OECONOMIA
COPERNICANA

VOLUME 12 ISSUE 2 JUNE 2021

p-ISSN 2083-1277, e-ISSN 2353-1827
www.oeconomia.pl

ORIGINAL ARTICLE

Citation: Bernardelli, M., Korzeb, Z., & Niedziółka, P. (2021). The banking sector as the absorber of the COVID-19 crisis' economic consequences: perception of WSE investors. *Oeconomia Copernicana, 12*(2), 335–374. doi: 10.24136/oc.2021.012

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Received: 15.01.2021; Revised: 4.06.2021; Accepted: 14.06.2021; Published online: 30.06.2021

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The banking sector as the absorber of the COVID-19 crisis' economic consequences: perception of WSE investors

JEL Classification: *G01; G10; G21*

Keywords: *banking sector; commercial banks; Warsaw Stock Exchange; COVID-19*

Abstract

Research background: The paper focuses on the research of investors' decisions with regard to shares of all 12 banks listed on the Warsaw Stock Exchange during the first half of 2020. It examines the behavior of a subindex reflecting bank shares' prices against the main WIG index WIG and 14 sector subindices. The authors identify groups of banks with different investors' responses. They also classify banks into separate groups on the basis of changes in the fundamental indicators describing their economic and financial performance. The study concentrates mainly on the verification of the stability of this attribution, explaining reasons for its modifications over time.
Purpose of the article: To identify the characteristics of bank clusters determining different capital market responses to their listed shares and to explain the reasons for volatility in investors' behavior within the analyzed period.
Methods: The methodology of the research can be described in three areas. The first is the statistical analysis with the emphasis on the use of a quarter range to capture changes in the volatility

of share prices. The second area is the clustering k-means method based on the interpolated — from quarterly to daily — measures of the bank's financial condition. This mathematical approach is a novelty in finance and economics. The last, third, area is forecasting with the use of linear regression analysis, which is the key factor in determining the abnormal rates of return. The indicated areas are combined through a generally understood correlation analysis.
Findings & value added: Large retail banks have been less affected compared to medium-sized ones with relatively rich corporate portfolios. The initial market reaction reflected concern about the resistance to the crisis of poorly capitalized banks with mean liquidity buffers. Upon the announcement of government support, investors' approach to the shares of banks of differentiated economic and financial performance conformed accordingly. These findings are valuable in the long term especially from the perspective of supervision authorities' policy during external shocks. The presented study suggests designing flexible and tailor-made regulatory approach aligned with the defined bank clusters. Its value added also consists in proposing a new method of analysis, combining interpolation and automatic clustering, which has proved to be adequate for the study of a bank's financial condition based on daily frequency data. Furthermore, assuming the same length of the estimation window, a close relationship is shown between the results of clustering and the forecasts based on different measures of rates of return.

Introduction

The pandemic crisis erupted after an unprecedented, nearly 11-year-long period of prosperity in the global economy. However, it cannot be compared to a completely unexpected event called the black swan (Taleb, 2007), but rather to a threat for which the international community should be prepared, although this risk was underestimated — the so-called grey rhino phenomenon (Wucker, 2016). From the European perspective, the first phase of the COVID-19 crisis had a strictly economic dimension and involved the disruption of supply chains and the need to revise business models based on globalization assumptions. The second phase involved a coincidence of a rapid surge in the number of infections and deaths, as well as a lockdown of many areas of economic and social life.

The response to the threats posed by the pandemic and actions to mitigate its negative effects have taken a dichotomous form. The first one refers to adjustment and restructuring processes initiated in business entities. Among them, the leading position belongs to the dissemination of remote working and the digitalization of purchasing and sales processes, in which the main obstacle seems digital deprivation due to infrastructural reasons (Kuc-Czarnecka, 2020). The second one is connected with multi-channel government support. It is done by providing debt financing, sureties, tax reliefs, reporting or payment deferrals, or through instruments aimed at reducing the burden on debtors (interest rate cuts, tax holidays).

The banking sector is not only a crucial intermediary in granting this aid (distribution of liquidity support products and provision of infrastructure), but it also takes over part of the costs of the crisis. This is a completely new

situation, as so far the banking sector has been rather a source of crisis and itself required state aid. At present, it is the banking sector that seems to be supporting the state in fighting the crisis. The government treats the banking sector as a channel for providing liquidity support to businesses and individuals. As a consequence of financial reforms implemented after the Global Financial Crisis (GFC), the pandemic shock found banks in a strong capital and liquidity position. That is why policymakers saw in the banking sector a part of the solution to the crisis. So far, banks have appeared to be shock absorbers rather than amplifiers, keeping credit flowing despite heavy drawdowns of credit lines at the beginning of the pandemic (Borio, 2020). Also, Demirguc-Kunt *et al.* (2020) proved that at the beginning of the pandemic crisis (between March and April 2020) banks' shares were underestimated compared to entities representing other sectors of the economy. These authors share the confidence of investors that banks will experience deeper income reductions than other sectors of the economy and other types of financial entities. The fact that banks belong to the group of sectors with the highest value loss, alongside recreational services, fitness centers, and consumer lending, is also confirmed by Thorbecke (2020). At the same time, further deterioration in bank profitability is to be expected. Altman (2020), warning against the uncritical use of bankruptcy prediction models, estimated the negative impact of the pandemic on the U.S. credit market at approx. 8% of total credit exposures.

Commercial banks in Poland entered the pandemic period in a relatively good financial condition, and the first 9 months of 2020 did not significantly change this state of affairs. Capital adequacy, liquidity, and leverage ratios have improved. Although the share of non-performing loans increased (from 6.6% as at the end of 2019 to 7.0% as of 30 September 2020) and also the cost of risk was subject of growth (from 85 to 106 basis points), this scale of deterioration does not entitle to conclude that the level of credit risk threatens the stability of the sector. The only area where the negative trend has intensified is profitability (NBP 2020, pp. 58-60). Upon the onset of the crisis, the banking sector in Poland was also characterized by a high level of digitalization as well as it was proved that e-banking in the period of the pandemic operated flawlessly (ZBP, 2020). The policy of the National Bank of Poland and the Polish Financial Supervision Authority is primarily aimed at maintaining high liquidity of the banking sector and removing regulatory barriers to credit expansion. This is evidenced by the simultaneous use of a wide range of liquidity-enhancing instruments, which were described extensively by Pietryka (2016). At the same time, no measures are taken to stop the erosion of banks' profitability (e.g. tempo-

rary reduction in bank tax) to which a low interest rate environment and high competition contribute.

The authors take into analysis the perception of the impact of the COVID-19 crisis on the Polish banking sector by stock market investors. Their reaction is reflected in the trend of the sub-index trend of commercial banks against the WIG index and the association of sector sub-indices with expectations regarding the scale of absorption of negative consequences of the crisis by the banking sector. On the basis of changes in values of selected indices, a clustering into 3 groups of banks was made using the k-means algorithm (Hartigan & Wong, 1979, pp. 100–108) with normalization and the Euclidean distance measure. The data originally came from quarterly financial reports, but were transformed into daily data (volatility of indices proportional to changes in bank share prices).

The authors believe that this study fills the research gap which is related to explaining on the microeconomic premises the reasons for the relatively high downgrade of bank share prices during the external shock. Based on the identified patterns of behavior with regard to different bank clusters, it may also help in defining flexible and differentiated macro-prudential and regulatory policies for distinct groups of banks. This study also reveals the impact of government intervention on stock market investors' perceptions of the banking sector and highlights the importance of the sectoral composition of credit and investment portfolios in assessing the risk of a financial institution.

The remainder of this article is structured as follows. Section 2 reviews the most significant literature related to the impact of COVID-19 on the banking sector and the reaction of stock investors to the pandemic. Section 3 is dedicated to the data and methodology employed in the empirical research. Section 4 presents and discusses the obtained results. Section 5 summarizes and presents the main conclusions.

Literature review

The channels for the impact of the COVID-19 pandemic on the banking sector were identified *inter alia* by Kulińska-Sadłocha *et al.* (2020). These issues in the context of not only the banking sector but also the financial markets are the subject of analysis by Deloitte team (Baret *et al.*, 2020). The above mentioned authors point out that risk weighted assets during the pandemics may be impacted by augmented chargers from intensified volatility and a material surge of counterparty risk. Also, some banks' contingency funding plans affecting liquidity positions may already have been

called into use. In line with GDP contraction, one can expect a decrease in demand for banking products (especially credit facilities) which, together with central banks cutting interest rates, may result in the plummeting of banks' profitability. The spectrum and taxonomy of costs for financial intermediaries were examined by Waliszewski and Solarz (2020, pp. 52–58).

Waliszewski and Warchłowska (2021) examined personal finance management applications during the COVID-19 crisis and found, *inter alia*, that customers tend to use non-bank solutions more often. This confirms the negative consequences (costs) of the pandemic for the banking sector, which may occur to be long-term and result from socio-demographic factors.

Gerding *et al.* (2020) came to the conclusion that following the beginning of the crisis, cumulative returns and cumulative CAPM-adjusted abnormal corporate returns were relatively lower in countries with higher indebtedness. As the pandemic evolves, the abnormal returns diminish more in response to the same increase in infections among countries having high low-debt-to-GDP ratios. The COVID-19 pandemic has influenced the decisions of stock market investors, but not all markets and not all types of listed companies are similarly affected. Arteaga-Garavito *et al.* (2020) quantified the exposure of financial markets to announcements related to COVID-19 and high-frequency data published on Twitter. In a 60-minute window around the announcement time, they did not find significant adjustment in bonds returns among advanced economies, whereas in emerging markets a sudden positive growth was observed. As far as stock markets are concerned, trading volumes around the announcement plummeted and then experienced a slow reversal. This pattern was more severe in emerging economies. Baker *et al.* (2020), using stock market volatility and newspaper-based economics as well as business expectation surveys, documented the evidence that about half of the forecasted contraction of GDP in the USA results from a COVID-induced one. Zhang *et al.* (2020) showed that global financial market risks have grown substantially in response to the pandemic and that individual reactions are tightly related to the severity of the outbreak in a given country. To estimate GDP growth changes, Gormsen and Koijen (2020) researched the volatility of claims to dividends in response to COVID-19 and respective policy announcements. Sansa (2020), based on the quotations of major stock indices and using simple regression in double log and semi-log linear models, proved the positive and significant impact of COVID-19 on capital markets in China and the USA. Employing data from NYSE, Nasdaq, or Amex and referring to 1,000 companies of the biggest capitalization index, Landier and Thesmar (2020) conclude that they expect a long-lasting and negative impact of the crisis on

stock prices. Due to COVID-19 driven unprecedented drop of stock market indices, Dias *et al.* (2020) decided to test the random walk hypothesis in developed, European and also non-European, capital markets. They analyzed capital market efficiency in its weak form, through 9 stock market indices for the period from December 2019 to May 2020.

Bieszk-Stolorz and Dmytrów (2021), using survival analysis methods, compared the intensity of drop and thereafter increase in main stock indices during the COVID-19 pandemic. The above mentioned authors found the highest intensity of decline in the European stock exchanges, whereas the highest increases were observed in the American stock exchanges.

Generally, stocks of companies less exposed to COVID-19 performed better, which was documented by Alfaro *et al.* (2020) and Hassan *et al.* (2020). This is consistent with the conclusions of Ding *et al.* (2020) who, using data of 6,000 firms from 56 economies, proved that entities with stronger balance sheets and less exposed to the pandemic, as well as carrying more sustainable operations experienced better returns and lower volatility. Based on data from the Indonesia Stock Exchange, Devi *et al.* (2020) came to the conclusion that during the COVID-19 pandemic there was an increase in the leverage ratio and short-term activity ratio, but in case of public companies diminished liquidity and profitability ratios were evidenced. Also, Ding *et al.* (2020), using data on over 6,000 firms across 56 economies during the first quarter of 2020, found that the pandemic-induced drop was milder for companies with relatively better financial performance, less exposed to COVID-19, less involved in global supply chains, and more engaged in CSR initiatives. Furthermore, stock prices of entities with greater hedge fund ownership performed worse, whereas shares of firms with larger non-financial corporate stakes yielded better returns. Pagano *et al.* (2020) came to the conclusion that companies more resilient to social distancing during the COVID-19 significantly outperformed firms with a lower level of resilience. Using stock option prices, they documented that up to the two-year horizon, stocks of firms more resilient to the pandemic are expected to report significantly lower returns than less resilient ones. The authors of the research noticed that market prices are exposed to a new risk factor, i.e. the pandemic risk. According to Ramelli and Wagner (2020), at the beginning of the pandemic crisis international trade and global value chains played a key role in corporate value. Then investors and analysts became concerned about highly indebted entities and companies whose survival chances were limited due to small cash reserves. Albuquerque *et al*. (2020) showed that stock prices of entities with ESG scores performed much better than the other ones.

Within the research trend dedicated to studying the impact of the pandemic on share prices of listed banks, one has to highlight a study of Iwedi *et al.* (2020), who analyzed Nigerian banks between 1 January 2020 and 30 September 2020. The authors used banks' share prices and a number of confirmed COVID-19 cases as variables in the vector autoregressive model. They proved a negative, though not statistically significant, impact of COVID-19 on bank share prices. Variance decomposition indicates a weakness of COVID-19 as a long-term predictor of changes in bank share prices. Even an increase in infections by 1 standard deviation has no significant impact on share prices. Thorbecke (2020) showed that the increase in the slope of the yield curve as a result of spread augmentation by 100 basis points causes a growth of bank share prices by 3–4 percent.

Demirguc-Kunt *et al*. (2020), using data from 896 commercial banks representing 53 economies, proved that due to the potential credit crunch, the shares of banks with low liquidity buffers recorded particularly large decreases, accompanied by an increase in the liquidity premium on the interbank market. They also analyzed 429 sovereign financial policy events in 44 countries that fall into the following categories: (i) liquidity support to the banking sector, (ii) prudential measures related to periodic relaxation of regulatory and supervisory requirements, (iii) support to household and corporate financing in the form of government credit lines or guarantees, (iv) monetary policy, including interest rate cutting and quantitative easing. The above mentioned authors designated abnormal returns of banks' stocks around the dates of the announcement day and found that the announcements of liquidity support and borrower assistance resulted in the boost of banks' stock prices in line with bank stocks overperformance around these events. The positive relation between excess stock returns and borrower assistance measures is exclusive to developed countries, whereas in the developing ones – due to a smaller space for fiscal expansion — these announcements had no effect. Larger banks and public banks in developing countries seem to benefit more than smaller and private banks respectively. Simultaneously, no important effect of countercyclical prudential measures was observed. This can be explained by the pricing by financial markets of the downside risk from the depletion of capital buffers as well as by further expansion of riskier loans portfolio. Also, banks with lower liquidity buffers displayed higher returns around the announcements, which confirms that the interest rate policy was a key tool upon the beginning of the pandemic.

Acharya and Steffen (2020) analyzed the "dash for cash" phenomenon during the COVID-19 pandemic and asked a question whether riskier companies increased cash holdings more than the ones characterized by better

financial performance. The authors evidenced better access of companies to improved liquidity performance during the first quarter of the pandemic. "Dash for cash" impacted the balance sheets of banks since unutilized and committed financing were turned into loans. The accelerated drawdowns, as well as growing credit provisions, might bring banks closer to capital adequacy requirements. This, in turn, may endanger financial stability as well as curb future intermediation with likely spillovers into the real economy. In another study, Acharya *et al.* (2020) proved that upon the onset of COVID-19 U.S. corporates (mainly BBB-rated and non-investment grade ones) drew down at least USD 235 billion, which coincided with a market value decline of U.S. banks by approx. 50%. Also, Li *et al.* (2020) noticed an unprecedented increase in loans in banks' balance sheets in March 2020 due to drawdowns made by non-financial clients.

A separate stream of research is devoted to the ranking of banks in terms of their sensitivity to the crisis. Chaikovska (2020) analyzed 12 banks listed on the Warsaw Stock Exchange in the period from 2015 to 2019. The subjects of the study were: capital adequacy ratio, leverage ratio, share of non-performing loans, LCR, and Tier 1 excess/deficit ratio. The division into quartile groups allowed for the identification of the safest ones and those with the lowest security level. In turn, Korzeb and Niedziółka (2020) documented that the largest Polish banks are the most resistant ones to the consequences of COVID-19 effects. Still, the resistance to the pandemic of Portuguese banks was investigated by Korzeb *et al.* (2021).

Research methodology

The analysis presented in this paper can be split into five stages:
1. descriptive statistics,
2. measures of the bank's financial condition,
3. bank's clustering,
4. measures of rates of return,
5. comparison of the results of the third and the fourth stage.

A detailed description of each stage is given in the remainder of this section.

The first stage covers the comparison between sectors of the economy represented by sectoral stock market indices in terms of pandemic-related impacts. The increases in WIG indices for March 2020 and the periods before the COVID-19 outbreak were analyzed independently. Based on the percentage increase in the quarter range in March 2020, compared to the quarter range before March 2020, the instability of share prices, their vola-

tility, and the pandemic effect were estimated. This stage gives a justification and quantitative argument for divergent economic sector responses to pandemic-induced changes. The remaining stages were focused on the comparative analysis of banks in terms of their financial condition and the study of potential determinants of the abnormal rates of return.

The second stage was concentrated on selected, 13 measures of financial conditions for 12 banks, which can be calculated with the use of quarterly financial reports (Table 1). All 12 banks listed on the Warsaw Stock Exchange were included in the survey. They accounted for 82.2% of own funds and 83.7% of total assets of the sector. Reports from the first and second quarter of 2020 were used for the estimation of changes in the banks' financial condition caused by the pandemic situation. The measures were selected with a view to maintaining a sufficiently high level of variability.

To make it comparable with the quantitative measures based on the daily frequency, the technique of piecewise linear polynomial interpolation was performed, where values for each measure were spread proportionally to share prices. To be more precise, each measure with a quarterly frequency (from the second stage of the analysis) was transformed to a daily frequency, taking into account percentage daily changes in the valuation of the bank's shares. The interpolation was performed separately in the first (31.12.2019–31.03.2020) and the second (31.03.2020–30.06.2020) quarter of 2020. This is one of many possible interpolation methods, which give the possibility to reflect the dynamics of changes in share prices individually for each bank. Those daily values of quantitative measures were used in two ways. The first application, and at the same time the third stage of the analysis, is the clustering into a group of similar banks in terms of changes in the value of interpolated indicators expressing the financial condition of the bank before and after the "zero point" of the pandemic, that is 12 March 2020. For indicators measured in percentage terms, only differences were calculated, whereas for those measured on a continuous scale the relative change was computed. This set of input data, after normalization, was used in the k-means algorithm. Normalization is meant the scaling of the values into a range of [0.1]. The grouping took place on the basis of observations made in a multidimensional space, where each of the coordinates was related to a specific change of the indicator. The dimension of the space was therefore equal to thirteen — the number of considered indicators. The Euclidean norm was adopted as a measure of distance, and clustering into three groups was considered. The chosen number of groups took into account a small group of banks used in the study. Apart from the transformation of input data, the k-means algorithm did not differ from the classical

implementation described by Hartigan and Wong (1979, pp. 100–108). Theoretically, the data from quarterly reports could be used as input data for clustering, but in this study the changes around the "event day zero" were crucial; therefore, the computations based on daily frequency measures better reflected changes in banks and thus gave a potentially more adequate clustering. Every possible subset of proposed indices was verified for different distances from the "event day zero": 5 to 30 days. By applying this brute-force approach, an optimal set of indicators was selected. The quality of the classification was not the key aspect in this context — these were changes in classification over time. Based on the changes in the affiliation of banks to particular groups depending on the range of days covered by the analysis, the conclusion was made about the similarities and dissimilarities between the banks in close proximity to the beginning of the pandemic in Poland. The combination of the clustering and interpolation from quarterly to daily data is a novelty in the banking analysis. This mathematical approach allows for capturing increased volatility caused by a crisis or any event significantly affecting a bank's performance. In the presented context, the sample of banks (12) was not big enough to be representative, but the idea itself is worth considering, and the resulting inferences certainly bring an added value to the existing state of knowledge.

The second application of daily interpolated measures involved estimating the existence and strength of the relationship between the set of financial indices and the classic measures of rates of return.

The essence of event analysis is calculating an abnormal rate of return of the bank's shares, i.e. the difference between the real and expected rate of return on bank assets if the event did not occur (MacKinlay, 1997):

$$AR_{it} = R_{it} - E(R_{it}|X_t), \tag{1}$$

where $AR_{i\tau}$, $R_{i\tau}$, and $ER_{i\tau}$ are the abnormal, actual (arithmetic), and normal returns on shares of *i-th* bank achieved on day t, X_τ is the conditioning information for the normal return model, $i = 1,2,.., N$, where N means the number of sampled banks. The expected return on the share of bank i is estimated on the market model.

Cumulative Abnormal Returns $CAR_{i\tau}$ is calculated as the sum of daily abnormal rates of return from successive session days in the analyzed period τ:

$$CAR_{i\tau} = \sum_{t=1}^{\tau} AR_{it}, \tag{2}$$

where $CAR_{i\tau}$ is the cumulative abnormal returns on shares of i-th bank over the analyzed period; AR_{it} is the abnormal returns of i-th bank shares on day t, and the time period τ is the period of observation (*CAR-window*), a time frame measured in session days t.

Buy-and-hold abnormal returns $BHAR_{i\tau}$ is calculated as a difference between the rate of return on investments in bank shares in the analyzed period and the expected rate of return (Barber & Lyon, 1997):

$$BHAR_{i\tau} = \prod_{t=1}^{\tau}(1 + R_{it}) - \prod_{t=1}^{\tau}[1 + E(R_{it})], \qquad (3)$$

where $BHAR_{i\tau}$ is the buy-and-hold abnormal returns on shares over the analyzed period; R_{it} is the real rate of return on shares of i-th bank on day t if the event did not occur; $E(R_{it})$ is the expected rate of return on shares of i-th bank on day t if the event did not occur.

The average of cumulative abnormal returns for the whole analyzed sample is calculated as an arithmetical mean of individual banks' cumulative rates of return:

$$ACAR_{N\tau} = \frac{1}{N}\sum_{i=1}^{N} CAR_{i\tau}\ , \qquad (4)$$

where $ACAR_{N\tau}$ is the average of cumulative abnormal returns on shares of N banks in an analyzed period τ.

Lastly, the average of cumulative buy-and-hold abnormal returns with N banks in the analyzed period is defined as:

$$ABHAR_{N\tau} = \frac{1}{N}\sum_{i=1}^{N} BHAR_{i\tau}\ , \qquad (5)$$

where $ABHAR_{N\tau}$ is the average of cumulative buy-and-hold rates of return on shares of N banks in an analyzed period τ.

The fourth stage of the analysis, therefore, is devoted to the computations of different measures of rates of return. The key aspect of each of these measures is the determination of the method of approximation of the expected rate of return on shares of each bank on each day under consideration. The analysis described in this paper covered three simple linear regression models with the WSE-banks index as the explanatory variable and stock quotes for a given bank as the explained variable. Each bank model was based on different lengths of the estimation window, that is a number of consecutive (arbitrarily chosen) 30, 60, and 90 stock quotes starting from 1 October 2019. The estimated parameters of these models were used in the

calculations of forecasts for March 2020 of CAR, and BHAR measures for each bank, as well as ACAR and ABHAR measures.

The results of the third stage with clustering and the fourth stage with different measures of rates of return were summarized and compared. This is the fifth, and the last, stage of the performed analysis. Both approaches are based on changes in indicators in the period covering the "event day". The indicators, however, in each case were different. In the first approach, the selected measures described the financial condition of the bank and the change measured in the period before and after the crucial point. In the second approach, indicators were chosen to quantify the abnormal stock quotation. In both cases the same period was used, therefore it was possible to make a comparison. The sample of banks is small, but the value of the Spearman correlation coefficient and ranking lists based on values of different indicators seem to prove the existence of the relationship between these two approaches.

Results

The first stage of the analysis boils down to presenting the sectoral economic situation from the statistical point of view. The comparison of volatilities of daily WIG indices for sectors of the economy represented by sectoral stock market indices was made for three periods:

1) 2017.Q1–2020.Q2,
2) 2020.Q1–2020.Q2,
3) March 2020.

The box diagrams, excluding observations considered outliers for each of these periods, are shown in Figures 1–3. As it was evidenced, many sectors significantly increased their volatility in March in terms of increments determined by the daily WIG indices. This means that in March 2020 there were the biggest drops (but also increases) in share prices in years as far as the daily changes compared to the previous trading day were concerned.

Selected descriptive statistics for the whole period and for March 2020 are collected in Table 2.

While for most sectors the median of price changes oscillated around 0%, in March all branches recorded more declines than increases in stock prices. Moreover, for all of them the biggest drop since 2017 was noticed in March 2020. However, not all sectors were equally affected by the introduction of restrictions related to the COVID-19 pandemic. Apart from the oil & gas and gaming, the share prices of all others mostly plummeted. Figure 4 shows the median share price movements in March 2020.

The loss of stability was measured by the estimation of the percentage increase of the quarter range in March 2020 compared to the situation before March 2020. A larger ratio means greater changes in share prices in subsequent quotations. A smaller one can be in turn identified with a greater stability of prices. From the summary shown in Figure 5, it appears that all sectors recorded much higher volatility in share prices, which ranged from 175% to as much as 553% in the preceding period.

The measures of the bank's financial condition given in Table 1 were taken from the quarterly financial reports. They provide a basis for the computations in stages three and four of the analysis. In the third stage for each bank separately, the daily values of the indicators describing the economic and financial situation of banks in the first two quarters of 2020 were estimated. It was assumed that the ratios change proportionally to the fluctuations of their share prices with the values at the beginning and the end of quarters being determined and coinciding with those obtained from the financial statements. Examples of estimations for PKO BP bank TCR and TIER 1 are shown in Figures 6–9. Visualizations of the values of selected indicators in +/–5, +/–10, +/–15, +/–20, +/–25, and +/–30 of consecutive quotations from the event day zero is shown in Figures 10–11.

Various combinations of indicators for different sizes of the event day zero neighbors were considered. Figure 12 shows the results of clustering based on the values at the beginning and the end of periods +/–5, +/–10, +/–15, +/–20, +/–25, and +/–30 of consecutive quotations from the event day zero. For example, GR5 is the notation used for the estimation window extending by 5 consecutive quotations from the event day zero, that is from 2020-03-05 (beginning of period) to 2020-03-19 (end of period). Next, the differences in the values of the indicators from these periods were determined. The resistance indices, which were assumed to be fixed during the year for each bank, as well as the "net result" (PLN thousand) were excluded from the procedure for which a relative error was calculated instead of an absolute difference. Based on the obtained values of changes in the selected set of indicators, an automatic division into 3 groups of banks was made using the k-means method with normalization and Euclidean distance measure. Groupings change depending on the length of the estimation window under consideration due to the high variability in index values in the immediate vicinity, which stabilizes after approximately 15 quotations. Having performed a series of experiments as an optimum, a set of indicators was finally chosen on the basis of a specific clustering : (i) TCR, (ii) ROE, (iii) LCR, (iv) Impaired (%) — (Stage 3 + POCI)/Gross credits, (v) Provision coverage, (vi) C/I, (vii) IND_D.

The clustering was conducted for different distances from the "event day zero". This has made it possible to observe a change in the composition of individual groups. PKO BP, Pekao SA, mBank, ING Bank Śląski, and Bank Handlowy are all classified into one group. At first, Alior, Idea, and BOŚ formed a separate group, but after about 15 quotations they resembled the other ones. This was due to greater differences in the values of the ratios of Santander BP and BNP Paribas BP banks. Santander BP fell out of the group of banks on about the 15th day of listing and was included in a separate group. BNP Paribas BP Bank has such different characteristics (similarly to Santander BP) that it became a separate group already upon around 10 days of listing. It is important to emphasize that clustering is not based on the value of indicators, but on their changes in the period before and after "event day zero". It is also not a simple division in relation to the selected indicator, but an automatic classification of banks into the most similar groups in the multidimensional space generated by normalized values of indicator differences.

The fourth stage involved making a comparison of the AR measure in "event day zero" of the pandemic (12 March 2020) for each bank and different estimation windows based on which the forecasting of three linear regression models was created. The results are shown in Figures 13–15. The number of stock quotes was set to 30, 60, and 90. The estimation window started from 1 October 2019 and ended on 14 November 2019 (30 quotations), 2 January 2020 (60 quotations), and 14 February 2020 (90 quotations).

The linear regression model based on 90 quotations incorporated the newest data, and therefore the forecast should be more accurate compared to the other two models. Depending on the used model (see Figures 6-8) different forecasts and related AR, CAR, and BHAR measures are obtained. For the selected banks, the comparison of the quotation forecast for March 2020 depending on the estimation window is given in Figure 16. The exemplary graphs allow for making a conclusion about the size of changes related to, among others, a pandemic situation. For some banks forecasts were quite accurate (like Santander Bank), for some too optimistic (e.g. BNP, mBank), for others quotations exceeded the assumed forecasts (e.g. PKO BP).

The forecasts affected the measures of the rate of return on investments in bank shares. A summary of CAR and BHAR measures designated for banks listed on the Warsaw Stock Exchange according to data from March 2020 is presented in Table 3.

ACAR and ABHAR measures determined for the data of March 2020 based on 30, 60, and 90 quotations are presented in Table 4. On average, no

matter what model was used for the forecast, the rate of return on investments in bank shares was negative. However, there were banks, like PKO BP SA or Santander Bank Polska SA, whose stocks haven't lost that much in value.

Based on 90 quotations' estimation window and the linear regression model, the CAR measure turns out to be negatively correlated with, among others, the difference in the cost of risk value determined at the beginning and the end of March 2020. The rho Spearman correlation coefficient, in this case, is -0.74 (Table 5). The p-value in the test of significance equals 0.006, which makes it very unlikely that the observed relationship is not true. This exemplary comparison as part of the fifth stage proves that there is a close relationship between the results of clustering and the forecasts based on different measures of rates of return.

Discussion

The analysis showed that the main factor influencing investors' behavior, and thus banks' quotations on the Warsaw Stock Exchange, was uncertainty about the duration of the pandemic and the sustainability of the economic recovery. Although government support was mainly directed at financing companies and protecting jobs, it also indirectly affected the banking sector. Until the first case of COVID-19 infection in Poland was recorded, i.e. 4 March 2020, the stocks of banks outperformed the main stock indices WIG and WIG-20 and were very close to the average of all industry indices. It, therefore, appears that at this point in time the market discounted the unfavorable system-wide information for the whole sector, such as:

- the issue of relatively high financial burdens resulting from the cost of adjustment to numerous regulatory solutions (e.g. CRD V/CRR II, MREL, MIFID II, RODO, PSD 2) as well as taxes on certain financial institutions,
- claims brought against individual banks due to the judgments of the European Court of Justice (CJEU) on: (i) foreign currency mortgages in CHF of 11 September 2019 and (ii) reduction of the total cost of a loan in the event of early repayment of 3 October 2019.

In addition, it should be considered that share prices also took into account a specific dichotomy of listed banks — banks in a relatively good financial situation — and banks with low capital adequacy and profitability. The increase in infections and deaths inducing restrictions, such as: suspension of school classes, closure of Poland's borders to air and rail traffic, introduction of a state of epidemics and restrictions on movement in March

2020, radically changed the situation on the capital market. The pressure on the valuation of banks caused mainly by concerns about the impact of the economic slowdown on the quality of their assets contributed to a situation where at the end of Q1 2020, out of all industries, the WIG-banks sub-index was one of the indices that suffered the largest losses according to the achieved rates of return. Despite the optimism in the markets associated with expectations of a rapid recovery with significant economic policy support in the second quarter of 2020, banks' valuations continued to be at a low level due to an uncertain horizon for improvement in the sector's performance. In the first half of 2020, among all industries, the banking sector in Poland was characterized by one of the lowest returns. An additional factor determining such a behavior of investors, apart from the increase in the risk accompanying banking activity in the face of the pandemic, was a three-fold reduction of interest rates carried out by the Monetary Policy Council. So far, based on the standard commercial banking model, they have generated relatively high income from deposit activity, resulting from the difference between the offered deposit rates and market rates, based on interbank rates. However, as Carletti *et al.* (2020, p. 53) stress, "the Covid-19 crisis implies that low interest rates are here to stay for even longer than previously expected. This will put further pressure on banks' profitability, while simultaneously mitigating NPLs and boosting collateral values, thus helping preserve bank capital and solvency." This issue is explained in detail by Altavilla *et al.* (2017). In their opinion, "…monetary policy easing — a decrease in short-term interest rates and/or a flattening of the yield curve — is not associated with lower bank profits once we control for the endogeneity of the policy measures to expected macroeconomic and financial conditions. Importantly, our analysis indicates that the main components of bank profitability are asymmetrically affected by accommodative monetary conditions, with a positive impact on loan loss provisions and non-interest income largely offsetting the negative one on net interest income…" They also found that, while more efficient banks benefit from monetary policy easing, banks relatively more involved in maturity transformation benefit from a yield curve's steepening. Another issue which does not allow for a more permanent reconstruction of previous bank valuations was the need to apply credit holidays for customers most affected by the pandemic. Banks introduced special facilities for their clients, thus supporting systemic activities of the government and state institutions. This situation has affected the spread of expected interest income over time.

The combination of CAR and BHAR measures set for banks listed on the Warsaw Stock Exchange shows relatively high volatility of share prices, especially when analyzing 30 quotations. Later on, there is a trend to-

wards higher rates of return for the three largest banks in the Polish banking sector in terms of assets and net profit: PKO BP, Santander BP, and Pekao SA. It should be noted that the investors appreciated the stable foundations of their operations, the financial results achieved so far and the positive assessments systematically obtained as part of stress-testing by supervisory institutions. High CAR 90 and BHAR 90 values were reported by Alior and Idea. This should be explained by the fact that investors abandoned their original concerns about the solvency and liquidity of these institutions. At the other extreme were: ING Bank Śląski, BNP Paribas BP, Bank Handlowy, BOŚ, and mBank. Their worse behavior, compared to the other analyzed banks, may therefore be explained by the fact that these banks are perceived as banks with relatively large corporate exposure. The risk here, due to the high concentration of the portfolio and the uncertainty about the duration and impact of the pandemic, is much higher than for banks with a retail profile (i.e. with large corporate assets limited to 25% of the total credit portfolio or without large corporate division). In addition, the manner in which write-downs (affecting net result) are determined is not as clear as in the case of the retail portfolio. These are also smaller institutions than those included in the first group as well as those that have lower external ratings. At the same time, it is worth considering a moderate reaction of the market in relation to other banks classified as medium or small banks (Millennium and Getin Noble). There are three ways to explain it. Firstly, these are retail banks, and given the arguments set out above, the market did not react with an additional stock price adjustment. Secondly, these are mainly banks in a relatively worse financial situation than those classified in the previously discussed groups (this is also reflected in lower rating grades assigned by CRAs) and their problems (large loan portfolios in CHF or need for pay back consumer credit commissions or undercapitalization or low profitability) date back to a period earlier than the COVID-19 pandemic. The market had already discounted this before the pandemic and the allocation of these banks to a relatively high-risk group largely coincides with the classification made by Chaikovska (2020). The third argument is related to the second phase of the study, which analyzed the relationship between the behavior of bank share prices and their standing and the bank's volatility.

On the basis of the obtained values of changes in the selected set of eight indicators, an automatic clustering into 3 groups of banks was made using the k-means method with normalization and the Euclidean distance measure. The largest group includes major banks operating in the Polish banking sector. Three additional banks: Alior, Idea, and BOŚ formed a separate group at the beginning, but after about 15 quotations they started

to resemble the other ones. The differences between the estimated and forecasted values in the vicinity of the "event day zero" — in the period of 15 quotations — may be due to the fact that these banks achieved worse financial results than average in the sector (e.g. for Idea the Tier 1 ratio was at the level of 0.30% with the required 8.5%, and the NPL ratio was 23.24% as at 30.06.2020) and informed about unfavorable events in the analyzed period (e.g. establishment of additional provisions by Alior charged in the first half of the year). This and conclusions drawn from the CAR and BHAR analysis mean that the first market reaction to the pandemic crisis in Poland was similar to other stock markets. Investors were most concerned about banks in a relatively worse capital and liquidity situation. This conclusion is in line with the observations by Demirguc-Kunt *et al.* (2020) and concerns about the impact of increased use of credit lines on the standing of banks expressed in the work of Acharya *et al.* (2020) and Li *et al.* (2020). The sentiment has contained with the announcement by the Polish Financial Supervisory Authority of the Supervisory Trigger Package and support programs for companies and individuals. Since then banks have been perceived quite uniformly with the exception of Santander BP and BNP Paribas BP. The listing behavior of Santander BP and BNP Paribas BP significantly deviates from the results of the other banks, which were included in the first group. Therefore, they were separated into other clusters. Both banks are owned by foreign shareholders. In the home countries of their shareholders: Spain and France, the first cases of Covid-19 took place already in January, i.e. much earlier than in Poland, which could also in a way influence the perception of both banks by investors. Among commercial banks, Santander BP has stood out for its high profitability in recent years. In the first 6 months of 2020 it achieved similar core business results as reported a year earlier (-3.5% y/y), despite the impact of interest rate cuts on the net interest margin, charging the interest income with the cost of returning part of the fees related to early repayment of consumer loans and the pandemic situation. Net fee and commission income decreased only by 1.2% compared to the corresponding period of the previous year. The additional net write-downs for expected credit losses, as an adjustment to the values resulting from the models in the conditions of uncertainty about the further development of the epidemic and economic situation, amounted to PLN 150.3 million in the first half of 2020. Although the biggest problem of Santander BP remains the CHF mortgage loans portfolio, the current level of surplus capital allows for a one-off posting of the loss resulting from both this and Covid-19, without violating significant capital adequacy ratios. On the other hand, the different pricing behavior of BNP Paribas BP results from the specific nature of its activity focused on

the agri-food segment. The share of impaired exposures in gross loans and advances to customers measured at an amortized cost was 5.9% at the end of 2019. According to the this bank's announcement (BNP, 2020): "Write-offs for impairment of financial assets and provisions for contingent liabilities on account of the impact of Covid-19 on risk costs in the first half of 2020 amounted to PLN 156.5 million and resulted mainly from the change of macroeconomic scenarios following Covid-19 (forward looking PD and LGD determined based on smoothed macro forecasts) and the bank's assessment of the expected future impact of the current economic situation on risk parameters for selected customer types." As a result, the total level of risk costs in the first half of 2020 was significantly higher than in the comparable period of the previous year, i.e. by 93.8% y/y. This bank was also in a phase of a complex integration of combined activities of the banks following the acquisition on 31 October 2018 of the core business of Raiffeisen BP S.A. This is also a bank with rules of capital management that differ from other banks. It consists in maintaining a relatively small capital buffer in relation to RWA, which determines the positioning of the bank in a group of institutions with relatively low stability (Chaikovska, 2020). However, the market perceives a difference between banks with capital shortages, low quality of the portfolio and low profitability and banks such as BNP Paribas BP, where the level of maintained capital is a function of the policy aimed at maximizing efficiency in terms of ROE. That is why this institution forms a separate cluster, although simultaneously the CAR 30 and BHAR 30 analysis confirmed that the investors' *ad hoc* reaction was not differentiated in terms of these two situations and was focused on capital adequacy without deeper reflection.

Conclusions

Alongside state interventionism, the banking sector became an essential part of rescuing the real economy during the pandemic. However, liquidity support to businesses and individuals (e. g. through credit holidays) came at the expense of bank liquidity, while interest rate cuts eroded their profitability. The above conclusions are consistent with the findings of other studies (Wu & Olson, 2020, pp. 89–99; ISDA, 2021). Actions taken by or through banks themselves, such as equity, liquidity or preferential funding schemes, guarantee mechanisms and the use of credit enhancements were instrumental in cushioning the recession. In addition to providing the funding necessary to preserve liquidity for businesses and households, an im-

portant role of banks during the pandemic proved to be an efficient allocation of capital through sectoral risk management.

The quotations of commercial banks' shares conducting their operations in Poland were determined by uncertainty as to the impact of the coronavirus epidemic on banks' operations and financial performance in subsequent periods. In case of some medium-sized private banks with relatively high share of mortgage loans denominated in foreign currencies (mainly in CHF) the quotations partially reflected investors' fears referring to legal risk materialization. This risk, in turn, can be approximated by the scale of litigations against banks, the probability of court judgements in favor of bank clients and, finally, the value of write-off and provisions created in reference to this risk. The problem of the FX mortgage portfolio intensified later than the time horizon of this study. At the same time, the explanatory variables were cleared of the impact of provisions related to the said portfolio. For these reasons, changes in bank share price quotations were considered to reflect investor sentiment related solely to the impact of the COVID-19 pandemic on the performance of the banking sector.

As regards the potential impact of the pandemic crisis on the commercial banking sector in the future, it should be noted that further financial performance of banks will depend, *inter alia*, on the duration and nature of the pandemic, the restrictions imposed on specific sectors as well as on the solutions of the aforementioned FX mortgage problem, fiscal, regulatory and monetary policy measures. A deterioration of the macroeconomic parameters, uncertainty and diminishing consumption, investment and government expenditures may in turn result in lower demand on banking products and, consequently, in the worsening of banks' economic and financial standing. This concern and the thesis of banking sector's role of pandemic shock absorber was verbalized by some researchers and bankers (like already referred to in this paper Demirguc–Kunt *et al.,* 2020 or Borio, 2020), especially at the onset of the crisis. The investors' reactions follow this way of analysis and that is why banks were relatively highly undervalued compared to other industries. Stock market investors, appreciating the stability of banks' performance in the first phase of the crisis were convinced that it would particularly affect banks with a relatively weak standing and these banks experienced the deepest erosion of the value. Following the announcement of government support measures for banks, businesses, and individuals, the issue of bank standing lost its meaning of the most important determinant of market value.

The CAR measure turned out to be negatively correlated with the difference in the cost of risk value determined at the beginning and the end of March 2020, which confirms the fact why investors pay attention to the

future banks' net result which can be affected by additional pandemic driven write-offs and a substantial growth of stage 3 exposures.

After the fire sale of shares of banks, regardless of their size, rating, profile, investors started to differentiate financial institutions. Due to the belief that businesses (especially representing COVID-sensitive industries) are more vulnerable to the negative impacts of the pandemic than individuals, investors came to the conclusion that in the long run the crisis will affect medium-sized banks with relatively important corporate portfolio to a greater extent, while banks with a dominant share of the retail portfolio would be less affected. This was proved by the AR 90 analysis. The conducted study also allowed to suggest that investors had the greatest confidence in large retail banks with strong investment credit ratings and reported good results even during the pandemic (like Santander Bank Polska). Investors also pay attention to differences in the quality of bank management, i.e. they prefer banks focused on efficiency maximization at the expense of low capital buffers being slightly above than the level required by supervision authorities (BNP Paribas BP).

The pre-pandemic structural problems of some banks (low capital buffers and huge write-offs affecting profitability) had been discounted by the market before the crisis. Apart from the already described reaction, immediately after the pandemic outbreak the shares of these banks did not experience different fluctuations patterns that in the case of the remaining banks.

One has to notice that the immediate effects of the pandemic were successfully mitigated or postponed by a number of government measures. Following EBA's guidelines, banks refrained from massive reclassification of corporate and individual exposures to stage 3 and the level of COVID-driven provisions is relatively low, compared to consequences of the above mentioned movement to basket 3. Bearing this in mind, as well as considering the probably long-term environment of low (or even negative) interest rates, the profitability of the banking sector is expected to decrease. This will limit the ability of the banking sector to strengthen its capital base and will put into question the future of dividends to shareholders in the upcoming years as well as a capacity to provide credit to the real economy. The inconvenient market conditions may lead to further polarization of commercial banks' market in Poland and intensify consolidation processes.

The study fills the research gap consisting in identification of factors (features of bank clusters) affecting banks' stocks during the pandemic crisis, and provides policy implications for the time of pandemic-driven economic downturns. Conclusions from this research will be useful for individual stock exchange investors and institutional ones (e.g. fund man-

agers), since its findings prove a certain pattern of behavior of shares of different groups of banks during the successive phases of the global pandemic crisis. It allows for making similar assumptions also with regard to the next crisis driven by a rapidly spreading disease. The findings seem to be important also for supervision institutions responsible for financial stability. This refers mainly to the scope and time schedule of macroprudential policy measures to banks' liquidity and capital buffers at levels appropriate to continue providing credit to the real economy as well as capital market regulations that would limit fire sales and rapid decrease of market capitalization. The results of the study also suggest that in times of external shocks, supervisory policies should be flexible and tailored to different groups of banks. Apart from the above mentioned policy implications the study also provides hints for bank managers on how to manage sector risk and immunize credit and investment portfolios against pandemic shocks.

The authors are aware of the limitations associated with this study which include a relatively small sample of banks and a short period of analysis. It should be noted, however, that the sample under examination covered all commercial banks listed on the Warsaw Stock Exchange, which is the largest stock exchange in Central and Eastern Europe. In other CEE countries, with a much smaller scale of the banking sector and the number of banks, banks listed on stock exchanges are not a representative sample, as can be said of banks listed on the Warsaw Stock Exchange (over 80% of the commercial banks sector in Poland). Further directions of studies will be focused on spreading the methodology to subsequent reporting periods; however, these are the first 3 months after the announcement of the pandemic state that are crucial. Apart from the analysis of price volatility, it is worth to investigate into the factors of volume fluctuations.

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Annex

Table 1. Selected characteristics of adopted measures

Selected measures	Description
TCR	Total Capital Ratio
Tier 1	Core Capital Ratio
Net profit	Net profit
ROE	Return on Equity
LCR	Liquidity Coverage Ratio (high quality liquid assets divided by net outflows within 30 days under extreme conditions)
Leverage Ratio	Financial leverage ratio (Tier 1 divided by the total exposure – in %)
C-D ratio	Credit-Deposit Ratio
Credit-impaired financial assets	(Impaired exposures + POCI)/gross credits (in %)
Credit loss provision coverage	Write-offs divided by the total portfolio impairment and value adjustment to the total portfolio impairment
Cost of risk	Cost of risk in in basis points
C/I	Cost to Income Ratio
IND_D	Resilience of credit portfolio to the COVID-19 crisis. Variable determined by banks' portfolios sector risk profile in the context of the COVID - 19 crisis according to the sector's risk estimation
INS_S	Resilience of credit portfolio to the COVID-19 crisis. Variable determined by banks' portfolios sector risk profile in the context of the COVID - 19 crisis according to rates of return of sectors in IQ 2020 (based on quotations of shares listed on the Warsaw Stock Exchange)

Table 2. Selected descriptive statistics for the whole period and for March 2020 for particular sectors of the economy

Index	2017.Q1–2020.Q2					03.2020				
	min	**Q1**	**Q2**	**Q3**	**max**	**min**	**Q1**	**Q2**	**Q3**	**max**
WIG	-12.7%	-0.5%	0.0%	0.5%	5.8%	-12.7%	-2.1%	-0.5%	2.5%	5.8%
WIG-media	-9.2%	-0.6%	0.0%	0.7%	8.8%	-9.2%	-5.3%	-1.1%	1.6%	8.8%
WIG-automobiles	-13.3%	-0.7%	0.0%	0.6%	13.5%	-13.3%	-3.8%	-0.3%	1.9%	5.8%
WIG-real estate	-7.6%	-0.5%	0.0%	0.5%	5.5%	-7.6%	-2.8%	-0.2%	0.6%	3.6%
WIG-oil & gas	-8.9%	-1.0%	0.0%	1.1%	7.1%	-8.9%	-3.7%	0.2%	3.4%	7.1%
WIG-clothes	-17.2%	-1.0%	0.0%	0.9%	12.7%	-17.2%	-3.3%	-2.0%	3.1%	10.2%
WIG-banking	-15.2%	-0.8%	0.0%	0.8%	6.8%	-15.2%	-3.3%	-0.9%	2.1%	5.8%
WIG-mining	-15.8%	-1.2%	0.0%	1.1%	10.7%	-15.8%	-3.9%	-0.4%	3.7%	7.8%
WIG-food	-11.2%	-0.7%	-0.1%	0.5%	11.2%	-11.2%	-2.2%	-0.3%	1.5%	11.2%
WIG-info	-7.3%	-0.6%	0.0%	0.7%	4.9%	-7.3%	-2.3%	-0.3%	1.7%	4.6%
WIG-pharmaceuticals	-18.7%	-1.0%	0.1%	0.9%	16.5%	-18.7%	-3.3%	-0.5%	2.2%	16.0%
WIG-games	-18.6%	-0.9%	0.3%	1.2%	9.3%	-18.6%	-1.2%	0.0%	5.0%	9.3%
WIG-chemical	-11.6%	-1.0%	-0.1%	0.9%	10.7%	-11.6%	-2.1%	-0.5%	2.4%	10.7%
WIG-energy	-13.8%	-1.1%	-0.1%	1.0%	11.0%	-13.8%	-2.4%	-1.4%	2.4%	11.0%
WIG-telecom	-9.3%	-0.7%	0.0%	0.8%	9.3%	-9.3%	-1.8%	-0.1%	1.5%	7.7%
WIG-construction	-6.9%	-0.6%	0.0%	0.7%	4.7%	-6.9%	-1.0%	-0.2%	1.2%	3.9%

Source: own elaboration based on the data of Warsaw Stock Exchange, https://www.gpw.pl/archiwum-notowan.

Table 3. CAR and BHAR for data from March 2020 and different estimation windows for which the projections of share prices were designated

Bank	**30 quotations**		**60 quotations**		**90 quotations**	
	CAR	BHAR	CAR	BHAR	CAR	BHAR
PKO BP	-0.04	-0.04	0.15	0.13	0.20	0.18
Santander BP	0.31	0.27	0.04	0.01	0.03	0.00
Pekao SA	0.07	0.07	-0.01	0.00	-0.01	0.00
mBank	0.35	0.28	-0.07	-0.10	-0.10	-0.13
ING Bank Śląski	-0.15	-0.16	-0.14	-0.15	-0.20	-0.20
Millennium	0.09	0.44	0.01	-0.02	-0.08	-0.09
BNP Paribas BP	-0.39	-0.44	-0.41	-0.46	-0.46	-0.51
Bank Handlowy	-0.14	-0.12	-0.27	-0.26	-0.33	-0.32
Alior	-0.70	-0.67	0.06	0.07	0.21	0.26
Getin Noble	-0.24	-0.30	-0.02	-0.06	-0.05	-0.09
Idea	-0.13	-0.17	0.16	0.11	0.35	0.27
BOŚ	-0.12	-0.12	-0.18	-0.17	-0.16	-0.16

Source: own elaboration based on the data of Warsaw Stock Exchange, https://www.gpw.pl/archiwum-notowan.

Table 4. ACAR and ABHAR for data from March 2020 and different estimation windows for which the projections of share prices were designated

Specification	**ACAR**	**ABHAR**
30 quotations	-0.09	-0.08
60 quotations	-0.06	-0.07
90 quotations	-0.05	-0.07

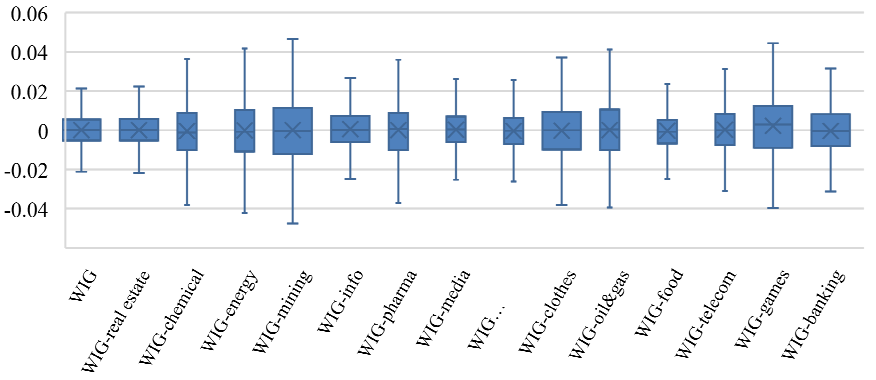
Source: own elaboration based on the data of Warsaw Stock Exchange, https://www.gpw.pl/archiwum-notowan.

Table 5. CAR and cost of risk measures as of March 2020 estimated on the basis of 90 quotations of banks' shares

Bank	CAR	Cost of risk difference	Ranking CAR (upward ranking)	Cost of risk difference (downward ranking)
Alior	0.21%	-46	11	12
ING Bank Śląski	-0.46%	44	1	3
BNP Paribas BP	-0.16%	10	4	9
PKO BP	-0.33%	116	2	1
Idea	0.35%	-7.05	12	11
BOŚ	-0.20%	13	3	7
Getin Noble	-0.10%	72	5	2
Millennium	-0.08%	18	6	5
Pekao SA	-0.05%	40	7	4
Bank Handlowy	-0.01%	18	8	6
Santander BP	0.20%	-3	10	10
mBank	0.03%	11	9	8

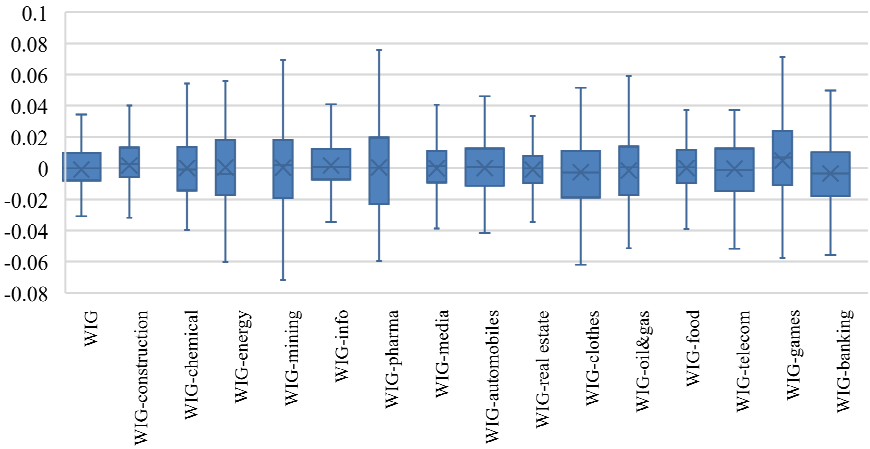
Source: own elaboration based on the data of Warsaw Stock Exchange, https://www.gpw.pl/archiwum-notowan.

Figure 1. Changes of sub-indices representing particular sectors of the economy in the period between 2017.Q1 and 2020.Q2 based on daily WIG indices



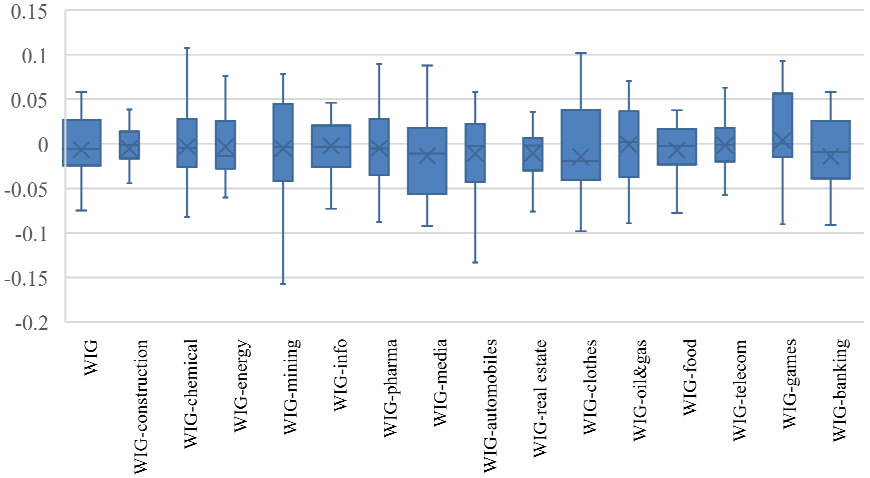
Source: own elaboration based on the data of Warsaw Stock Exchange, https://www.gpw.pl/archiwum-notowan.

Figure 2. Changes of sub-indices representing particular sectors of the economy in the period between 2020.Q1 and 2020.Q2 based on daily WIG indices



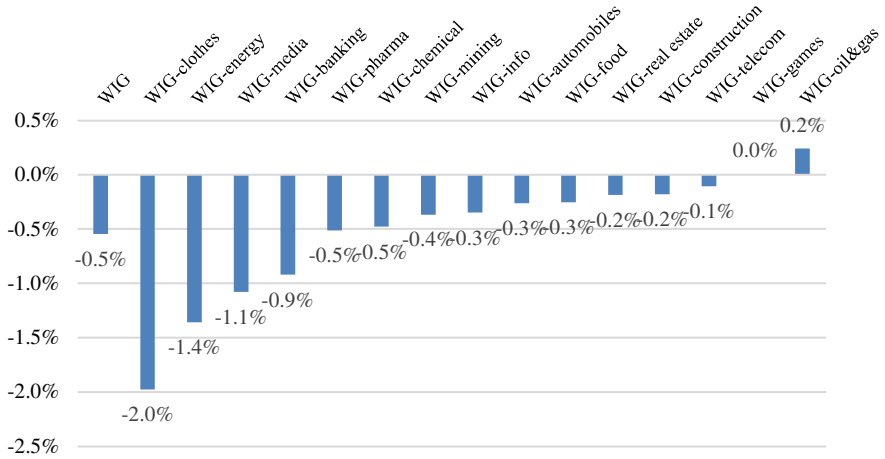
Source: Own elaboration based on the data of Warsaw Stock Exchange, https://www.gpw.pl/archiwum-notowan..

Figure 3. Changes of sub-indices representing particular sectors of the economy in March 2020 based on daily WIG indices



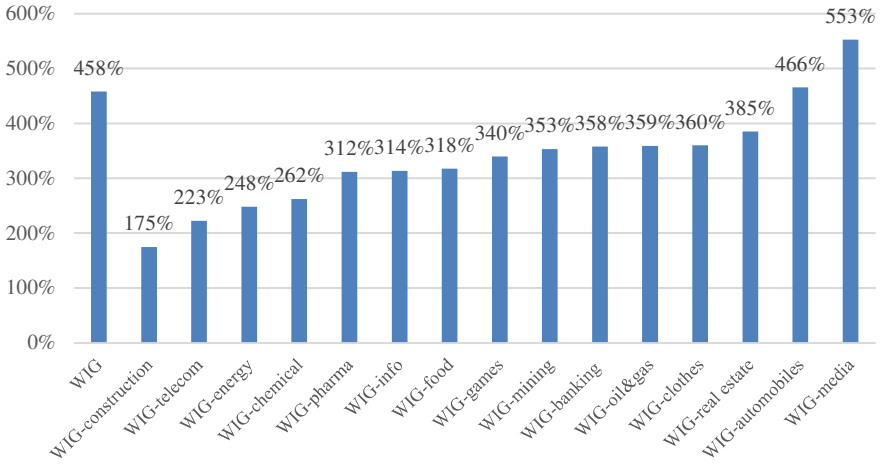
Source: own elaboration based on the data of Warsaw Stock Exchange, https://www.gpw.pl/archiwum-notowan.

Figure 4. Median share price movements for particular sectors of the economy in March 2020 based on daily WIG indices



Source: own elaboration based on the data of Warsaw Stock Exchange, https://www.gpw.pl/archiwum-notowan.

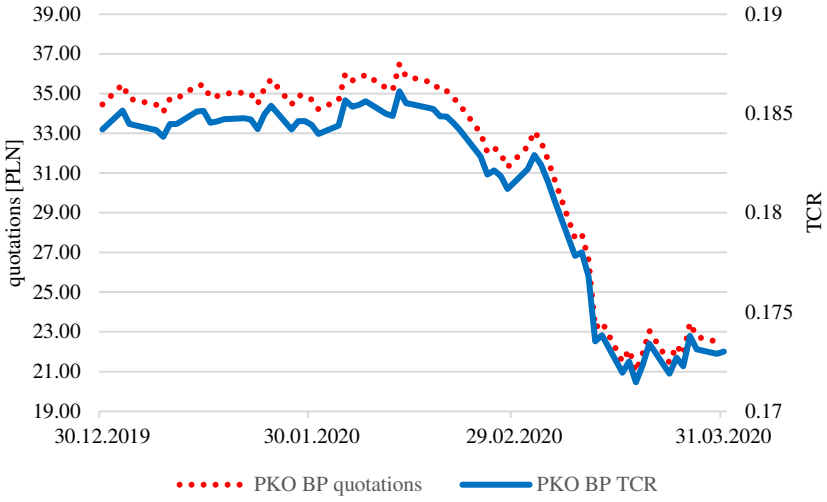
Figure 5. The loss of stability of subsequent sectors in March 2020 compared to the situation (measured by quarter range) before March 2020



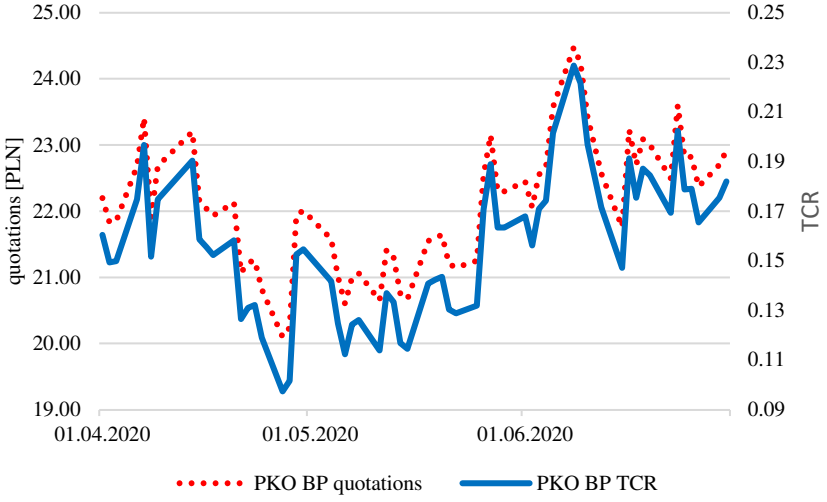
Source: own elaboration based on the data of Warsaw Stock Exchange, https://www.gpw.pl/archiwum-notowan.

Figure 6. Estimated values of TCR for PKO BP

a) in the first quarter of 2020

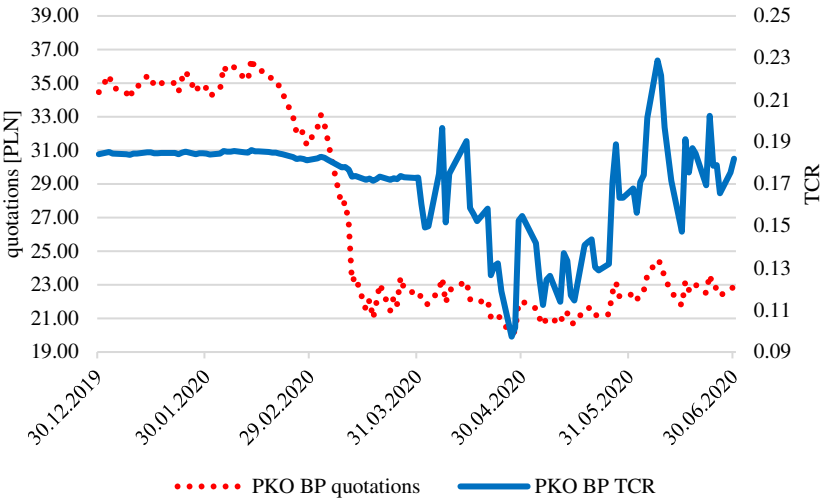


b) in the second quarter of 2020



Source: own elaboration based on the data of consolidated financial reports of Bank PKO BP, https://www.pkobp.pl/relacje-inwestorskie/wyniki-finansowe-i-prezentacje/#category=154443.

Figure 7. Estimated values of TCR for PKO BP in the first half of 2020



Source: own elaboration based on the data of consolidated financial reports of Bank PKO BP, https://www.pkobp.pl/relacje-inwestorskie/wyniki-finansowe-i-prezentacje/#category=154443.

Figure 8. Estimated values of Tier 1 for PKO BP

a) in the first quarter of 2020

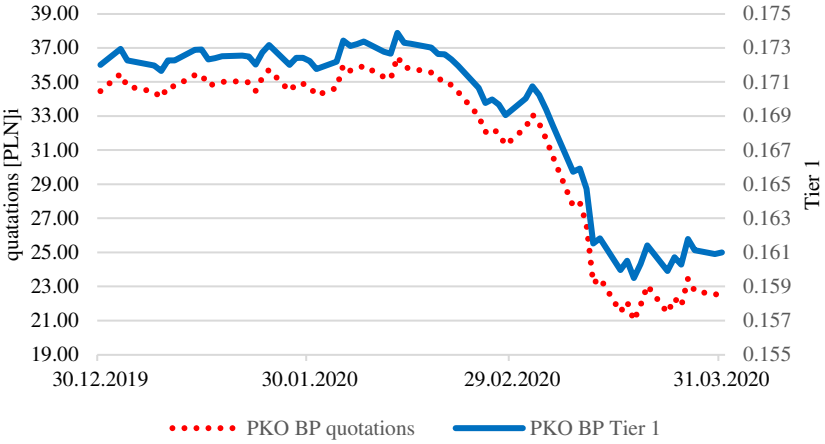
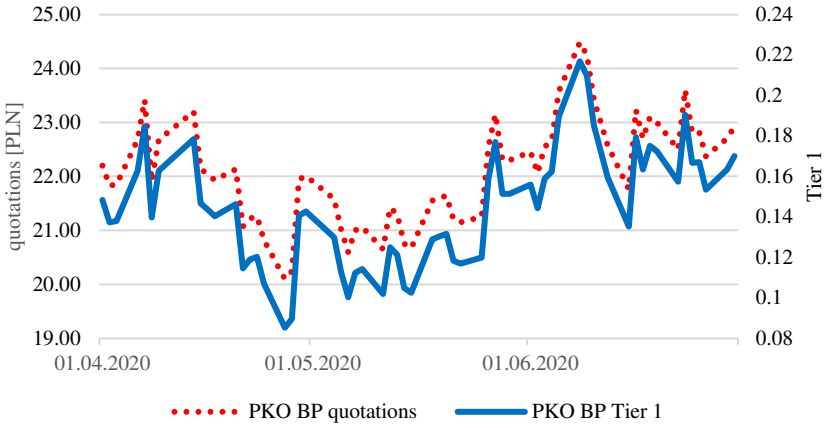


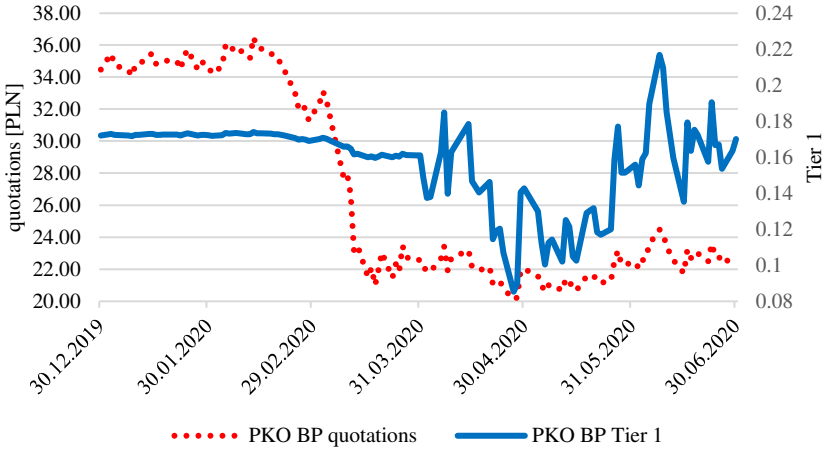
Figure 8. Continued

b) in the second quarter of 2020



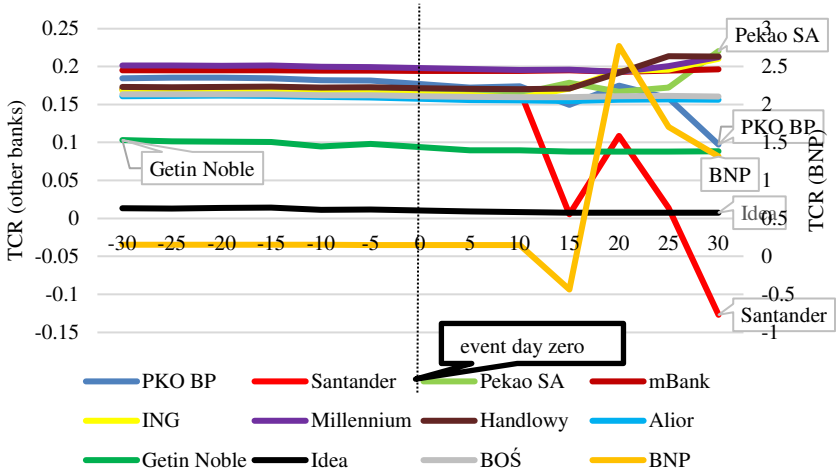
Source: Own elaboration based on the data of consolidated financial reports of Bank PKO BP, https://www.pkobp.pl/relacje-inwestorskie/wyniki-finansowe-i-prezentacje/#category=154443.

Figure 9. Estimated values of Tier 1 for PKO BP in the first half of 2020



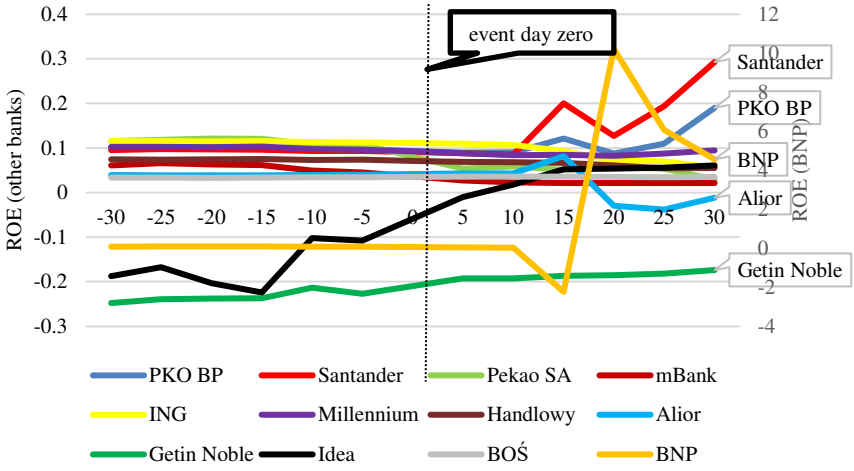
Source: Own elaboration based on the data of consolidated financial reports of Bank PKO BP, https://www.pkobp.pl/relacje-inwestorskie/wyniki-finansowe-i-prezentacje/#category=154443.

Figure 10. Summary graph of estimated TCR values on quotation days in the vicinity of "event day zero"



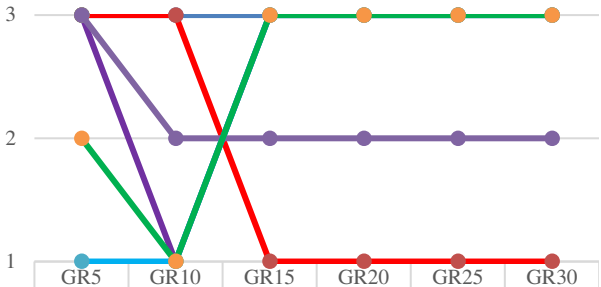
Source: own elaboration based on consolidated financial available on the websites of the analyzed banks.

Figure 11. Summary graph of estimated values of ROE on quotation days in the vicinity of "event day zero"



Source: own elaboration based on consolidated financial available on the websites of the analyzed banks.

Figure 12. Comparison of clustering depending on the size of the estimating window in the vicinity of "event day zero"



	GR5	GR10	GR15	GR20	GR25	GR30
PKO BP, Pekao SA, mBank, ING Bank Śląski, Bank Handlowy	3	3	3	3	3	3
Santander BP	3	3	1	1	1	1
Millennium	3	1	3	3	3	3
BNP Paribas BP	3	2	2	2	2	2
Alior, Idea, BOŚ	1	1	3	3	3	3
Getin Noble	2	1	3	3	3	3

Figure 13. AR measure for "event day zero" of the pandemic based on the simple linear regression model with estimation window length of 30 quotations

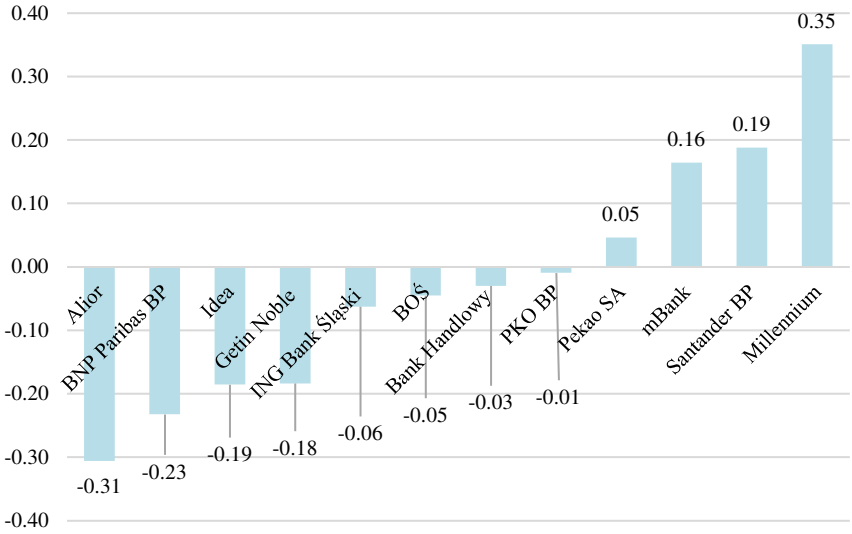


Figure 14. AR measure for "event day zero" of the pandemic based on the simple linear regression model with estimation window length of 60 quotations

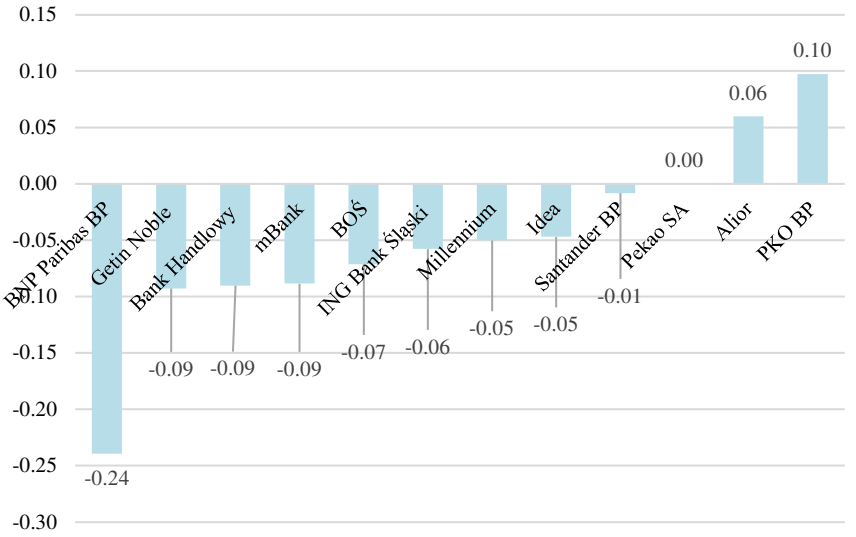


Figure 15. AR measure for "event day zero" of the pandemic based on the simple linear regression model with estimation window length of 90 quotations

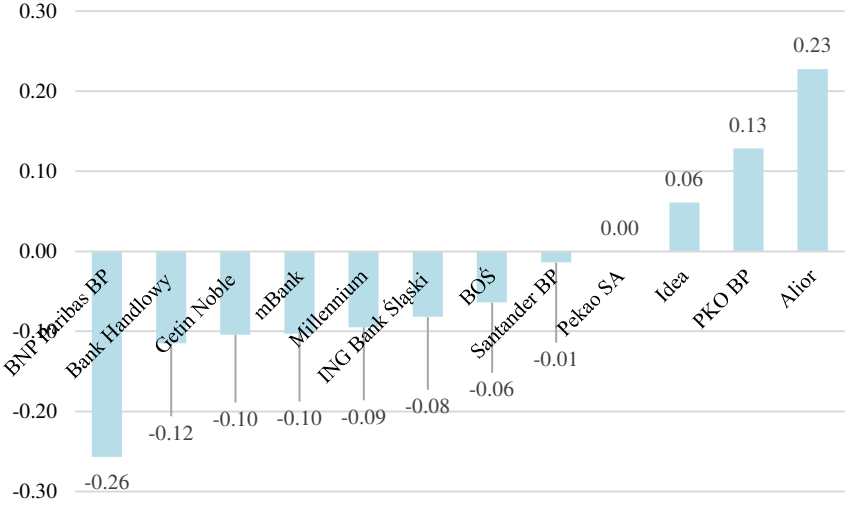
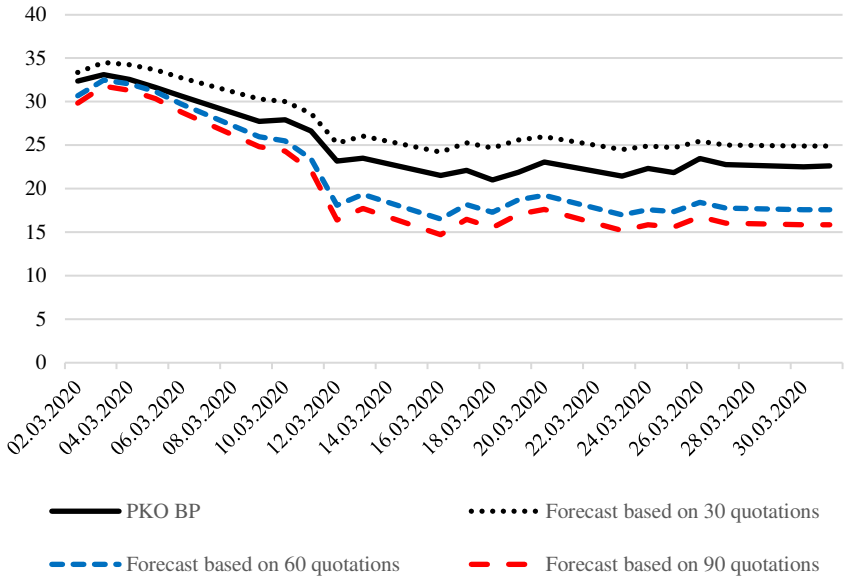


Figure 16. Comparison of the quotation forecast for March 2020 depending on the estimation window. Visualization for selected banks



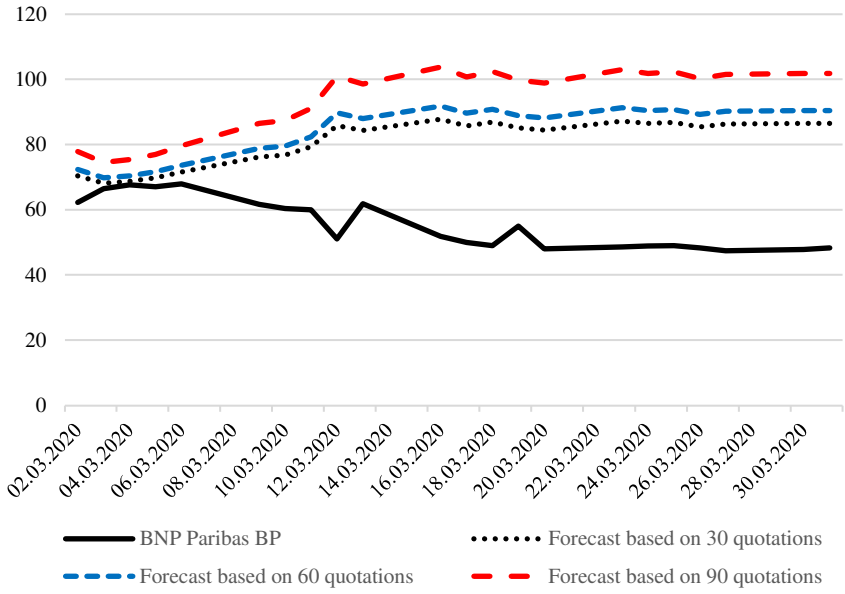
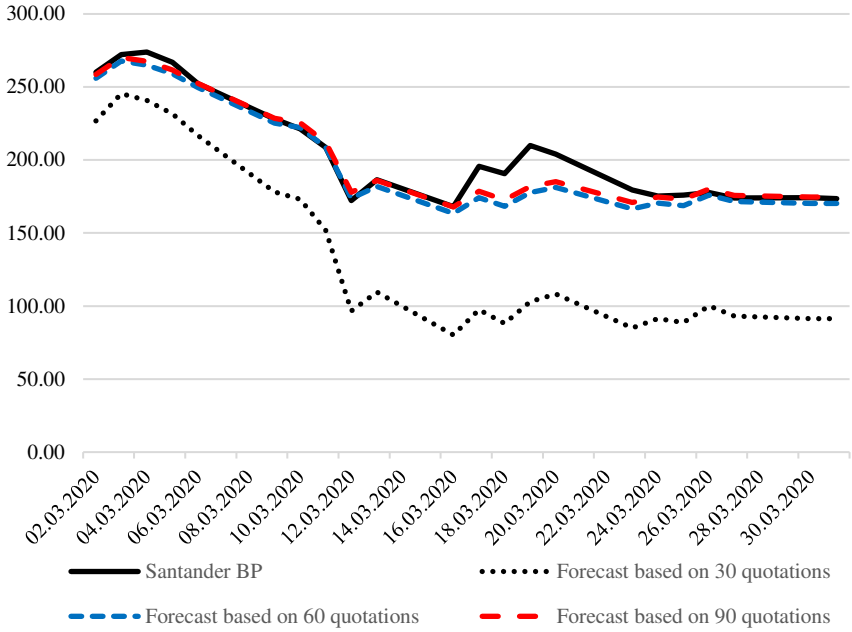
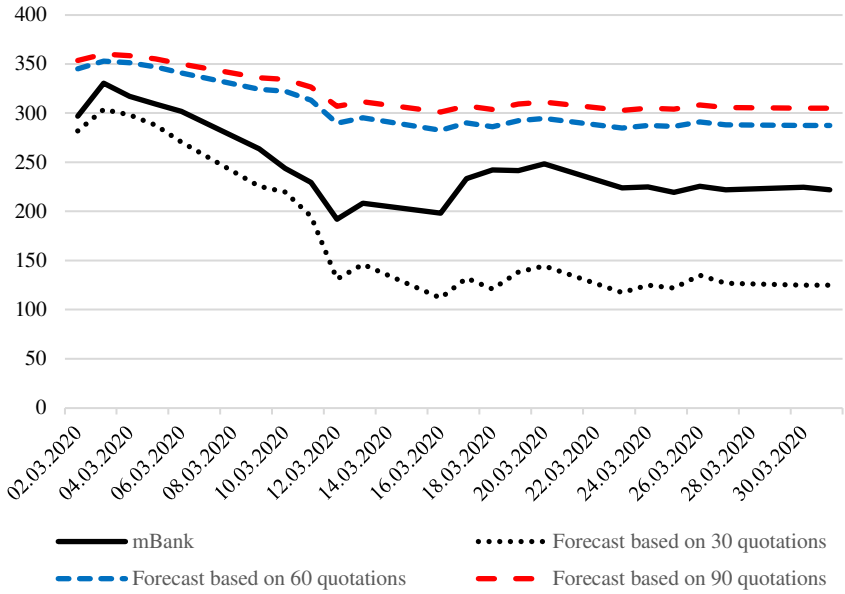



Figure 16. Continued