Research Journal of Finance and Accounting
ISSN 2222-1697 (Paper) ISSN 2222-2847 (Online)
Vol.13, No.14, 2022

Polish Stock Market Performance and Its Relationships with Macroeconomic Variables

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Abstract
This study is the first attempt to apply the VAR model to analyze the impact of macroeconomic variables on Polish stock market performance measured as stock market indexes. It examines short-run and long-run relationships between selected macroeconomic variables, meaning gross domestic product, money supply, consumer price index proxy for inflation and exchange rate (PLN per USD), and stock prices represented by WIG20 and its 3 separate sectors: banking, fuel and real-estate markets WIG banks, WIG fuels, and WIG real-estate.
Keywords: Stock Prices, Macroeconomic Variables, Cointegration, VAR model, VECM model, Polish stock market.
DOI: 10.7176/RJFA/13-14-07
Publication date: August 31st 2022

Introduction

Polish stock market and its impact on the economy have grown significantly over the past decades. Warsaw Stock Exchange which started its activity in 1991, is currently one of the biggest European Stock Exchanges. Indicators such as growing ratio of the capitalization of the Warsaw Stock Exchange to the GDP or Number of companies listed on the Warsaw Stock Exchange illustrated the strong interaction between the stock exchange and the real economy and its significant role in the entire economy. Therefore, an interesting issue seems to be the empirical verification of these relationships between the stock exchange and the real economy. The beginnings of empirical verification of the influence of macroeconomic values on the behavior of stock prices date back to the end of the 1970s and the beginning of the 1980s, it was initially done for the United States, and later for Japan and Great Britain. The study of this type for the Polish market was performed in 2006. The Polish market in this context is relatively little verified. This study is the first one to focus on separate industries and their indexes reactions to macroeconomic changes.

The study has used Dickey-Fuller Unit Root Cause Test and Pearson Correlation Test, Johansen- Juselius Cointegration Test to examine long-term relationships, as well as Granger Causality Test, VECM Causality Test, and VAR model from the short-term perspective.

Methodology

The main methodology used in this article is Vector autoregression model (C.Sims 1980). VAR model is a multi-equation model with an autoregression structure. It can be also treated as a generalization of the ARDL model. The VAR model is usually used for stationarity analyzes. To describe and examine nonstationary variables, the VAR is being transformed into Vector Error Correction Model (VECM), which is the most often used in practice. The areas of application of both VAR and VECM models are as follows:

- dependency modeling;
- forecasting;
- cointegration examination, meaning long-term relationship between two nonstationary variables;
- impulse response function analysis, that let the researcher assume to what extend does one variable react to the shock of the other variable;
- variance decomposition, based on which it is determined what is share of other variables in explaining the error of a specific variable in the model;
- causality tests.

The VAR model can be represented as follows:

$$\Delta X_t = A_0 D_t + \sum_{i=1}^{k} A_i \Delta X_{t-1} + \varepsilon_t \quad (1)$$

where:
X_t- vector of observations of the current values of the analyzed processes;

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D_t –a vector containing deterministic components (e.g. trend, seasonality);
A_i –matrix of autoregressive operators of individual processes;
A_0 – matrix of parameters at the components of the vector Dt;
ε_t – vector of residual processes;
k- VAR model row.

The VAR model deviates from the classical distinction between endogenous and exogenous variables, and does not limit the value of the parameters. The VAR model deviates from the classical distinction between endogenous and exogenous variables, and does not limit the value of the parameters (Osińska 2006). In the conditions of cointegration of time series, the VECM model is usually used. Time series integration implies the existence of a common long-term equilibrium path for these series. In practice, cointegration occurs when time series are not stationary (most often they are integrated in the first difference) and there is a stationary linear combination thereof. In studies of the phenomenon of cointegration, the most commonly used are the trace test, the maximum eigenvalue test (Johansen 1991, 1992), or the Engle- Granger procedure. The VECM model can be written as follows (Johansen 1995)

$$X_t = \Psi_0 D_t + \sum_{i=1}^{k-1} \Pi_i X_{t-i} + \Pi X_{t-1} + \xi_t \qquad (2)$$

where:
$\Pi -$ a matrix of coefficients containing the effects of short-term adjustments and long-term cointegrating relationships $\Pi = \sum_{i=1}^{k} A_i - I$;
Ψ_0 –matrix of coefficients with deterministic components of a vector D_t;
Π_i –matrix of autoregression coefficients $\Pi_i = -\sum_{i=j+1}^{k} A_i$;
ξ_t –white noise process.

The complexity of the structure of the model in question and the mutual interactions of variables may make it difficult to interpret the parameters. Accordingly, the impulse response function is used to selectively analyze the effect of one variable on another variable. For this purpose, the vector autoregression model is reduced to the moving average process in which it is taken into account also the impact of random variable (ξ).

$$X_t = \sum_{i=1}^{\infty} \Phi_i \xi_{t-i} \qquad (3)$$

where:
$\Phi_i = A^i B^{-1}$,B- matrix of parameters standing at non-lagging vector component values X_t.

The elements of the matrix Φ_i can be interpreted as responses of any variable of vector X_t to an impulse from another variable of this vector, assuming ceteris paribus conditions. A method supplementing the analysis of interactions between the variables is the decomposition of the variance of errors in the forecasts of individual components of the X_t vector. It makes it possible to determine the contribution of each component of this vector to the explanation of the forecast error of the highlighted forecast variable.

Empirical analysis

Data

The data set includes 100 observations from the period of 24 years. The sample used quarterly data from 1996Q1 to 2020Q4. The study contains Warsaw Stock Exchange Index WIG20, WIG banks, WIG fuels, WIG real-estate, Money Supply M2, Consumer Price Index CPI proxy for inflation, Exchange Rate EX and Gross Domestic Product GDP.

Table 1 Description of variables

Variable	Description	Variable Type	Source
WIG20	Warsaw Stock Exchange Index for the 20 biggest and the most liquid companies	Dependent Variable	Stooq database
WIG banks	Warsaw Stock Exchange Index for banking sector	Dependent Variable	Stooq database
WIG fuels	Warsaw Stock Exchange Index for fuels sector	Dependent Variable	Stooq database
WIG real-estate	Warsaw Stock Exchange Index for real-estate sector	Dependent Variable	Stooq database
GDP	Gross Domestic Product (quarterly percentages)	Explanatory Variable	Bankier database
M2	Money Supply (M2) (YOY%)	Explanatory Variable	Bankier database
CPI	Consumer Price Index (proxy for inflation)	Explanatory Variable	OECD database

Variable	Description	Variable Type	Source
EX	Exchange rate (PLN per USD)	Explanatory Variable	OECD database

Source: own work based on collected data set.

Empirical results

Pearson Correlation

Table 2 Pearson Correlations (N=100)

Variable	WIG20	WIG banks	WIG fuels	WIG realestate	GDP	M2	CPI	EX
WIG20	1.0000							
WIG banks	0.8024	1.0000						
WIG fuels	0.4512	0.7356	1.0000					
WIG realestate	0.7535	0.3857	0.1781	1.0000				
GDP	0.2900	0.0403	0.0125	0.3670	1.0000			
M2	0.3208	0.7229	0.8577	-0.0321	-0.3611	1.0000		
CPI	-0.3996	-0.6463	-0.4743	-0.2063	0.3135	-0.5525	1.0000	
EX	0.5390	0.2901	-0.1146	0.5427	0.2784	-0.1572	0.1546	1.0000

Source: own work based on collected data set.

Table 2 presents the Pearson's Correlation Test conducted on the previously determined data set and reveals information on the strength and slope of the relationships between the eight macroeconomic variables. The results prove a positive relationship between WIG20/ WIG banks and GDP, M2, exchange rate, between WIG fuels and GDP and M2, and between WIG real-estate and GDP and exchange rate. A negative correlation was observed between all stock market indexes and inflation, WIG fuels and exchange rate, and WIG real estate and M2. Nevertheless, the correlation for most of the pairs is weak (value of 0.10-0.39). The correlation between WIG banks or WIG fuels and M2 are clearly the strongest. M2 is regulated by the Central Bank of Poland, but it is impacted also by the value of cash and non-cash loans granted by commercial banks, therefore the stock prices in this sector are higher in short term.

Stationarity test

To verify the stationarity, two diagnostic tests were used: Dickey-Fuller and Philips- Perron. Tests were performed including both the intercept only model and the intercept and trend components. It is clear that the null hypothesis of non-stationarity cannot be rejected for any of the series in their levels since ADF statistics for all variables are not less than the critical values at any significance level, i.e., 1%, 5%, and 10%. Therefore, we conclude that all series are non-stationary in levels. The test results were consistent in all cases and clearly indicated the non-stationarity of the variables and the stationarity of their first differences. The test outcome proves non stationary as the p-value doesn't change much in the sequence with lags(1). In this way, it was confirmed that the considered variables are first-level integrated.

VAR model

In order to establish the most reasonable and ideal VAR model, we model the sequence data step by step, and use LR / FPE / AIC / SC / HQ criterion to find the optimal lag period. The test results are shown in Table 3, when the lag order P = 1, LR / FPE / AIC / SC / HQ can achieve the best at the same time, the VAR model is the best.

Table 3 Optimal Lag Lengths of the VAR Model

Log	Log- Likelihood	LR	FPE	AIC	SBIC	HQ
0	-94.2444		1.8e-09	2.55611	2.65161	2.79431
1	676.91	1542.3	3.8e-17*	-15.1227*	-14.2632*	-12.9789*
2	736.705	119.59	4.4e-17	-15.0176	-13.3941	-10.9682
3	793.974	114.54	5.8e-17	-14.8494	-12.4618	-8.89429
4	863.226	138.5*	6.5e-17	-14.9806	-11.8291	-7.11995

Source: own work based on collected data set.

LR: Sequential modified LR test statistic (each test at 5% level) FPE: Final prediction error

AIC: Akaike information criterion SBIC: Schwarz information criterion

HQIC: Hannan-Quinn information criterion

Table 4 Results of Vector Autoregression for WIG20

	Coef.	Std.Err.	z	P>|z|	[95% Conf. Interval]	
			dWIG20			
L1	.1307589	.1140709	1.15	0.252	-.092816	.3543339
L2	-.0951668	.1165232	-0.82	0.414	-.323548	.1332145
L3	.0295774	.1188396	0.25	0.803	-.203344	.2624987
L4	-.0732534	.0995174	-0.74	0.462	-.268304	.1217971
			dWIG banks			
L1	-.1154671	.2150629	-0.54	0.591	-.5369827	.3060485
L2	.1202152	.2496884	0.48	0.630	-.3691651	.6095956
L3	-.0510951	.2464438	-0.21	0.836	-.5341162	.4319259
L4	.0141579	.1823803	0.08	0.938	-.3433009	.3716167
			dWIG fuel			
L1	-.1463878	.2408143	-0.61	0.543	-.6183752	.3255995
L2	.1019906	.3832825	0.27	0.790	-.6492292	.8532105
L3	.1006581	.4107926	0.25	0.806	-.7044806	.9057969
L4	-.1318114	.2790864	-0.47	0.637	-.6788106	.4151878
			dWIG real estate			
L1	-.056549	.1899046	-0.30	0.766	-.4287553	.3156572
L2	.651094	.3059849	2.13	0.033	.0513747	1.250813
L3	-.4615752	.2556641	-1.81	0.071	-.9626676	.0395173
L4	-.1844523	.1542426	-1.20	0.232	-.4867623	.1178576
			dGDP			
L1	.8488139	18.87837	0.04	0.964	-36.15211	37.84974
L2	33.38011	21.31618	1.57	0.117	-8.39884	75.15906
L3	29.73333	28.0009	1.06	0.288	-25.14743	84.61408
L4	-7.802389	26.09992	-0.30	0.765	-58.957	43.35252
			dM2			
L1	-.4074015	1.38624	-0.29	0.769	-3.124393	2.30959
L2	.4220227	1.40747	0.30	0.764	-2.336567	3.180613
L3	.4397201	1.623562	0.27	0.787	-2.742404	3.621844
L4	-.4060977	1.68731	-0.24	0.810	-3.713167	2.900972
			dCPI			
L1	6.895417	30.12673	0.23	0.819	-52.15189	65.94272
L2	-36.87104	32.3948	-1.14	0.255	-100.3637	26.6216
L3	11.8266	32.45271	0.36	0.716	-51.77955	75.43275
L4	-16.72498	29.79893	-0.56	0.575	-75.12982	41.67986
			dEX			
L1	4851.601	1148.138	4.23	0.000	2601.291	7101.911
L2	-2294.426	1188.722	-1.93	0.054	-4624.278	35.42556
L3	-212.7222	1166.448	-0.18	0.855	-2498.919	2073.474
L4	-654.4366	1211.811	-0.54	0.589	-3029.542	1720.669
_cons	3.559231	48.9277	0.07	0.942	-92.33729	99.45575

Source: own work based on collected data set.

Table 5 Results of Vector Autoregression for WIG banks

	Coef.	Std.Err.	z	P>|z|	[95% Conf. Interval]	
			dWIG20			
L1	-.4166223	.5759142	-0.72	0.469	-1.545393	.7121488
L2	-.0594784	.5596331	-0.11	0.915	-1.156339	1.037382
L3	-.3775326	.5611123	-0.67	0.501	-1.477292	.7222272
L4	1.190882	.5462758	2.18	0.029	.1202011	2.261563
			dWIG banks			
L1	-.0461792	.1526885	-0.30	0.762	-.3454432	.2530847
L2	.0059907	.1460659	0.04	0.967	-.2802932	.2922745
L3	.0369764	.1602662	0.23	0.818	-.2771396	.3510923
L4	-.1043038	.1544983	-0.68	0.500	-.407115	.1985074
			dWIG fuel			
L1	.1515956	.1704566	0.89	0.374	-.1824933	.4856845
L2	- .5040061	.1858996	-2.71	0.007	-.8683627	-.1396495
L3	.3353083	.202808	1.65	0.098	-.0621882	.7328047
L4	-.3137314	.1948853	-1.61	0.107	-.6956996	.0682369
			dWIG real estate			
L1	.2696297	.2968349	0.91	0.364	-.3121561	.8514154
L2	.6371976	.3199365	1.99	0.046	.0101336	1.264262
L3	-.0905974	.3126101	-0.29	0.772	-.703302	.5221072
L4	-.8297067	.3098743	-2.68	0.007	-1.437049	-.2223642
			dGDP			
L1	92.91936	47.79548	1.94	0.052	-.7580616	186.5968
L2	138.5932	54.77916	2.53	0.011	31.22803	245.9584
L3	-4.154959	65.56858	-0.06	0.949	-132.667	124.3571
L4	-8.071955	60.93717	-0.13	0.895	-127.5066	111.3627
			dM2			
L1	-4.739731	3.432341	-1.38	0.167	-11.467	1.987534
L2	1.50006	3.432514	0.44	0.662	-5.227544	8.227664
L3	-.0341692	3.944885	-0.01	0.993	-7.766003	7.697664
L4	-2.378815	4.011201	-0.59	0.553	-10.24062	5.482994
			dCPI			
L1	-102.7028	72.04949	-1.43	0.154	-243.9172	38.5116
L2	5.388067	80.85688	0.07	0.947	-153.0885	163.8646
L3	-56.22658	81.02115	-0.69	0.488	-215.0251	102.572
L4	52.68026	69.59442	0.76	0.449	-83.7223	189.0828
			dEX			
L1	13428.38	3059.692	4.39	0.000	7431.494	19425.26
L2	2246.404	3015.939	0.74	0.456	-3664.727	8157.535
L3	2854.444	3073.248	0.93	0.353	-3169.011	8877.898
L4	-685.7138	3287.221	-0.21	0.835	-7128.548	5757.121
_cons	162.2489	121.4626	1.34	0.182	-75.81346	400.3112

Source: own work based on collected data set.

Table 6 Results of Vector Autoregression for WIG fuels

	Coef.	Std.Err.	z	P>|z|	[95% Conf. Interval]	
			dWIG20			
L1	.0371509	.4793305	0.08	0.938	-.9023196	.9766214
L2	-.3280266	.4657798	-0.70	0.481	-1.240938	.5848851
L3	-.3808565	.4670109	-0.82	0.415	-1.296181	.5344681
L4	-.077721	.4546626	-0.17	0.864	-.9688433	.8134013
			dWIG banks			
L1	-.1153542	.1270819	-0.91	0.364	-.36443	.1337217
L2	.0444164	.1215699	0.37	0.715	-.1938562	.282689
L3	-.092367	.1333887	-0.69	0.489	-.3538041	.1690701
L4	.1127045	.1285882	0.88	0.381	-.1393237	.3647328
			dWIG fuel			
L1	.426032	.1418702	3.00	0.003	.1479715	.7040925
L2	-.7368888	.1547233	-4.76	0.000	-1.040141	-.4336366
L3	.4474597	.1687961	2.65	0.008	.1166254	.778294
L4	-.4196308	.1622021	-2.59	0.010	-.737541	-.1017205
			dWIG real estate			
L1	-.448401	.2470542	-1.81	0.070	-.9326184	.0358163
L2	.9286378	.2662815	3.49	0.000	.4067356	1.45054
L3	-.0730534	.2601838	-0.28	0.779	-.5830044	.4368976
L4	.078226	.2579068	0.30	0.762	-.4272621	.5837141
			dGDP			
L1	-15.92573	39.77994	-0.40	0.689	-93.89297	62.04151
L2	121.3904	45.59242	2.66	0.008	32.03092	210.7499
L3	74.33772	54.5724	1.36	0.173	-32.62221	181.2977
L4	-123.7037	50.7177	-2.44	0.015	-223.1086	-24.29881
			dM2			
L1	-4.659685	2.85672	-1.63	0.103	-10.25875	.9393837
L2	-6.953151	2.856864	-2.43	0.015	-12.5525	-1.3538
L3	2.641314	3.283308	0.80	0.421	-3.793852	9.07648
L4	3.073801	3.338502	0.92	0.357	-3.469542	9.617145
			dCPI			
L1	-56.85425	59.96642	-0.95	0.343	-174.3863	60.67778
L2	25.87248	67.29678	0.38	0.701	-106.0268	157.7717
L3	88.47989	67.4335	1.31	0.189	-43.68734	220.6471
L4	-6.352569	57.92308	-0.11	0.913	-119.8797	107.1746
			dEX			
L1	2415.357	2546.566	0.95	0.343	-2575.82	7406.535
L2	-5508.693	2510.15	-2.19	0.028	-10428.5	-588.8882
L3	-671.7191	2557.848	-0.26	0.793	-5685.01	4341.572
L4	369.8651	2735.937	0.14	0.892	-4992.473	5732.204
_cons	175.364	101.0927	1.73	0.083	-22.7741	373.502

Source: own work based on collected data set.

Table 7 Results of Vector Autoregression for WIG real-estates

	Coef.	Std.Err.	z	P>|z|	[95% Conf. Interval]	
		dWIG20				
L1	-.3362988	.3090489	-1.09	0.277	-.9420236	.2694259
L2	-.1622132	.3003121	-0.54	0.589	-.7508142	.4263877
L3	-.0184224	.3011059	-0.06	0.951	-.608579	.5717342
L4	.3540317	.2931443	1.21	0.227	-.2205205	.9285839
		dWIG banks				
L1	.024931	.0819362	0.30	0.761	-.135661	.1855229
L2	.0222677	.0783823	0.28	0.776	-.1313588	.1758943
L3	-.0767355	.0860025	-0.89	0.372	-.2452974	.0918264
L4	-.082169	.0829074	-0.99	0.322	-.2446645	.0803265
		dWIG fuel				
L1	-.0625645	.091471	-0.68	0.494	-.2418443	.1167153
L2	-.0445911	.099758	-0.45	0.655	-.2401133	.1509311
L3	.0261497	.1088315	0.24	0.810	-.1871562	.2394555
L4	-.0526541	.10458	-0.50	0.615	-.2576271	.1523189
		dWIG real estate				
L1	.4113784	.1592885	2.58	0.010	.0991786	.7235781
L2	.3908665	.1716853	2.28	0.023	.0543694	.7273635
L3	-.0312758	.1677539	-0.19	0.852	-.3600673	.2975157
L4	-.1917069	.1662857	-1.15	0.249	-.5176209	.1342072
		dGDP				
L1	39.94584	25.64816	1.56	0.119	-10.32364	90.21531
L2	29.4081	29.39577	1.00	0.317	-28.20655	87.02275
L3	-24.31866	35.18562	-0.69	0.489	-93.28121	44.64389
L4	8.766529	32.7003	0.27	0.789	-55.32488	72.85794
		dM2				
L1	-1.138301	1.841874	-0.62	0.537	-4.748308	2.471705
L2	2.692693	1.841967	1.46	0.144	-.9174954	6.302882
L3	.627774	2.116917	0.30	0.767	-3.521307	4.776855
L4	-4.292169	2.152503	-1.99	0.046	-8.510998	-.0733404
		dCPI				
L1	-24.9238	38.66342	-0.64	0.519	-100.7027	50.85512
L2	38.54875	43.38968	0.89	0.374	-46.49345	123.591
L3	-28.04605	43.47783	-0.65	0.519	-113.261	57.16893
L4	16.49978	37.34598	0.44	0.659	-56.69699	89.69656
		dEX				
L1	2983.015	1641.901	1.82	0.069	-235.053	6201.083
L2	-3316.039	1618.423	-2.05	0.040	-6488.089	-143.9893
L3	-3323.419	1649.176	-2.02	0.044	-6555.744	-91.09311
L4	-784.8212	1763.999	-0.44	0.656	-4242.195	2672.553
_cons	47.75206	65.17965	0.73	0.464	-79.9977	175.5018

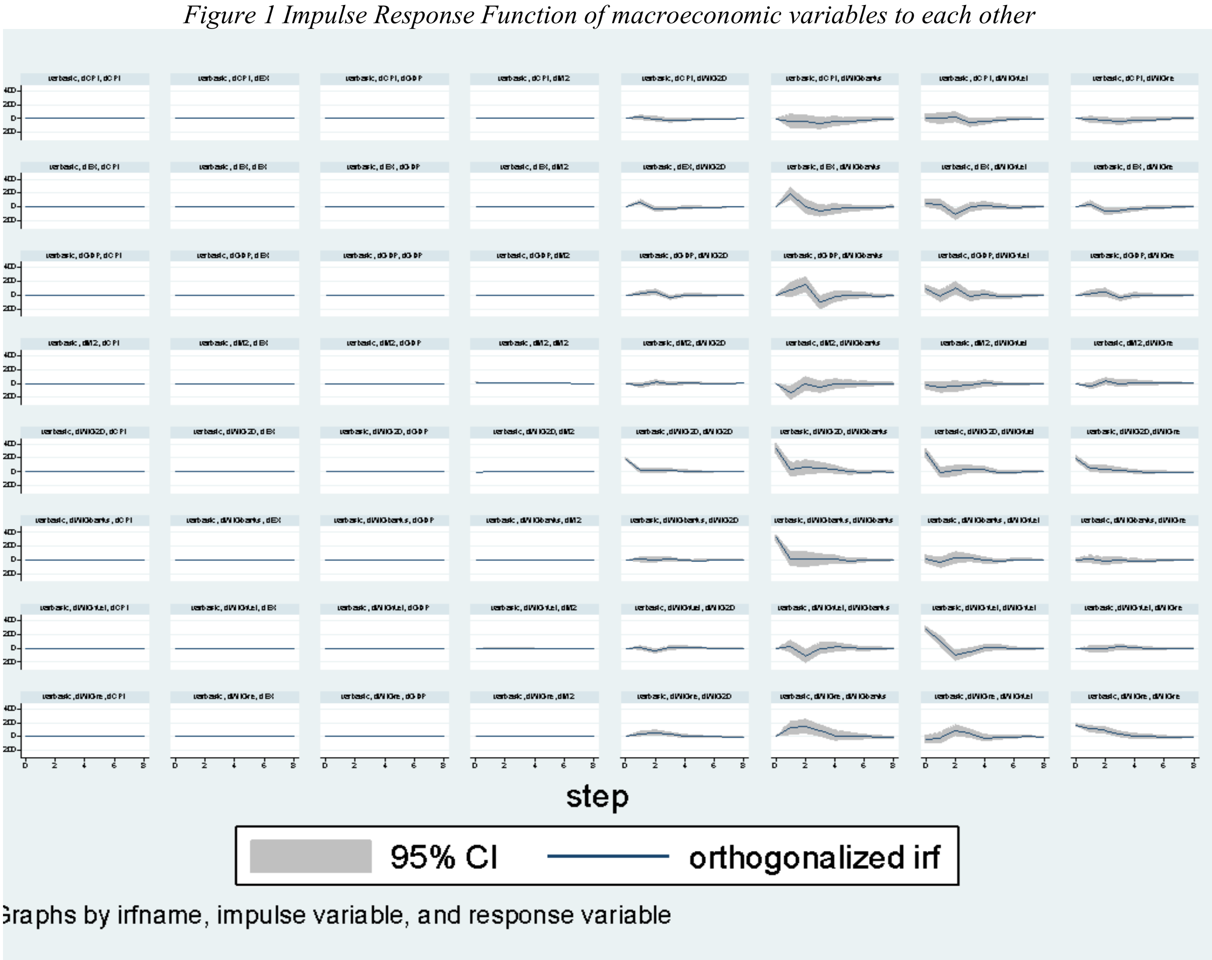
Source: own work based on collected data set.

Impulse Response Function

Figure 1 shows the results of the impulse responses of stock prices to Cholesky one standard deviation innovations of the endogenous variables: stock price (WIG20), stock price for the banking sector (WIG banks), stock price for fuels sector (WIG fuel), stock price for the real-estate sector (WIG real-estate), consumer price index (CPI), the exchange rate (EX), gross domestic product (GDP) and money supply (M2). The X-axis represents the periods, in the example below 16 quarters were considered while the Y-axis shows the percentage variation to the shock. Reactions of all stock indexes, meaning WIG20, WIG banks, WIG fuel, and WIG real-estate present the same trends with the impulse of one macroeconomic variable. The response of the stock prices themselves to each shock indicates that a one standard deviation shock on WIG20 has a positive effect on its prices throughout the first eight quarters. An extremely rapid effect was observed just after implementation of the shock, which is quickly dropping in the first period and then fluctuate in the eighth one. The impulse of GDP presents the biggest error and a slight increase in reaction to shock after the second period. The impulse of EX presents increase up to around 80% in the first period and then drop -20% in the second period, the ratio fluctuate slightly. The reaction of WIG20 to the shock of M2 manifests in a 20% drop in the first period and then comes back to the regular level. The impulse of CPI remains quite stable but is followed by a relatively huge error. The responses of the macroeconomic variables do not show any reaction of shocks into GDP, M2, CPI, and EX.

As trends of all other WIG indexes remain the same as WIG20, they are all going to be discussed together. Firstly, the impulse of CPI on WIG banks, WIG fuel, and WIG real estate is slightly negative until the fourth period, nevertheless, it is not as significant as impulses of other macroeconomic variables. Secondly, the impulse of EX in long run is reported positive, it is especially visible in the case of WIG banks. An increase in the exchange rate has always positive impact on the banking sector, making them earn more and increase their stock price. The analyzing GDP's impact we can say that the reaction is much more intense in terms of sectoral WIG indexes than on WIG20. Nevertheless, it keeps fluctuating until the sixth period. Finally, the impact of M2 is slightly negative for WIG20, WIG fuels, and WIG real estate, but reports a more rapid reaction on WIG banks in the second period.

Figure 1 Impulse Response Function of macroeconomic variables to each other



Opposite impulse response functions were performed for four WIG indexes on macroeconomic variables. It was observed that non of the indexes impact macroeconomic variables in the short run.WIG20, WIG banks, WIG fuels, and WIG real estate has just an impact on each other.

Conclusion

The conclusions are that the increase (decrease) in the value of the stock exchange index WIG20 is usually preceded by:

- economic recovery (cooling) expressed by an increase in the real rate of changes in GDP;
- decrease (increase) of inflation;
- increase (decrease) of exchange rate in the long run;
- decrease (increase) of money supply in the short run, and increase (decrease) of money supply in the long run.

The results for sectoral indexes do not differ for WIG20 in the short run. Nevertheless, in long run, 2 study problems were verified contrary to WIG20. They are:

- the decrease in the exchange rate makes the WIG fuel index rise;
- the decrease in money supply makes the WIG real-estate drop.

Implications of this study include the following. (i) Prediction of stock market returns becomes more difficult as the volatility of the macroeconomic variables increases in the short run. (ii) Investors should look at the systematic risks revealed by these macroeconomic variables when structuring their portfolios and diversification strategies. (iii) Policymakers should seek to minimize macroeconomic fluctuations considering the effect of macroeconomic variables changes on the stock market when formulating economic policy.

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