	98.49	TCI= 50.38
NET	-5.05	-5.91	33.91	8.87	-0.79	-3.70	-0.89	-3.65	-5.66	-3.51	-3.71	-8.41	-1.51	

Note: USD, EUR volatility USD/PLN and EUR/PLN exchange rates, WIG - volatility for Polish stock market, BK, BM, CHE, CO, DEV, EN, FOOD, IT, ME, OG - volatility for Polish stock markets sectors
Source: Results obtained by the authors

In the extreme upper quantile, volatility transmissions from the two exchange rates (USD and EUR) increase in intensity, reaching maximum values of 7.43% for the chemicals sector and 7.44% for the developers' sector, respectively. Although exchange rates still act as net receivers of volatility, the intensity is much lower, the lowest of all three analyzed situations. Regardless of the stock market situation, whether under extreme or normal conditions, volatility in stock market sectors is transmitted to the foreign exchange market, albeit with a different net intensity, highlighting the asymmetry of volatility transmission.

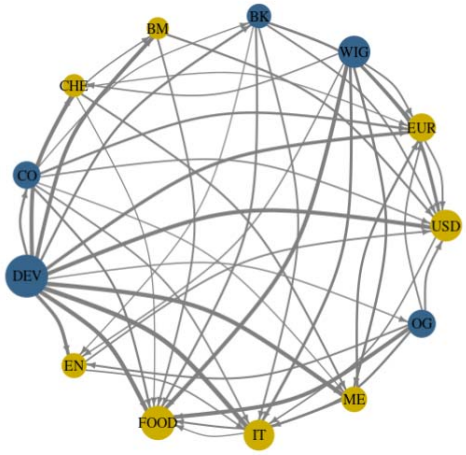
Table no. 4 Risk spillovers estimated on the quantile VAR (q=0.95)

Var	USD	EUR	WIG	BK	BM	CHE	CO	DEV	EN	FD	IT	ME	OG	FROM
USD	**9.58**	8.25	7.54	7.46	7.53	7.43	7.37	7.74	7.41	7.41	7.25	7.46	7.57	90.42
EUR	8.07	**9.53**	7.51	7.62	7.42	7.55	7.50	7.76	7.38	7.29	7.25	7.56	7.55	90.47
WIG	7.23	7.32	**9.06**	8.21	7.80	7.58	7.51	7.80	7.55	7.25	7.37	7.38	7.94	90.94
BK	7.28	7.38	8.31	**9.24**	7.61	7.58	7.64	7.65	7.55	7.25	7.34	7.43	7.75	90.76
BM	7.33	7.38	7.87	7.63	**9.43**	7.55	7.56	7.79	7.39	7.33	7.53	7.44	7.76	90.57
CHE	7.43	7.43	7.73	7.54	7.58	**9.13**	7.66	7.85	7.49	7.47	7.53	7.53	7.64	90.87
CO	7.22	7.27	7.58	7.52	7.42	7.58	**9.82**	7.99	7.56	7.49	7.57	7.50	7.49	90.18
DEV	7.35	7.44	7.70	7.41	7.42	7.47	7.76	**9.75**	7.69	7.49	7.47	7.48	7.57	90.25
EN	7.24	7.42	7.69	7.67	7.50	7.40	7.66	8.02	**9.58**	7.44	7.35	7.40	7.63	90.42
FD	7.34	7.39	7.64	7.46	7.52	7.58	7.70	7.91	7.43	**9.17**	7.51	7.63	7.72	90.83
IT	7.40	7.33	7.65	7.52	7.51	7.62	7.73	7.92	7.50	7.39	**9.37**	7.41	7.63	90.63
ME	7.39	7.32	7.63	7.49	7.52	7.74	7.62	7.90	7.44	7.45	7.45	**9.53**	7.52	90.47
OG	7.36	7.38	7.95	7.71	7.69	7.60	7.52	7.70	7.44	7.33	7.40	7.55	**9.36**	90.64
TO	88.66	89.32	92.80	91.25	90.53	90.67	91.23	94.03	89.84	88.59	89.00	89.77	91.76	1177.45
Incl Own	98.23	98.86	101.86	100.49	99.96	99.80	101.05	103.78	99.42	97.76	98.38	99.30	101.13	TCI= 90.57
NET	-1.77	-1.14	1.86	0.49	-0.04	-0.20	1.05	3.78	-0.58	-2.24	-1.62	-0.70	1.13	

Source: Results obtained by the authors

In a situation of extremely high volatility, the number of net volatility transmitters increases (similarly to the case of very low volatility), but the sectors involved are different. The highest net transmission is recorded for the developers sector at 3.78%, followed by the overall stock market, oil and gas, construction, and banks.

Figure no. 2. Net pairwise directional connectedness network at extreme high quantile



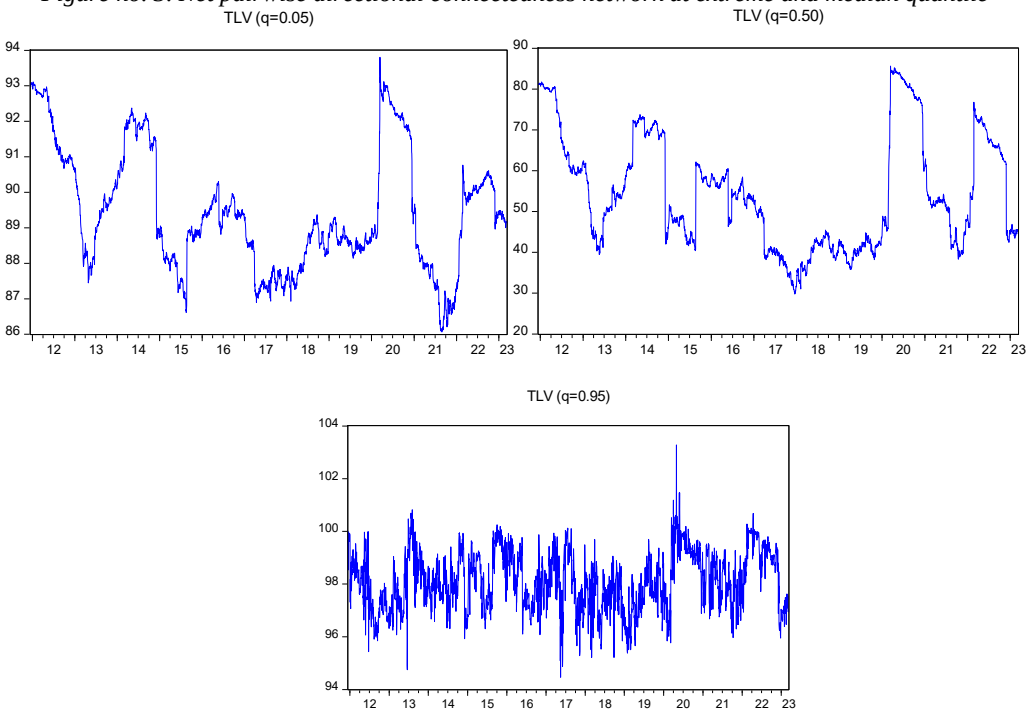
Source: Results obtained by the authors

The total volatility transmission index in the constructed system has the highest value of 93.57% in the extreme upper quantile, 82.56% in the extreme lower quantile, and 50.38% in the median quantile, confirming the existence of much more intense transmission under extreme conditions, which confirms the asymmetry of volatility transmission.

4.2 Dynamic volatility transmission analysis

While the static analysis of volatility transmission allowed us to identify the average level of transmission under different market conditions, we are now interested in examining how the total transmission index evolves over the studied period, also under various market conditions. Figure 3 shows a cyclical evolution of this total volatility transmission index in the extreme lower quantile and in the median quantile, while in the extreme upper quantile a significant fluctuation is observed, without the ability to distinguish volatility cycles.

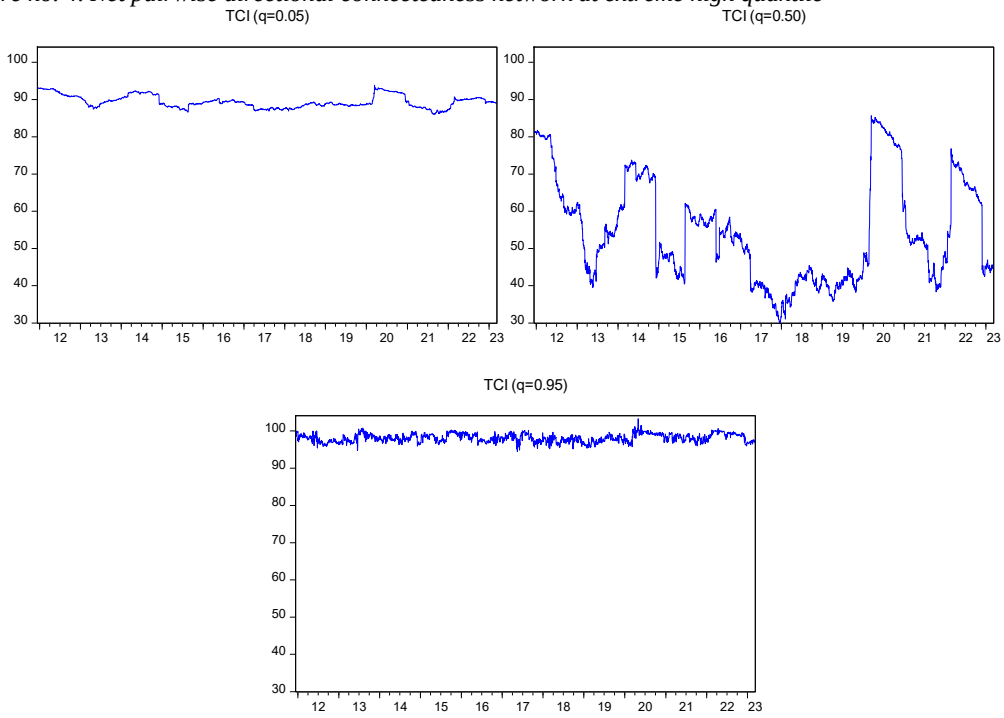
Figure no. 3. Net pairwise directional connectedness network at extreme and median quantile



Source: Results obtained by the authors

Figure 3 captured the evolution of the total transmission index by considering different scale values, allowing us to distinguish potential patterns even in small variations.

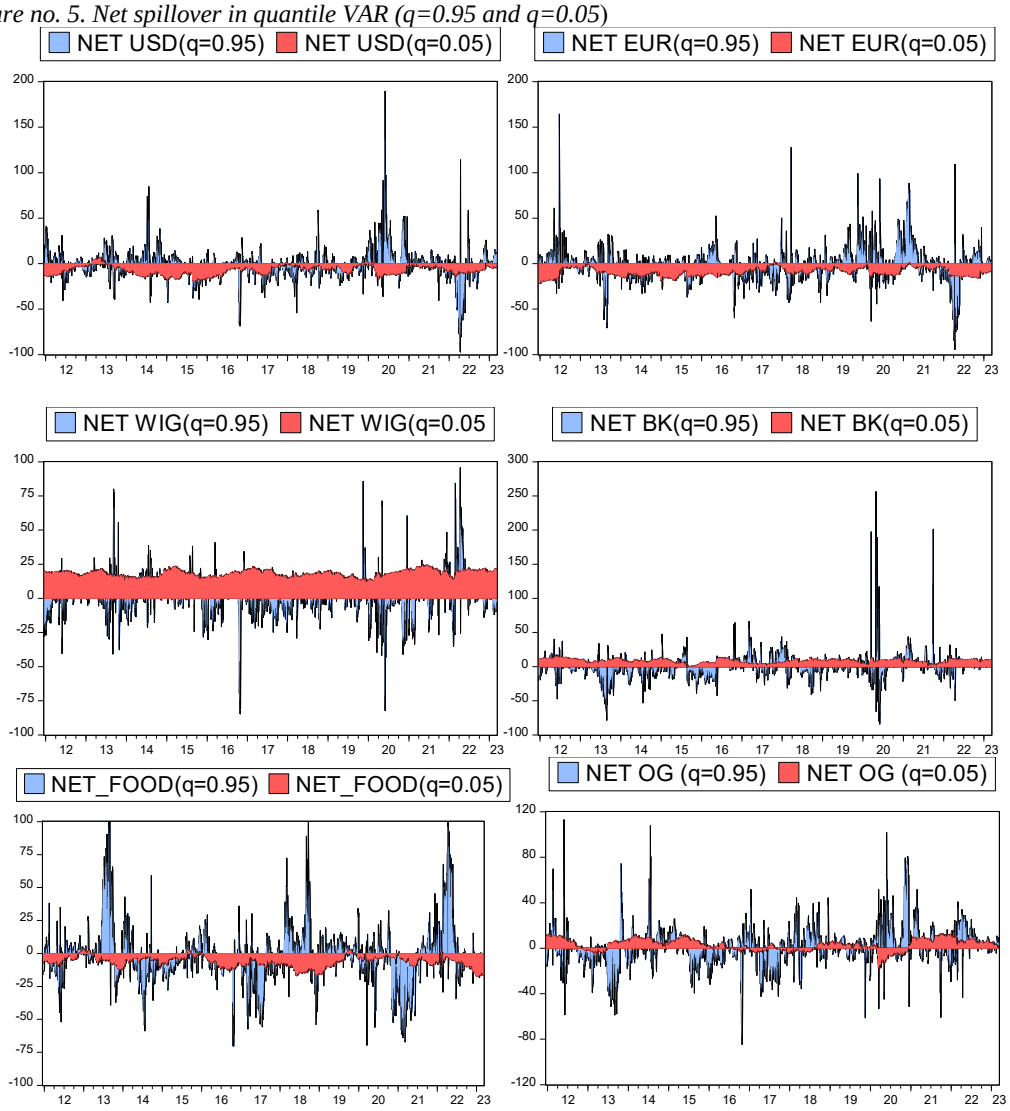
Figure no. 4. Net pairwise directional connectedness network at extreme high quantile



Source: Results obtained by the authors

When considering the same measurement scale (with values falling within the 30% to 100% range), as shown in *Figure 4*, it is evident that, under extreme conditions, the transmission index records very high values and fluctuations are relatively small compared to its value. However, we observe that in the final period of the European Debt Crisis (January 4, 2010 - December 31, 2012), oil crises, Brexit period (August 21, 2015 - September 29, 2019), pandemic period (January 2, 2020 - November 9, 2020), and the Russo-Ukrainian War (from February 24, 2022) until the final date of the sample, as well as in normal market conditions, volatility transmission has increased significantly, reaching maximum values.

Figure no. 5. Net spillover in quantile VAR (q=0.95 and q=0.05)



Source: Results obtained by the authors

Figure 5 illustrates the net volatility transmission in various extreme situations, as highlighted by the extreme low and high quantiles for several economic sectors and exchange rates. The key finding is the substantial time variation in volatility transmission. While in the extreme low quantile, the transmission index values could be considered "relatively" close, in the extreme high quantile, extremely large variations are the norm. Positive values represent net volatility transmission, while negative values of the index indicate net volatility reception. The banking sector and the PLN/USD exchange rate are characterized by the highest transmission index values, reaching around 250% and 190%, respectively, during the COVID-19 crisis. The PLN/EUR

exchange rate recorded the highest volatility transmission value, 160%, in the first part of the study period characterized by the European Debt Crisis. For both exchange rates, two distinct situations are observed: during the COVID-19 crisis, they were net volatility transmitters; however, with the start of the war in Ukraine, they became net volatility receivers.

5. Conclusions

Studying the transmission of volatility between the foreign exchange market and economic sectors of the stock market reveals essential features necessary for coordinating activities and making specific portfolio management decisions.

By applying quantile VAR to a system created from the volatility of two exchange rates and the indices of economic sectors on the Polish stock market, we identified several important characteristics regarding the transmission of volatility. The research objectives were achieved by identifying the average level of volatility transmission between the foreign exchange markets and the economic sectors of the Polish stock market in different market conditions, estimating the evolution of the transmission level over the studied period, and identifying the extreme points of the volatility transmission level both in the system and for the two exchange rates.

Regarding the first research question, whether the intensity of information spillovers varies in different market conditions, we can affirm that the total transmission of volatility varies and we identified higher transmission values in extreme conditions compared to normal market conditions, which confirms all the researches that had been able to estimate the evolution over time of the volatility connection.

For the second research question regarding the net direction of volatility transmission, we can say that the stock market exerts greater net transmission to the foreign exchange market, a situation that has also been confirmed in other works (Hung, 2022).

The third research question aimed to identify the sectors of the Polish stock market that are the strongest connected with changes in exchange markets. We identified the strongest connections between the volatility of the USD/PLN exchange rate and the basic materials and IT sectors in the extreme low quantile, the basic materials sector in the median quantile, and the chemicals sector in the extreme high quantile. The strongest connections between the volatility of the EUR/PLN exchange rate occur with the IT sector in the extreme low quantile, the chemicals sector in the median quantile, and the developers sector in the extreme high quantile.

Research into volatility transmission can be extended to analyze it between the foreign exchange market and each of the companies that are part of an economic activity sector.

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