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Financial Contagion of Russian Companies During the COVID-19 Pandemic

Marina Malkina
Doctor of Economics, Professor, Chief Researcher, Center for Macro- and Microeconomics,
Lobachevsky State University of Nizhny Novgorod, Nizhny Novgorod, Russia,
mmuri@yandex.ru, ORCID

Dmitry Rogachev
Candidate of Sciences in Sociology, Researcher, Center for Macro- and Microeconomics,
Lobachevsky State University of Nizhny Novgorod, Nizhny Novgorod, Russia,
rogistyle@mail.ru, ORCID

Abstract

The article examines the financial contagion of Russian companies during the pandemic COVID-19. Financial contagion refers to the strengthening of interconnections between segments of the financial market during a crisis, when turbulence from one market is transferred to others, and the relationship between parameters goes beyond normal market interactions. The study involved shares of 27 companies in the energy, financial, telecommunications, consumer and raw materials sectors of the Russian economy. As exogenous variables supposedly influencing the market values of these companies, we tested the rouble exchange rate against the US dollar, the spot price of Urals oil and the yield on annual government bonds (proxies for the cost of borrowings). Identification of the potential contagion period was based of the sliding coefficient of variation of these variables. The construction of VARX models convincingly proved the increasing influence of the exchange rate and the bond yield rate on the fundamental (market) return of Russian companies in the short term (during the acute phase of the pandemic) and the delayed impact of oil prices on it, which manifested itself during the chronic crisis. Contagion testing was also carried out on the basis of a change (growth) in the coefficient of determination in the acute phase of the pandemic as compared to the pre-crisis and post-crisis periods. For a more accurate assessment of the contribution of each variable to contagion, we used the method of source decomposition of the coefficient of determination with a correction for heteroscedasticity. This made it possible to identify the companies most vulnerable to financial contagion during the pandemic, and the sources of their contagion, as well as the market segments that showed the greatest resilience. The study can be useful for managers in maintaining their companies' market value, for investors in effective portfolio diversification, and for public authorities when pursuing a policy of financial stabilization in a crisis. The limitations of the study are related to the imperfections of the VARX models method, as well as to the specifics of the pandemic crisis, the conclusions from which can only be partially applied to other types of crises.

Keywords: Russian companies, market return, financial contagion, COVID-19 pandemic, exchange rate, oil price, yield of government bonds, VARX model

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Introduction

Researchers all over the world pay increasingly more attention to the financial contagion and systemic risk concept which implies that a shock in one country, industry or economic sector may be transmitted to other countries, industries and economic sectors.

The strengthening interrelation between financial markets, the global market integration and the growing role of financial intermediaries induce rapid spillover effects which may spread any minor shock throughout the economy. Capital flows, trade and commercial relationships, competitive devaluation are the main reasons for spreading the spillover effects of an economic shock among countries and markets [1–3]. Investors' behavior, their sentiment, fears and concerns have a special impact on the spillover of shocks among markets [4]. Financial contagion between different sectors of the economy is caused by a strong bond between stock market indices and exchange rate fluctuations, oil price yield, energy demand, industrial production and functioning of commodity markets [5; 6].

The COVID-19 pandemic once again pointed out financial fragility and vulnerability of the economy to exceptional risks such as "black swan" events. The state policy measures taken to keep the infection at bay, for example, isolation, suspension of industrial and commercial activities, mobility restrictions caused a serious economic shock both in supply and demand which has far-reaching consequences in various industries. The COVID-19 pandemic had a significant, extensive influence on the world stock markets affecting the return on stock assets and their volatility [7].

Before the pandemic the markets had already shown a high co-integration accompanied by spillover of external shocks of mixed nature. However, the pandemic due to the specific nature of its external causes and response methods made adjustments in the financial contagion processes. Study of the interrelation between financial assets in new circumstances will allow investors to adjust their portfolio diversification and risk hedging strategies while regulatory bodies will be able to develop sound macroprudential measures to combat the effects of financial contagion.

Development and use of adequate mathematical and econometric tools for analysis of markets' interrelatedness play a particularly important role because they enable a comprehensive assessment of the direction and scope of systemic risk propagation. The present research addresses these issues.

Review of Studies Dedicated to the Problem under Investigation

There are two main notions in the financial contagion concept. "*Spillover*" (overflow, side effect) describes financial contagiousness as a situation when assets' price volatility in one market spreads to another market. "*Co-movement*" refers to a significant increase in joint dynamics of markets after an exogenous shock which cannot be attributed to fundamental economic factors [8].

Paper [9] describes three contagion channels through which a financial shock spreads to financial markets: *the information, liquidity and financial channel*. Information channel contagion is caused by transfer of information about the asset price. In this case the shock in one market is a signal to investors resulting in immediate price effects in other markets. Market shocks spillover is more significant in the early stage of a crisis due to global uncertainty, panic and investors' herding mentality. Liquidity channel contagion occurs due to a decrease in borrowers' creditworthiness and an overall liquidity deficit in all financial markets and this affects prices and returns on assets. Financial channel contagion is related to shocks in the stock returns in a crisis-ridden market. They may be an indicator of future returns on other assets and influence the market participants' readiness to assume risks.

Paper [10] defines four possible channels of contagion: *the macroeconomic, political, trade and financial one*. The macroeconomic and political channels are attributed to the markets' identical response to interrelated macroeconomic changes (for example, an increase in debt burden) and economic policy changes (for example, change in the key rate of the Central Bank). The trade channel is related to mutual influence of markets/countries through supply of resources, goods, and services while the financial channel – to capital flow between them. Paper [11] also defined four financial contagion channels: the information channel, liquidity channel, flight-to-quality channel (switching to less risky assets), risk premium channel.

In order to measure the dependence between stock markets linear correlations are often used. However, their results are unreliable because they are static and do not cover the constantly developing dynamic relationships between markets. To eliminate these drawbacks researchers apply copula methods [3; 12; 13]; the generalized autoregressive conditional heteroskedasticity models (GARCH) [14; 15]; vector autoregression models (VAR) [16; 17]; vector error correction models (VECM) [18; 19]; DCC-GARCH models [20] and others.

Construction of VAR models of various specifications are a rather widespread approach for detecting contagion effects [11]. VAR models have the following advantages: simplicity and flexibility in modeling the market relationships; taking into account control variables and influence of previous returns of the tested variables [13]; ability to assess the contribution of each variable into the variance of the modeled variable by means of its decomposition [21]. At the same time VAR models have several drawbacks: they are sensitive to selection of variables and time periods; it may also be difficult to choose the optimal lags for different variance in them; they do not take into consideration possible cross connections between endogenous and exogenous variables generating the endogeneity problem [13].

A special area of modern research is study of interrelations between markets and financial contagiousness during the COVID-19 pandemic. Thus, in paper [22] the authors reach the conclusion that there is the financial contagion effect between the markets of the emerging countries intensified in case of especially strong interrelation between them. The authors of another paper [23] make the conclusion that during the COVID-19 pandemic there was a relationship between the S&P 500 index and industry-related indices which manifested itself most of all in the periods of elevated uncertainty. Paper [24] analyzed spreading of financial contagion from the USA stock market to stock markets of emerging countries through global factors such as inflation, interest rates, exchange rate and political uncertainty.

The present paper makes a contribution to the topic of financial contagion. For the first time we study contagion of the fundamental (market) return on stocks of Russian companies during the pandemic from three financial markets: the currency, oil and debt market. The novelty of this research also consists in use of VARX models and methods of decomposition of the coefficient of determination with a correction for heteroscedasticity.

Data

Ordinary shares of 27 companies were used to test contagion[1]:

1) *energy sector*: PJSC Gazprom (GAZP); PJSC Lukoil (LKOH); PJSC Novatek (NVTK); PJSC Oil Company Rosneft (ROSN); PJSC Surgutneftegas (SNGS); PJSC Tatneft (TATN); PJSC RusHydro (HYDR); PJSC Inter RAO UES (IRAO);
2) *financial sector*: AFK Sistema PJSFC (AFKS); PJSC Credit Bank of Moscow (CBOM); PJSC Sberbank of Russia (SBER); PJSC Moscow Exchange (MOEX); PJSC VTB Bank (VTBR);
3) *telecommunications sector*: PJSC Mobile TeleSystems (MTSS); PJSC Rostelecom (RTKM); Yandex N.V. LLC (YNDX);
4) *consumer sector*: PJSC Aeroflot (AFLT); PJSC Magnit (MGNT);
5) *raw material sectors*: PJSC Severstal (CHMF); PJSC MMC Norilsk Nickel (GMKN); PJSC Magnitogorsk Iron & Steel Works (MAGN); PJSC ALROSA (ALRS); PJSC NMLK (Novolipetsk Steel Company) (NLMK); PJSC PhosAgro (PHOR); PJSC Polyus / Polyus Gold (PLZL); JSC Polymetal (POLY); PJSC United Company Rusal (RUAL).

We used for analysis data on the average daily prices of these stocks (RUB) at the MOEX.

The following variables are taken as exogenous variables which presumably influence the stock price:

1) spot price of Urals oil, US dollar[2];
2) Russian roubles to US dollar exchange rate, RUB/US dollar[3];
3) annual yield of Russian government bonds, %[4].

Government bonds yield is considered as a proxy variable of the capital cost. Besides, high-frequency data necessary for analysis is available for government bonds.

Research Hypothesis

The research hypothesis suggests that the relationship between the studied variables should manifest itself or strengthen only at the time of economic shocks.

If the stock price index of a certain company traditionally correlates with the oil price, the dollar exchange rate and the yield of government bonds, and the relationship is not strengthened significantly after a shock their joint movement will be indicative of strong real connections rather than financial contagion. However, if in the periods of rapid changes in economic conditions, fluctuations in exogenous variables are accompanied by an intensification of their relationship with the prices and yield of the studied financial assets, contagion may be diagnosed. Besides, effects of financial contagion may be manifested both in the acute phase of the crisis (in the short-term period when uncertainty grows which entails chaotic movements and influences overall market volatility) and in the chronic crisis period (when relative prices of assets change).

Methodology

In the present research the periods of heightened market turbulence (acute crisis) and relative market lull were differentiated by means of constructing the sliding coefficients of variation for three exogenous variables. The acute crisis period was determined on the basis of consistent exceedance by the coefficient of variation of its mean value throughout the entire considered period. The periods adjacent to it from the left and right and equal in duration were identified as the pre-crisis and post-crisis period.

The sliding coefficient of variation CV_X of variable X was calculated by steps for each point in time on the basis of 10 values of the indicator up to the specified date, the indicator value on such date and 10 values of the indicator after the corresponding date. 21 values were chosen because this is the average number of trading sessions per month.

$$CV_X = \frac{\sigma_X}{\mu_X}, \qquad (1)$$

where σ_X – standard deviation of indicator X within the considered period; μ_X – its mean value.

In order to have a better visualization of the coefficients of variation we normalized them by means of adjusting to the linear scale (0; 1):

[1] URL: https://m.ru.investing.com/indices/rtsi-components

[2] URL: https://www.profinance.ru/chart/urals/max/?s=Urals_med&hist=true&p=VXJhbHNfbWVkIzIjMTAjOTcwIzU1MCM3IzMjMg==

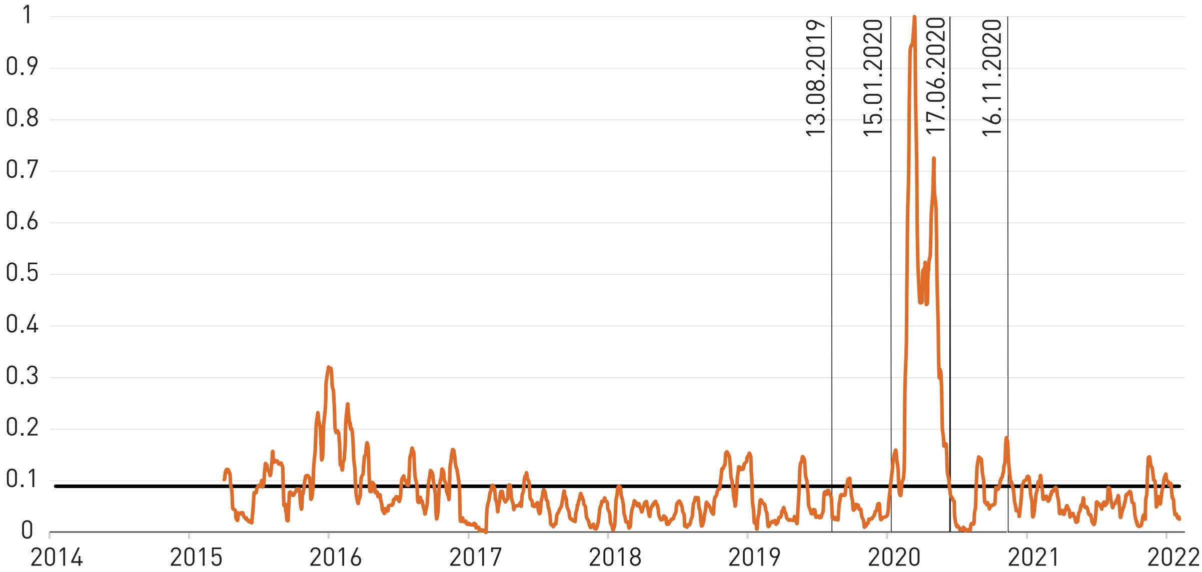
[3] URL: https://ru.investing.com/currencies/usd-rub

[4] URL: https://ru.investing.com/rates-bonds/russia-1-year-bond-yield-historical-data

$$ICV_X = \frac{CV_X - \min CV_X}{\max CV_X - \min CV_x} \,. \qquad (2)$$

Figure 1 presents dynamically the results of calculation of the sliding coefficient of variation of the logarithm of Urals oil prices. The black line shows its mean value within the considered period.

Figure 1. Sliding normalized coefficient of variation of the logarithm of the Urals oil price



On the basis of Figure 1 we determined the period of heightened volatility of the Urals oil price: 15 January 2020 – 17 June 2020 (totally 105 observations for 5 months) which corresponds to the acute phase of the pandemic. Consequently, we defined the pre-crisis period (13 August 2019 – 14 January 2020) and the post-crisis period (18 June 2020 – 16 November 2020) which also comprise 105 observations before and after the acute phase of the pandemic.

The pre-crisis, crisis and post-crisis periods, similar in length, were shown graphically for two other exogenous variables (Figures 2 and 3).

Figure 2. Sliding normalized coefficient of variation of the logarithm of the US dollar exchange rate against the Russian rouble

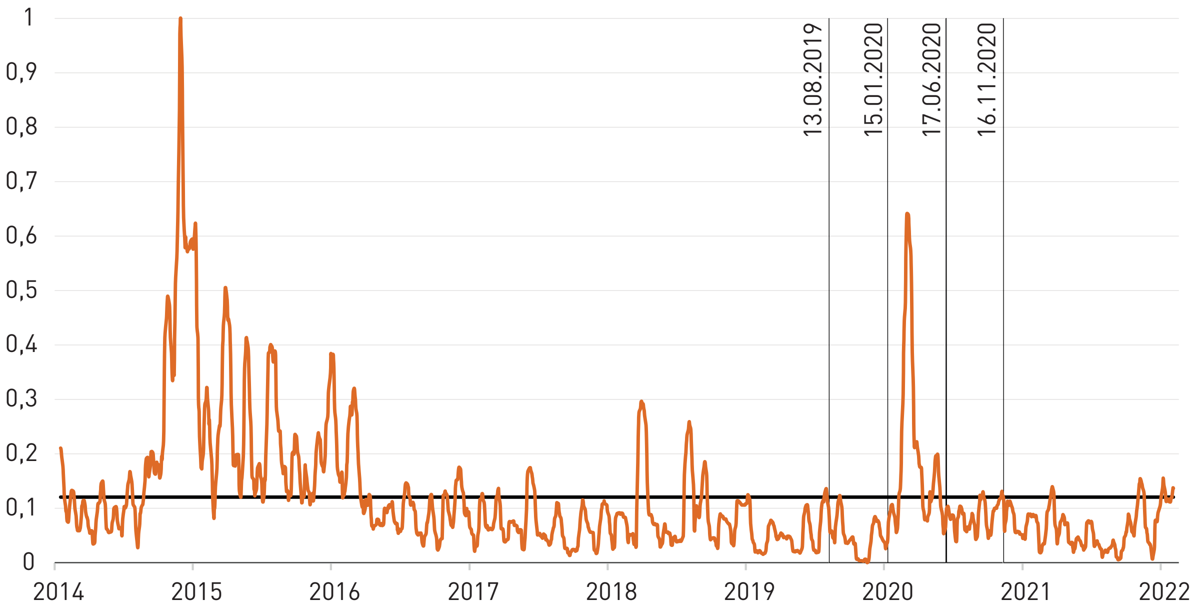
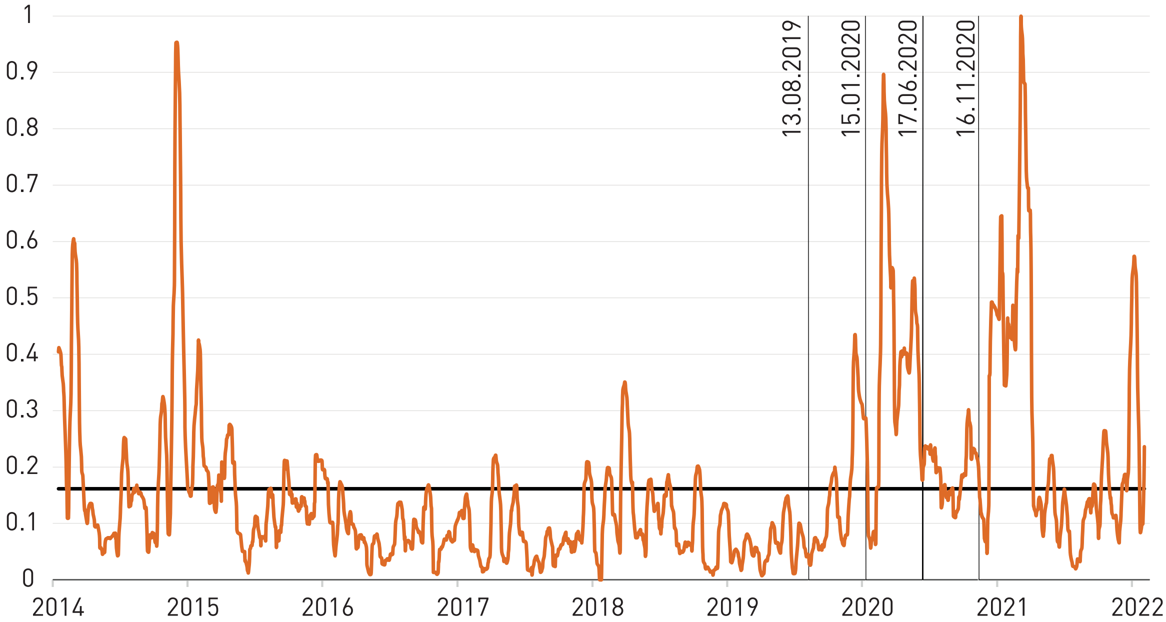


Figure 3. Sliding normalized coefficient of variation of the logarithm of yield on annual government bonds



To test contagion we applied the vector autoregression model with exogenous variables (VARX) which is an extension of the standard VAR model:

$$Y_t = c + \sum_{i=1}^{p} a_i Y_{t-i} + \sum_{j=1}^{k} b_j X_{t-j} + \varepsilon_t , \quad (3)$$

where Y_t – vector p·1 exogenous variables at the time point t;

c – constant;

X_t – vector k·1 exogenous variables at the time point t;

a_i – matrix p·p of coefficients of exogenous variables with a lag up to order p;

b_j – matrix p·k of coefficients of exogenous variables with a lag up to order k;

ε_t – vector of model residuals at the time point t.

The maximum value of lag p of the model was determined using the Akaike, Schwarz and Hannan-Quinn generalized information criteria. In the majority of models the criteria indicated a lag value of 2. Apart from that, we excluded the constant in the constructed models because its estimates were close to zero and were statistically insignificant.

Stationarity in time series of data was achieved by using the first differences of logarithmic variables (approximate values of assets' fundamental return) in the models. It was confirmed by means of the augmented Dickey-Fuller test.

The following tests were used to diagnose the quality of the models: 1) the Portmanteau test for the residual autocorrelation; 2) the autoregressive conditional heteroscedasticity test (ARCH) – a test for presence of nonpermanent variance in the residuals of regression analysis; 3) the Doornik-Hansen test (DH test $\chi 2$) – a comprehensive statistical test to verify normality of distribution, homoscedasticity and absence of residuals' autocorrelation; 4) the F-test – to verify whether the previous values of variables included in the VAR model have any predictive power for the current value of these variables (whether the subset of lags of the model makes a joint significant contribution to explanation of dependent variables' variance).

Financial contagion of stock assets from exogenous variables is confirmed in two ways: 1) if during the acute crisis period the explanatory variable coefficient exceeds in modulus its value in both pre-crisis and post-crisis period; 2) if during this period the share of the dependent variable variance explained by exogenous factors increases.

As mentioned in the theoretical part, an advantage of the VARX model is decomposability of the variance (Var) and, subsequently, the coefficient of determination (R^2). This allows to identify the contribution of each exogenous variable X_j into the variance of return on asset in each tested period:

$$\mathrm{Var}\left(X_j / Y\right) = \frac{b_j^2 \mathrm{Var}\left(X_j\right) + b_j \sum_{k=1, k\neq j}^{K} \mathrm{CoVar}\left(X_j ; b_k X_k\right)}{\mathrm{Var}\left(Y\right)} . \quad (4)$$

The first term of the numerator estimates the variable's own contribution to the variance of Y and the second term – the cross impact of the tested variable with other exogenous variables. The sum of contributions of all exogenous variables defines the part of the coefficient of determination which is explained only by exogenous variables[5].

It is comparison of $\sum_{j=1}^{K} \mathrm{Var}\left(\frac{X_j}{Y}\right)$ for pre-crisis, crisis

[5] It should be noted that this approach does not take into consideration possible interrelations between exogenous and endogenous variables but in the well-specified model devoid of endogeneity such interrelations should be minimized.

and post-crisis periods which enables us to make conclusions about the presence or absence of contagion.

However, paper [25] raised the important problem which consists in the fact that during the crisis increase in the variance of exogenous variables creates the heteroscedasticity problem (one of the results is overestimation of correlation coefficients). In order to solve the problem of nonconstancy of variance of the model explanatory parameters, the abovementioned paper offered a way of adjusting the correlation coefficient of the crisis period using the parameter δ^*. This parameter is indicative of the increment in the variance of variables – which are potential contagion sources during the crisis period (*cr*), as compared to their variance during non-crisis periods (*no_cr*):

$$\delta_j^* = \frac{\mathrm{Var}\left(X_{j\_cr}\right)}{\mathrm{Var}\left(X_{j\_no\_cr}\right)} - 1, \quad (5)$$

According to [25] and taking into consideration decomposability of the coefficient of determination we may use the calculated δ_j^* coefficients to adjust the contribution to the coefficient of determination of each exogenous variable separately:

$$\mathrm{Var}\left(X_j / Y\right)^* = \frac{\mathrm{Var}\left(X_j / Y\right)}{1 + \delta_j^* \cdot \left(1 - \mathrm{Var}\left(X_j / Y\right)\right)}, \quad (6)$$

Research Results and Their Discussion

Table 1 shows change of logarithms of stock prices and exogenous parameters of the model as well as their coefficients of variation in the three tested time intervals.

Table 1. Some Descriptive Statistics of Model Variables

X	*Pre-crisis period, BC*		Crisis period, C		Post-crisis period, PC	
	$\overline{\ln X_t - \ln X_{t-1}}$	CV_X	$\overline{\ln X_t - \ln X_{t-1}}$	CV_X	$\overline{\ln X_t - \ln X_{t-1}}$	CV_X
Exogenous variables						
USD	–0.060	0.516	–0.392	1.869	0.084	0.893
URALS	0.075	1.065	–0.277	11.171	0.046	1.250
BONDS	–0.196	4.553	0.121	7.846	–0.002	1.895
Energy sector						
GAZP	0.078	0.976	–0.190	2.165	–0.053	1.261
LKOH	0.194	0.811	–0.153	1.695	–0.076	0.981
NVTK	–0.011	0.393	–0.234	1.590	0.148	0.619
ROSN	0.159	0.761	–0.303	3.066	0.141	0.660
SNGS	0.671	5.844	–0.344	4.822	–0.036	1.320
TATN	0.090	0.652	0.174	2.801	–0.097	1.842
HYDR	0.214	1.114	–0.154	2.626	–0.072	0.676
IRAO	0.307	1.240	0.121	1.619	0.045	0.852
Financial sector						
AFKS	0.267	4.542	–0.063	5.431	0.579	4.888
CBOM	–0.019	1.129	0.008	2.520	0.039	1.454
MOEX	0.176	1.419	–0.208	2.142	0.162	1.635
SBER	0.146	0.807	–0.246	2.458	0.167	0.980
VTBR	0.145	4.355	0.121	11.821	0.018	3.983

X	Pre-crisis period, BC		Crisis period, C		Post-crisis period, PC	
	$\overline{\ln X_t - \ln X_{t-1}}$	CV_X	$\overline{\ln X_t - \ln X_{t-1}}$	CV_X	$\overline{\ln X_t - \ln X_{t-1}}$	CV_X
Telecommunications sector						
MTSS	0.192	1.334	−0.003	1.145	−0.008	0.476
RTKM	0.016	0.354	0.127	2.025	0.143	0.997
YNDX	0.103	1.207	0.121	0.835	0.413	1.459
Consumer sector						
AFLT	-0.017	0.560	0.159	4.664	−0.193	3.307
MGNT	-0.061	0.575	0.121	1.341	0.222	0.687
Raw materials sector						
CHMF	−0.002	0.633	−0.036	0.822	0.236	1.026
GMKN	0.272	0.874	−0.113	0.740	0.073	0.392
MAGN	0.095	1.385	−0.326	2.420	0.085	1.095
ALRS	0.172	1.410	−0.065	3.360	0.287	1.686
NLMK	0.022	1.160	0.083	1.702	0.371	2.039
PHOR	−0.009	0.316	0.356	0.963	0.127	0.501
PLZL	0.040	0.433	0.250	1.975	0.382	1.424
POLY	0.143	0.646	−0.190	2.204	0.274	1.613
RUAL	0.190	1.491	0.121	4.673	0.217	2.511

Note. The indicator $\overline{\ln X_t - \ln X_{t-1}}$ is an average (intersession) market return on asset; CV_X – coefficient of variation of the asset price. For better visualization both indicators were multiplied by 100 and presented in %.

Analysis of data from table 1 shows that when the acute phase of the crisis began the stock prices of the studied companies came down. An especially significant drop occurred in the energy sector where 6 out of 8 studied companies lost on average 0.14% during one session in comparison to the positive daily growth of 0.21% in the pre-crisis period. During the crisis period the financial sector (3 out of 5 companies) showed an average daily drop of 0.08% as compared to a growth of 0.14% in the previous period. The raw materials sector turned out to be more resilient to the crisis: the average daily intersession returns of 5 out of 9 companies decreased to 0.01% in comparison to 0.10% in the base period but positive. The consumer and telecommunications sectors, on the contrary, showed growth in the stock return during the acute phase of the pandemic which may be due to development of remote work and consumer fever in anticipation of and in the first months of lockdown.

In the post-crisis period the situation stabilized: all sectors except for the energy sector showed better price dynamics as compared to the pre-crisis period. The stocks of AFK Sistema (AFKS) demonstrated the highest growth. On average they gained 0.58% daily, Yandex (YNDX) – 0.41% which is probably due to the growth of e-commerce, ride-tech and delivery services. The raw materials sector showed the best stock returns in the post-crisis period. The average daily growth was 0.23%. On the contrary, Aeroflot (AFLT) stocks demonstrated a decline of -0.19% which had probably been caused by lockdowns and mobility restrictions related to the COVID-19 pandemic.

The coefficients of variation represented in table 1 indicate that in the acute phase of the pandemic volatility increased not just in the explanatory variables but also in stock prices of the majority of companies except for Surgutneftegas (SNGS), Mobile TeleSystems (MTSS), Yandex (YNDX) and Norilsk Nickel (GMKN). The biggest growth in volatility was observed in Urals oil prices (CV increased by 10.1 p.p.) and VTB stocks (CV increased by 7.5 p.p.)

In transition to the post-crisis period the coefficients of variation returned to pre-crisis values with slight changes (±1 p.p.) except for yield of government bonds (their relative variation decreased by 2.7 p.p.) and Surgutneftegas (SNGS) stock prices (their CV decreased by 4.5 p.p.). Volatility of Aeroflot (AFLT) stock prices, on the contrary, increased by 2.8 p.p. in the post-crisis period in comparison to the pre-crisis period.

As long as according to our hypothesis the contagion effect manifests itself in change of influence of the studied variables during different crisis periods we built VARX models for all three periods (formula 3). For convenience of visualization and presentation of the obtained results in the three periods Table 2 was made (the models are presented in more detail in Appendices 1–3). It demonstrates significance and signs of the variables' coefficients (+) (–), significance of the model in general (R^2) and results of tests for absence of autocorrelation and heteroscedasticity as well as for normality of residuals distribution.

Now we are going to consider the results of VARX models in more detail.

In the *pre-crisis period* (BC) some companies of the energy and raw materials sectors showed a positive relation between current and previous periods' returns which is indicative of an onward growth of stock prices (bullish trend). For Rostelecom (RTKM) a negative relation of returns was observed which may suggest that a correction in the value of previously overvalued stocks took place. The F-test results for lags confirm significance of the lagged variable of the 1st and 2nd order for Rostelecom (RTKM) and Severstal (CHMF).

In the *crisis period* (C) dependences are mainly changed into the opposite ones. Change in the coefficient sign of lagged variables for Lukoil (LKOH) is indicative of an oncoming recession while change in the direction of influence of lagged variables for Rostelecom (RTKM), on the contrary, implies that the telecommunications company has gained advantages during the COVID-19 crisis. The F-test results confirm significance of lagged variables for these companies in the crisis period. Apart from that, according to the F-test results in the crisis period negative coefficients of lagged variables of return of the 1st and 2nd order are also statistically significant for SBER, CBOM, MAGN, NLMK.

In the *post-crisis period* (PC) the negative influence of previous return on the current return was preserved for the Credit Bank of Moscow (CBOM), SNGS and manifested itself for RTKM. LKOH, TATN, SBER, NVTK, ALRS showed an opposite trend which is indicative of a correction in stock prices. The F-test results for the above companies are statistically significant.

Now we are going to consider significance and direction of influence of exogenous variables on stock return of companies.

The *dollar exchange rate* (*USD*) shows a statistically significant negative influence on returns of almost all studied companies in the crisis period. At the same time, for some companies the negative influence of the USD variable on change of the stock price persists even after the crisis is over. As long as shares are denominated in the domestic currency, the correlation, of their fundamental return with the dollar/rouble exchange rate seems rather logical. A significant drop in the rouble exchange rate during the crisis reduces interest to assets in the domestic currency. Heightened currency volatility creates uncertainty which also influences investor behavior. As a result, stocks become highly sensitive to the USD exchange rate.

As we see in Table 3, *Urals oil price* has a significant impact on stock returns mainly in the post-crisis period (PC), to be more precise, after passing the acute phase of the crisis. When the real sector companies restore the pre-crisis outputs, the demand for energy resources boosts raising the prices of the energy sector companies. In the post-crisis period there is also a positive relation between oil prices and prices of assets of the majority of companies from the raw materials sector and some companies from the financial sector (CBOM, MOEX, SBER, VTBR) as well as the telecommunications sector (MTSS and RTKM).

Yield on government bonds (BONDS), similar to the oil price during the crisis, has a significant negative impact on almost all studied companies except for the raw materials companies. This is due to a rise in the cost of borrowing which most of all affects the companies attracting borrowed capital for financing. Unlike the dollar exchange rate, after transition to the post-crisis period (PC) the influence of the BONDS variable becomes statistically insignificant almost for all observed models.

In general, the coefficients of the USD and BONDS variables are indicative of change of the state of the stock market during the crisis which may imply that there exists the financial contagion effect while the coefficients of the Urals variable are indicative more of a delayed impact after the acute phase of the pandemic has passed.

A low coefficient of determination ($R^2<0.3$) for all companies in the pre-crisis period is succeeded by a significant increase during the acute phase of the pandemic ($R^2>0.3$) and then declines again below the established threshold in the post-crisis period. During the acute crisis the coefficient of determination is significant for all energy companies, the majority of financial companies (except for the Moscow Exchange's shares which are the most diversified securitized asset), telecommunications companies MTSS and AFLT, 4 out of 9 companies from the raw materials sector (GMKN, ALRS, NLMK, RUAL). These companies may be suspected of financial contagion.

The results of tests (*Portmanteau test, ARCH test, (DH) test* χ^2) indicate that for the majority of models the assumptions of normality, homoscedasticity and absence of autocorrelation are true. In general, this is indicative of correctness of the chosen models specifications. Absence of normality of residuals distribution in some studied models (according to *(DH) test* χ^2) suggests that the model fails to explain the whole variation of data and/or contains systematic errors. This may imply presence of outliers or a non-linear relationship between the dependent variable and its predictors, and this may reduce its predictive capability. However, this does not reduce significance of these variables for explaining stock market returns.

Table 2. Summary Visualization of Coefficient Estimates and Tests of VARX Models

$Y_{tl.n\_ln-1}$	Y_{t-1}			Y_{t-2}			X_{1t} (USD)			X_{2t} (URALS)			X_{3t} (BONDS)			R^2			Portmant. test			ARCH test LM Lag 1			ARCH test LM Lag 2			(DH) test χ^2			F-test Lags			F-test Vars		
	BC	C	PC	BC	C	PC	BC	C	PC	BC	C	PC	BC	C	PC	BC	C	PC	BC	C	PC	BC	C	PC	BC	C	PC	BC	C	PC	BC	C	PC	BC	C	PC
Energy sector																																				
GAZP								(−)	(−)	(+)		(+)		(−)			✓		✓	✓	✓		✓	✓	✓	✓	✓								✓	
LKOH	(+)	(−)	(+)		(−)	(+)		(−)		(+)		(+)		(−)			✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓			✓	
NVTK						(+)		(−)				(+)					✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓								✓
ROSN								(−)		(+)		(+)		(−)			✓		✓	✓	✓	✓	✓	✓	✓		✓			✓						
SNGS	(+)		(−)					(−)	(−)			(+)		(−)			✓		✓	✓	✓		✓	✓		✓	✓		✓	✓	✓					
TATN			(+)					(−)	(−)	(+)		(+)		(−)			✓		✓	✓	✓	✓	✓	✓	✓	✓	✓			✓			✓			
HYDR	(+)							(−)	(−)			(+)		(−)			✓		✓	✓	✓		✓	✓		✓	✓		✓		✓					
IRAO							(−)	(−)				(+)		(−)			✓		✓	✓	✓	✓	✓		✓	✓			✓						✓	
Financial sector																																				
AFKS								(−)						(−)			✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓							
CBOM		(−)	(−)				(−)	(−)				(+)		(−)	(−)		✓			✓				✓	✓		✓		✓			✓	✓			
MOEX				(+)				(−)				(+)							✓	✓	✓	✓	✓	✓	✓	✓	✓			✓						
SBER			(+)		(−)			(−)	(−)			(+)		(−)			✓		✓	✓	✓	✓		✓	✓		✓	✓				✓			✓	
VTBR								(−)	(−)			(+)		(−)			✓		✓	✓	✓	✓	✓	✓	✓	✓	✓									
Telecommunications sector																																				
MTSS								(−)				(+)	(−)	(−)			✓		✓	✓	✓	✓		✓	✓		✓	✓								
RTKM	(−)	(+)		(−)		(−)		(−)				(+)	(+)						✓	✓	✓	✓	✓	✓	✓		✓				✓	✓		✓		
YNDX								(−)						(−)					✓	✓	✓	✓	✓	✓	✓	✓	✓		✓							
Consumer sector																																				
AFLT		(+)						(−)	(−)								✓		✓	✓	✓	✓		✓	✓		✓	✓	✓			✓				
MGNT														(−)					✓	✓	✓	✓	✓	✓	✓		✓	✓		✓						
Raw materials sector																																				
CHMF	(+)			(−)	(−)			(−)											✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓				✓	
GMKN		(+)		(+)				(−)	(−)								✓		✓		✓	✓	✓	✓	✓	✓	✓	✓		✓						
MAGN					(−)			(−)		(+)	(−)								✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓						
ALRS	(+)					(+)		(−)	(−)			(+)			(−)		✓		✓	✓	✓	✓	✓		✓	✓		✓	✓	✓			✓			✓
NLMK					(-)			(−)	(+)			(+)					✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓			✓	
PHOR	(+)						(+)		(+)		(−)	(+)							✓	✓	✓	✓		✓	✓		✓	✓								
PLZL												(+)			(−)				✓	✓	✓	✓	✓		✓		✓	✓								
POLY							(+)								(−)				✓	✓	✓	✓	✓	✓	✓	✓	✓									
RUAL		(+)		(+)				(−)				(+)					✓		✓		✓	✓	✓	✓	✓	✓	✓	✓		✓						

Notes. Estimates of standard errors (adjusted for heteroscedasticity), version HC1:
(+) positive value of the significant variable coefficient ($P \leq 0.05$);
(−) negative value of the significant variable coefficient ($P \leq 0.05$);
R^2 (✓) coefficient of determination ≥ 0.3;

Portmanteau test (✓) – no autocorrelation;
ARCH test LM Lag 1 (✓) – homoscedasticity of the 1st order lag;
ARCH test LM Lag 2 (✓) – homoscedasticity of the 2nd order lag;
(DH) test χ^2 (✓) – distribution of residuals corresponds to normal;

F-*test* Lags (✓) – subset of lags has a statistically significant impact;
F-*test* Vars (✓) – subset of variables has a statistically significant impact.

F-test Vars is indicative of significance (✓) of influence of the subset of variables. Many models fail to pass this test. This may mean that significance in them pertains only to individual variables rather than the whole subset or that these companies have not been infected. At the same time, the number of statistically significant models is much larger particularly in the crisis period. This also supports the *hypothesis* that influence of the examined variables manifests itself or intensifies only during economic shocks, and this implies presence of the financial contagion effect in some of the studied companies.

Following the methodological part of the paper, in order to enhance correctness of the conclusions on change of the influence of exogenous variables on stock returns we calculated the contribution of these variables to the variance of the explained variable using formula (4). In other words, we distinguished the part of the coefficient of determination which may be attributed to influence of exactly the exogenous variables. Subsequently we corrected it for heteroscedasticity using formulas (5) and (6). The results are presented in Table 3. The cells which confirm contagion are yellow.

Table 3. Contribution of the variance of exogenous variables to the variance of stock returns of Russian companies in three periods: diagnosing financial contagion, %

	USD			Urals			BONDS			Sum*			Sum-corr.*	
	BC	C	PC	BC	C	PC	BC	C	PC	BC	C	PC	C/BC	C/PC
GAZP	0.73	25.83	6.29	4.34	–0.75	10.66	0.72	19.83	0.22	5.80	44.91	17.17	11.76	30.30
LKOH	0.67	27.63	1.56	8.14	6.71	26.03	0.23	28.91	–0.17	9.04	63.26	27.41	17.41	40.52
NVTK	1.25	31.34	–0.19	2.25	4.72	16.39	0.39	–1.03	–0.14	3.89	35.03	16.06	4.90	15.45
ROSN	0.56	25.73	4.24	21.06	0.82	27.02	0.55	31.74	–0.20	22.16	58.29	31.07	18.01	41.50
SNGS	0.02	23.80	11.60	0.00	–1.99	13.31	0.05	18.13	0.37	0.07	39.94	25.28	10.48	27.47
TATN	–0.08	29.56	7.01	7.91	1.80	15.93	2.28	26.02	–0.11	10.11	57.38	22.83	15.77	38.47
HYDR	0.00	12.82	3.64	0.06	1.22	6.44	0.86	28.01	0.06	0.91	42.05	10.13	13.92	31.22
IRAO	6.51	25.40	1.92	–0.11	–1.71	5.51	0.98	25.01	–0.06	7.38	48.70	7.37	14.11	34.75
AFKS	0.07	18.38	0.37	0.33	3.15	0.18	1.10	17.16	0.02	1.50	38.69	0.57	9.63	24.15
CBOM	2.11	24.29	0.35	–0.04	4.53	3.37	0.02	17.62	1.64	2.09	46.44	5.35	10.97	27.91
MOEX	4.30	16.45	3.79	1.90	–1.45	6.95	0.01	4.46	1.54	6.21	19.46	12.28	3.64	11.32
SBER	2.38	37.02	8.63	1.58	2.29	17.67	1.27	13.89	0.08	5.24	53.20	26.38	11.77	32.14
VTBR	3.29	30.59	10.16	3.41	0.49	4.03	0.01	23.26	0.06	6.71	54.34	14.25	14.46	36.41
MTSS	1.69	16.34	-0.05	1.83	–2.14	7.71	3.56	29.69	–0.03	7.08	43.90	7.63	15.03	34.23
RTKM	0.35	14.34	0.17	0.35	–0.17	3.27	15.53	3.68	0.44	16.23	17.85	3.88	3.15	9.70
YNDX	0.55	13.77	0.27	0.93	–0.42	1.02	0.41	6.36	0.44	1.88	19.71	1.72	4.06	11.76
AFLT	–0.12	36.33	5.57	5.72	3.46	6.31	0.35	7.62	0.01	5.96	47.41	11.89	9.13	26.16
MGNT	0.90	5.99	0.31	0.11	1.04	1.54	0.42	18.75	0.42	1.43	25.78	2.26	8.42	19.44
CHMF	0.36	14.60	0.13	0.01	–0.19	1.42	0.58	2.48	0.08	0.95	16.89	1.63	2.74	8.76
GMKN	0.94	32.86	5.61	0.27	–1.12	3.84	0.49	4.03	1.35	1.71	35.77	10.80	6.50	20.28
MAGN	–0.06	26.37	0.00	2.58	–1.90	2.57	0.01	2.50	0.29	2.53	26.97	2.86	4.54	14.93
ALRS	0.06	33.23	8.50	0.10	–0.79	3.68	0.18	1.99	3.97	0.35	34.43	16.16	5.86	18.75
NLMK	0.70	19.69	3.33	0.47	0.93	1.74	0.85	7.43	0.05	2.02	28.05	5.12	5.51	15.85
PHOR	8.99	0.41	5.57	1.79	4.47	1.65	0.01	1.60	1.28	10.78	6.48	8.51	1.06	2.00
PLZL	0.80	0.05	0.86	0.02	0.15	3.59	1.72	0.66	3.00	2.54	0.86	7.45	0.26	0.61
POLY	10.41	0.12	0.10	0.00	0.56	0.49	1.12	3.38	4.91	11.53	4.06	5.50	1.30	3.07
RUAL	1.47	26.91	0.86	0.71	–0.84	8.01	0.17	8.87	0.25	2.36	34.94	9.12	7.19	20.99

Notes. * Sum – the combined contribution of the three exogenous variables to the coefficient of determination. ** Sum-corr. is the contribution corrected for heteroscedasticity (growth of the variance of the exogenous variables).

The obtained results confirm the increasing impact on the fundamental stock return of the majority of Russian companies in the acute phase of the pandemic exerted by the exchange rate of the dollar and borrowing costs, and subsequently – by oil prices. Apart from that, for the majority of companies in the crisis period the joint impact of the three studied exogenous variables increased. This is indicative of financial contagion spilling over from the oil market, currency and debt markets to the stock market. The heteroscedasticity-adjusted explained variation, on the whole, confirmed these conclusions.

The performed analysis showed that some companies in the energy sector (IRAO, HYDR, TATN, SNGS, LKOH, GAZP[6]), financial sector (AFKS, VTBR, CBOM, SBER) and consumer sector (MGNT, AFLT) responded to crisis manifestations to a greater degree. Telecommunications companies (except for MTSS) and the raw materials companies were affected less by the crisis contagion. The exception is the diamond-mining company ALRS and metallurgical plants NLMK and RUAL, which were exposed to contagion, but significantly lower than companies in other sectors.

At the same time there is a series of companies which returns turned out to be the most resilient one to crisis manifestations. First of all, they are Polyus (PLZL) and Polymetal (POLY) engaged in manufacture of noble metals and PhosAgro (PHOR) – a fertilizer producing company. And this is no coincidence because gold and silver are a good portfolio hedging instrument, and many researchers consider them as “safe havens” for investment. Change in their returns is often out of accord with general market trends. PhosAgro is a supplier of mineral fertilizers for agriculture which depends on natural conditions to a greater extent and is less related to global crises. The stocks of the Moscow Exchange (MOEX) also showed a high crisis resilience which may be due to their serious diversification. All these assets may be used for short-term portfolio adjustment during crises in order to reduce the total investment risks.

Conclusion

Financial contagion manifests itself as an increased reaction of some markets to shocks emerging in other markets. It takes the form of strengthened interconnections between them during the crisis. Scientists distinguish liquidity, information, financial, macroeconomic, political and other channels of financial contagion.

We have studied influence of the oil, currency and debt markets on market return of stocks of 27 Russian companies during the pandemic. In order to define the acute crisis period we calculated the sliding coefficient of variation. To test contagion we constructed VARX models for the crisis period as well as the pre-crisis and post-crisis periods equal in length. Contagion was tested on the basis of change and significance of estimates of the exogenous variables’ coefficients as well as their contribution to the coefficient of determination adjusted for heteroscedasticity.

The research showed that the dollar/rouble exchange rate and the borrowing costs had the greatest impact on returns of Russian companies during the pandemic acute phase while the oil price – during the chronic crisis. Energy, financial and consumer sector companies turned out to be the most exposed ones to financial contagion during the pandemic shock. As long as an elevated turbulence of the assets' prices may cause loss of control, such companies need special measures to strengthen their resilience in the periods of external shocks.

Telecommunications and base materials companies (with some exception) showed the highest resilience to the pandemic shock. Besides, the greatest resilience was demonstrated by stocks of the noble metals and fertilizer manufacturing companies. This substantiates to recommend them as reliable tools of investment portfolio diversification during crisis.

Understanding of the factors which facilitate spillover of market shocks may assist regulatory bodies in taking efficient measures to implement the policy of financial regulation and maintenance of long-term financial stability, developing timely fiscal and monetary measures intended to combat the effects of financial contagion in the time of exposure to external shocks.

Limitations of the performed research are related to some drawbacks of VAR models and analysis of the sole pandemic shock of 2020 which had specific reasons and mechanisms. In future the research may be developed as improvement of the methodology and study of financial contagion of Russian companies exposed to shocks of another nature, in particular, those related to sanctions. These issues may be solved in future.

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[6] Henceforward the companies are ranked in decreasing order of the contagion scale

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Appendix 1

VARX Model for the Pre-Crisis Period (13 August 2019 – 14 January 2020), N = 105

Y_{tLn_In-1}	Y_{t-1}	Y_{t-2}	X_{1t} (USD)	X_{2t} (URALS)	X_{3t} (BONDS)	R^2	Portmanteau test	ARCH test		(DH) test χ^2	AIC	BIC	F test	
								LM Lag 1	LM Lag 2				Lags	Variables
							Energy sector							
GAZP	0.038 (0.119)	0.133 (0.120)	−0.156 (0.250)	**0.110*** (0.040)	−0.069 (0.052)	0.074	**20.311**	4.324*	**5.103**	8.22**	−-6.034	−5.906	1.002	1.809
LKOH	**0.207**** (0.082)	−0.027 (0.101)	0.431 (0.390)	**0.200***** (0.074)	−0.050 (0.089)	0.117	**17.961**	**0.162**	**0.197**	**2.76**	−5.779	−5.651	2.368	0.077
NVTK	−0.057 (0.098)	−0.104 (0.122)	−0.260 (0.449)	0.080 (0.080)	0.053 (0.114)	0.049	**17.716**	**0.568**	**2.226**	**4.36**	−5.879	5.751	0.605	0.976
ROSN	0.090 (0.114)	−0.091 (0.108)	−0.081 (0.257)	**0.234***** (0.059)	0.052 (0.066)	0.209	**13.541**	**3.252**	**4.015**	14.43***	−6.296	−6.168	0.930	0.977
SNGS	**0.379**** (0.176)	−0.115 (0.110)	−0.091 (0.654)	−0.007 (0.146)	−0.045 (0.164)	0.129	**8.598**	17.328***	18.332***	18.53***	−4.163	−4.036	**6.914****	1.288
TATN	0.075 (0.087)	0.022 (0.091)	0.033 (0.287)	**0.171***** (0.061)	0.131 (0.089)	0.106	**27.413**	**0.014**	**0.402**	9.31**	−5.902	−5.774	0.361	0.050
HYDR	**0.580***** (0.312)	0.021 (0.175)	−0.014 (0.244)	−0.019 (0.041)	0.100 (0.087)	0.158	**16.479**	10.950***	11.377**	78.99***	−5.521	−5.393	**8.764*****	0.019
IRAO	0.125 (0.125)	−0.068 (0.098)	**−1.150*** (0.636)	−0.017 (0.127)	0.139 (0.156)	0.085	**16.822**	**1.044**	**1.044**	6.75*	−4.956	−4.828	0.822	0.427
							Financial sector							
AFKS	0.101 (0.091)	0.148 (0.109)	−0.128 (0.322)	−0.046 (0.074)	−0.113 (0.076)	0.056	**17.463**	**0.570**	**1.022**	6.44*	−5.465	−5.337	1.937	2.331
CBOM	−0.031 (0.163)	−0.187 (0.137)	**−0.278*** (0.149)	−0.013 (0.027)	0.009 (0.044)	0.055	40.683*	4.853*	**5.441**	40.74***	−6.691	−6.563	1.789	3.522
MOEX	−0.074 (0.107)	**0.156*** (0.090)	−0.461 (0.289)	0.057 (0.058)	−0.006 (0.080)	0.078	**26.076**	**0.015**	**0.097**	10.09**	−6.158	−6.030	1.640	2.520
SBER	−0.020 (0.088)	−0.053 (0.095)	−0.292 (0.268)	0.048 (0.044)	−0.074 (0.069)	0.052	**18.516**	**0.912**	**1.634**	**1.39**	−6.469	−6.341	0.158	0.277
VTBR	0.001 (0.117)	0.059 (0.097)	−0.494 (0.358)	0.107 (0.080)	−0.010 (0.072)	0.066	**20.218**	**0.118**	**0.256**	44.24***	−5.680	−5.552	0.179	0.357
							Telecommunications sector							
MTSS	−0.048 (0.101)	0.060 (0.117)	−0.243 (0.267)	0.056 (0.045)	**−0.127*** (0.069)	0.077	**14.514**	**0.085**	**2.915**	**2.33**	−6.334	−6.206	0.297	0.359
RTKM	**−0.257**** (0.107)	**−0.244***** (0.065)	0.160 (0.235)	0.033 (0.032)	**0.295***** (0.139)	0.266	**19.868**	**0.059**	**0.178**	62.25***	−6.377	−6.249	**6.572****	**7.357****
YNDX	−0.074 (0.091)	−0.031 (0.036)	0.358 (0.389)	−0.109 (0.115)	0.116 (0.107)	0.026	**21.296**	**0.0001**	**0.051**	73.52***	−4.366	−4.238	0.303	0.096
							Consumer sector							
AFLT	−0.014 (0.092)	0.050 (0.081)	−0.060 (0.253)	−0.119 (0.092)	−0.040 (0.070)	0.061	**19.33**	**0.283**	**2.778**	**0.76**	−6.227	−6.099	0.129	0.236
MGNT	0.129 (0.113)	−0.037 (0.102)	0.238 (0.233)	0.026 (0.041)	−0.047 (0.081)	0.032	**26.44**	**2.194**	**2.213**	**1.25**	−6.228	−6.100	0.843	0.125

Y_{t,ln_ln-1}	Y_{t-1}	Y_{t-2}	X_{1t} (USD)	X_{2t} (URALS)	X_{3t} (BONDS)	R^2	Portmanteau test	ARCH test LM Lag 1	ARCH test LM Lag 2	(DH) test χ^2	AIC	BIC	F test Lags	F test Variables
							Raw materials sector							
CHMF	**0.298***** (0.090)	**–0.173*** (0.089)	0.164 (0.268)	0.013 (0.063)	–0.060 (0.055)	0.105	**27.74**	**0.412**	**4.421**	**0.11**	–6.113	–5.986	**4.907****	2.848
GMKN	0.104 (0.099)	**0.198**** (0.099)	–0.270 (0.350)	0.026 (0.055)	–0.064 (0.077)	0.073	**28.965**	**0.038**	**0.104**	**5.03**	–5.717	–5.589	2.761	3.709
MAGN	0.049 (0.097)	–0.086 (0.105)	0.055 (0.301)	**0.109*** (0.055)	–0.010 (0.080)	0.038	**33.146**	**0.047**	**0.115**	**0.23**	–5.624	–5.496	0.481	0.738
ALRS	**0.189*** (0.102)	–0.044 (0.105)	–0.069 (0.294)	0.019 (0.073)	0.042 (0.091)	0.038	**26.119**	**0.010**	**0.018**	**0.02**	–5.639	–5.511	1.740	0.187
NLMK	0.106 (0.106)	–0.155 (0.988)	0.293 (0.296)	0.054 (0.048)	–0.087 (0.097)	0.056	**34.171**	**1.002**	**1.116**	**0.24**	–5.739	–5.611	1.568	2.268
PHOR	**0.189*** (0.112)	–0.063 (0.074)	**0.583***** (0.166)	0.072 (0.044)	0.003 (0.043)	0.139	**16.230**	**1.977**	**3.637**	**1.46**	–6.888	–6.760	2.000	0.424
PLZL	–0.037 (0.092)	–0.074 (0.993)	0.295 (0.364)	-0.003 (0.097)	–0.134 (0.100)	0.030	**13.117**	**0.392**	**0.405**	**0.43**	–5.509	–5.381	0.324	0.547
POLY	0.103 (0.103)	-0.058 (0.919_	**1.078***** (0.402)	0.001 (0.057)	–0.111 (0.078)	0.111	**22.236**	**0.099**	**0.124**	6.03*	–5.603	–5.475	0.703	0.377
RUAL	0.015 (0.110)	**0.163*** (0.093)	-0.313 (0.277)	0.042 (0.044)	–0.036 (0.094)	0.056	**22.440**	**1.176**	**1.486**	**3.98**	–5.878	–5.750	1.324	2.614

Note. * P ≤ 0.05 ** P ≤ 0.01 *** P ≤ 0.001

Robust estimates of standard errors are indicated in parentheses (heteroscedasticity-adjusted), version HC1.

Appendix 2

VARX Model for the Crisis Period (15 January 2020 – 17 June 2020), N = 105

Y_{t,ln_ln-1}	Y_{t-1}	Y_{t-2}	X_{1t} (USD)	X_{2t} (URALS)	X_{3t} (BONDS)	R^2	Portmanteau test	ARCH test LM Lag 1	LM Lag 2	(DH) test χ^2	AIC	BIC	F test Lags	Variables
							Energy sector							
GAZP	0.019 (0.090)	-0.138 (0.089)	**-0.734***** (0.275)	–0.008 (0.314)	**–0.336***** (0.093)	0.425	**25.682**	**1.146**	**1.260**	8.56*	–5.151	–5.023	1.537	**3.043***
LKOH	**-0.245**** (0.101)	**-0.232***** (0.088)	**-1.185***** (0.262)	0.077 (0.068)	**–0.688***** (0.165)	0.591	**28.832**	**0.106**	**1.376**	**3.91**	–4.419	–4.291	**10.245*****	**11.271*****
NVTK	-0.050 (0.147)	-0.062 (0.111)	**-1.379***** (0.213)	0.065 (0.043)	0.056 (0.210)	0.355	**20.791**	**0.743**	**4.305**	25.45***	–4.205	–4.077	0.443	0.581
ROSN	0.076 (0.095)	-0.069 (0.101)	**-1.132***** (0.283)	0.011 (0.050)	**–0.735***** (0.138)	0.586	**26.873**	**2.245**	5.796*	7.84*	–4.473	–4.345	0.921	1.008
SNGS	0.042 (0.102)	-0.032 (0.081)	**-1.126***** (0.284)	–0.040 (0.044)	**–0.510***** (0.154)	0.398	**29.885**	**0.004**	**0.032**	**5.86**	–4.217	–4.089	0.180	0.154
TATN	-0.010 (0.105)	-0.094 (0.096)	**-1.454***** (0.298)	0.028 (0.064)	**–0.738***** (0.211)	0.543	**18.997**	**1.776**	**3.665**	11.55**	–4.073	–3.945	0.888	1.716
HYDR	0.056 (0.092)	0.007 (0.110)	**-0.607*** (0.319)	0.017 (0.029)	**–0.604***** (0.122)	0.452	**20.054**	**0.114**	**0.447**	**5.11**	–4.574	–4.446	0.271	0.008
IRAO	0.022 (0.076)	-0.159 (0.099)	**-0.918***** (0.168)	–0.024 (0.031)	**–0.502***** (0.123)	0.493	**30.755**	**0.232**	**0.303**	**3.27**	–4.790	–4.662	2.405	**4.768***

Y_{tLn_ln-1}	Y_{t-1}	Y_{t-2}	X_{1t} (USD)	X_{2t} (URALS)	X_{3t} (BONDS)	R^2	Portmanteau test	ARCH test LM Lag 1	ARCH test LM Lag 2	(DH) test χ^2	AIC	BIC	F test Lags	F test Variables
Financial sector														
AFKS	0.046 (0.087)	-0.046 (0.108)	**-0.810***** (0.279)	0.039 (0.035)	**−0.431***** (0.132)	0.386	**29.873**	**0.646**	**0.647**	**5.27**	−4.419	−4.291	0.269	0.314
CBOM	**-0.179*** (0.106)	-0.111 (0.105)	**-0.477***** (0.109)	0.025 (0.022)	**−0.210**** (0.083)	0.446	**32.673**	5.985*	5.985**	**4.78**	−5.911	−5.783	**3.196***	2.027
MOEX	0.080 (0.109)	-0.163 (0.099)	**-0.687***** (0.167)	−0.049 (0.037)	−0.148 (0.111)	0.218	**34.827**	**0.017**	**0.269**	30.58***	−4.834	−4.706	1.813	3.179
SBER	-0.109 (0.112)	**-0.209*** (0.110)	**-1.184***** (0.225)	0.024 (0.034)	**−0.318***** (0.104)	0.528	**26.771**	12.203***	12.232**	7.26**	−4.820	−4.692	**5.221*****	**8.757*****
VTBR	0.030 (0.061)	0.101 (0.110)	**-0.952***** (0.167)	0.005 (0.030)	**−0.433***** (0.129)	0.595	**21.929**	**0.027**	**0.035**	37.09***	−5.132	−5.004	1.323	2.242
Telecommunication sector														
MTSS	-0.105 (0.111)	0.045 (0.101)	**-0.476***** (0.100)	−0.024 (0.026)	**−0.403***** (0.071)	0.461	**26.741**	10.505**	14.196***	16.56***	−5.481	−5.353	1.191	0.348
RTKM	**0.259**** (0.118)	-0.107 (0.181)	**-0.560**** (0.220)	−0.003 (0.035)	−0.113 (0.157)	0.248	**22.700**	**0.194**	12.519**	53.50***	−5.030	−4.902	**4.095***	1.392
YNDX	-0.055 (0.104)	-0.074 (0.101)	**-0.609***** (0.211)	−0.007 (0.034)	**−0.192**** (0.095)	0.199	**31.074**	**1.404**	**1.415**	**3.99**	−4.487	−4.359	0.445	0.609
Consumer sector														
AFLT	**0.197**** (0.092)	-0.143 (0.126)	**-1.387***** (0.176)	0.043 (0.031)	−0.236 (0.170)	0.504	**25.663**	5.070**	11.074**	**3.5295**	−4.487	−−4.359	**4.065****	3.358
MGNT	-0.055 (0.113)	0.046 (0.178)	-0.374 (0.279)	0.017 (0.048)	**−0.490***** (0.148)	0.278	**27.455**	**3.185**	20.643***	13.98***	−4.370	-4.242	0.330	0.280
Raw materials sector														
CHMF	-0.040 (0.082)	**-0.209**** (0.076)	**-0.534***** (0.151)	−0.003 (0.026)	−0.078 (0.139)	0.212	**2.,484**	**0.343**	**0.353**	21.47***	−5.110	−4.982	2.748	**5.380****
GMKN	**0.150*** (0.085)	-0.020 (0.058)	**-1.315***** (0.227)	−0.020 (0.031)	−0.149 (0.120)	0.355	41.618**	**0.003**	**0.265**	46.96***	−4.375	−4.247	1.632	0.056
MAGN	0.022 (0.095)	**-0.172**** (0.081)	**-0.962***** (0.156)	**−0.056**** (0.027)	−0.092 (0.141)	0.285	**31.190**	**0.256**	**0.343**	**3.41**	−4.784	−4.656	1.961	3.885
ALRS	-0.076 (0.117)	-0.062 (0.104)	**-1.216***** (0.212)	−0.013 (0.030)	−0.075 (0.144)	0.342	**27.806**	**1.283**	**3.175**	**5.60**	−4.535	−4.407	0.645	0.528
NLMK	0.070 (0.126)	**-0.220**** (0.085)	**-0.695***** (0.165)	0.011 (0.026)	−0.188 (0.143)	0.300	**32.315**	**2.753**	**2.810**	**2.95**	−4.871	−4.743	**3.213***	**6.196***
PHOR	0.011 (0.124)	-0.140 (0.128)	0.064 (0.139)	**−0.053*** (0.027)	−0.125 (0.115)	0.089	**16.155**	4.819*	9.329**	11.46**	−5.493	−5.365	1.033	2.065
PLZL	0.067 (0.120)	0.140 (0.145)	0.083 (0.265)	−0.022 (0.054)	−0.124 (0.165)	0.037	**31.412**	**0.896**	6.955*	22.06***	−4.110	−3.982	1.206	1.788
POLY	0.025 (0.071)	0.170 (0.130)	0.169 (0.234)	−0.050 (0.058)	−0.297 (0.210)	0.071	**23.258**	**0.324**	**0.632**	32.28***	−3.985	−3.857	1.439	2.795
RUAL	**0.167*** (0.094)	-0.005 (0.097)	**-1.218***** (0.197)	−0.015 (0.032)	−0.298 (0.219)	0.369	35.729*	**0.822**	**4.483**	40.08***	−4.239	−4.111	2.058	0.003

Note. * P ≤ 0.05 ** P ≤ 0.01 *** P ≤ 0.001

Robust estimates of standard errors are indicated in parentheses (heteroscedasticity-adjusted), version HC1

Appendix 3

VARX Model for the Post-Crisis Period (18 June 2020 – 16 November 2020), N = 105

Y_{tLn_ln-1}	Y_{t-1}	Y_{t-2}	X_{1t} (USD)	X_{2t} (URALS)	X_{3t} (BONDS)	R^2	Portmanteau test	ARCH test LM Lag 1	ARCH test LM Lag 2	(DH) test χ^2	AIC	BIC	F test Lags	F test Variables
							Energy sector							
GAZP	0.019 (0.091)	0.055 (0.117)	-0.360** (0.135)	0.219*** (0.077)	-0.058 (0.057)	0.188	18.031	0.007	0.138	31.61***	−5.656	−5.528	0.177	0.312
LKOH	0.126** (0.062)	0.117* (0.068)	-0.144 (0.142)	0.421*** (0.088)	-0.013 (0.075)	0.347	18.786	0.232	0.456	27.09***	−5.548	−5.420	2.561	1.928
NVTK	-0.026 (0.106)	0.211*** (0.080)	0.036 (0.233)	0.352*** (0.127)	-0.064 (0.081)	0.211	18.437	0.049	0.368	15.99***	−5.329	−5.202	2.516	4.999*
ROSN	0.112 (0.110)	0.035 (0.073)	-0.248 (0.176)	0.355*** (0.073)	-0.015 (0.054)	0.340	27.444	2.173	3.070	2.79	−5.855	−5.727	1.017	0.164
SNGS	-0.169* (0.099)	0.044 (0.099)	-0.532** (0.203)	0.251*** (0.076)	-0.071 (0.071)	0.286	30.466	0.101	3.050	3.27	−5.695	−5.567	2.002	0.217
TATN	0.173* (0.101)	0.107 (0.091)	-0.484*** (0.178)	0.343*** (0.112)	-0.015 (0.085)	0.309	32.019	1.817	2.367	5.57	−5.293	−5.165	3.487*	1.488
HYDR	-0.124 (0.121)	0.117 (0.090)	-0.286* (0.149)	0.170** (0.072)	0.007 (0.082)	0.158	33.913	3.504	4.285	9.87**	−5.538	−5.410	1.894	1.473
IRAO	0.069 (0.069)	0.041 (0.109)	-0.221 (0.074)	0.185** (0.074)	-0.019 (0.799)	0.081	17.527	6.490*	6.549*	27.87***	−5.206	−5.079	0.365	0.180
							Financial sector							
AFKS	0.138 (0.138)	-0.002 (0.108)	-0.140 (0.249)	0.034 (0.131)	0.012 (0.096)	0.025	17.924	0.811	0.867	8.30*	−4.691	−4.563	0.931	0.0003
CBOM	-0.394* (0.202)	-0.116 (0.108)	-0.055 (0.095)	0.126* (0.051)	-0.091* (0.053)	0.298	52.791***	0.007	0.028	11.88**	−6.492	−6.364	15.425***	2.670
MOEX	0.118 (0.090)	-0.058 (0.109)	-0.288 (0.195)	0.195** (0.092)	-0.108 (0.072)	0.131	20.897	0.515	0.516	0.24	−5.449	−5.321	0.882	0.366
SBER	0.157* (0.089)	-0.010 (0.093)	-0.475*** (0.162)	0.324*** (0.101)	-0.070 (0.067)	0.277	15.499	0.069	0.290	25.55***	−5.497	−5.369	1.616	0.015
VTBR	0.082 (0.086)	-0.062 (0.126)	-0.567*** (0.163)	0.132** (0.059)	-0.030 (0.061)	0.148	16.160	0.050	0.862	25.72***	−5.395	−5.267	0.537	0.421
							Telecommunications sector							
MTSS	0.065 (0.097)	-0.045 (0.111)	0.093 (0.116)	0.140*** (0.036)	-0.002 (0.040)	0.079	26.493	0.011	0.060	25.78***	−6.302	−6.174	0.307	0.208
RTKM	-0.053 (0.122)	-0.127* (0.075)	-0.032 (0.134)	0.098* (0.051)	0.026 (0.049)	0.053	27.956	3.247	4.912	21.66***	−5.997	−5.869	1.029	1.758
YNDX	0.006 (0.091)	0.005 (0.112)	0.176 (0.299)	0.111 (0.126)	0.053 (0.083)	0.017	19.964	0.478	0.913	11.14**	−4.630	−4.502	0.003	0.002
							Consumer sector							
AFLT	0.047 (0.112)	0.124 (0.109)	-0.500** (0.229)	0.223 (0.151)	0.002 (0.125)	0.148	24.250	1.213	3.241	12.62**	−4.952	−4.824	1.032	1.737

Y_{tLn_ln-1}	Y_{t-1}	Y_{t-2}	X_{1t} (USD)	X_{2t} (URALS)	X_{3t} (BONDS)	R^2	Portmanteau test	ARCH test LM Lag 1	ARCH test LM Lag 2	(DH) test χ^2	AIC	BIC	F test Lags	F test Variables
MGNT	-0.004 (0.101)	-0.069 (0.092)	-0.082 (0.196)	0.090 (0.068)	0.040 (0.063)	0.029	**17.725**	**0.041**	**0.095**	**1.53**	–5.298	–5.170	0.264	0.526
Raw materials sector														
CHMF	0.037 (0.088)	0.047 (0.107)	0.080 (0.158)	0.071 (0.056)	0.009 (0.052)	0.020	**28.929**	**0.212**	**0.250**	7.34*	–5.880	–5.752	0.178	0.214
GMKN	0.098 (0.098)	-0.079 (0.085)	**-0.357**** (0.163)	0.128 (0.085)	-0.088 (0.071)	0.120	**22.294**	**0.365**	**0.962**	**0.82**	–5.598	–5.470	0.7890	0.675
MAGN	-0.013 (0.090)	0.081 (0.103)	-0.001 (0.177)	0.125 (0.087)	-0.053 (0.071)	0.034	**17.954**	**1.574**	**1.585**	**4.56**	–5.407	–5.279	0.328	0.637
ALRS	-0.047 (0.117)	**0.283***** (0.078)	**-0.532**** (0.213)	**0.150*** (0.082)	**-0.167**** (0.070)	0.249	**11.513**	7.377**	10.660**	**4.27**	–5.383	–5.255	**4.768***	**8.763****
NLMK	0.016 (0.104)	0.128 (0.099)	**0.329**** (0.144)	**0.107*** (0.060)	0.005 (0.065)	0.064	**28.314**	**0.001**	**0.053**	8.58*	–5.613	–5.485	0.829	1.628
PHOR	–0.058 (0.097)	0.028 (0.090)	**0.352***** (0.128)	**0.106**** (0.053)	–0.073 (0.064)	0.097	**9.9795**	**0.328**	**0.655**	11.55**	–6.123	–5.995	0.228	0.080
PLZL	0.102 (0.150)	0.065 (0.103)	0.401 (0.297)	**0.282**** (0.130)	**–0.226*** (0.122)	0.092	**21.285**	3.967*	**4.634**	23.32***	–4.514	–4.386	0.858	0.439
POLY	–0.001 (0.114)	0.117 (0.091)	0.172 (0.297)	0.135 (0.145)	**–0.256**** (0.107)	0.075	**10.423**	**0.280**	**0.391**	8.97**	–4.526	–4.398	0.670	1.338
RUAL	0.031 (0.096)	–0.140 (0.101)	–0.104 (0.203)	**0.209***** (0.077)	–0.062 (0.077)	0.097	**17.5877**	**0.130**	**0.607**	**0.28**	–5.464	–5.336	1.032	1.976

Note. * P ≤ 0.05 ** P ≤ 0.01 *** P ≤ 0.001

Robust estimates of standard errors are indicated in parentheses (heteroscedasticity-adjusted), version HC1.

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