

Estimation of Bank Profitability Using Vector Error Correction Model and Support Vector Regression

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Abstract

The research problem defined in this article is the identification and the metrification of the macro-economic drivers of bank profitability of the Bulgarian banks. The aim is to establish the relationship between the macroeconomic factors and the indicators measuring bank profitability using an iterative testing methodology of the Vector Error Correction Model (VECM) and the Support Vector Regression (SVR). The relationships between key indicators of bank profitability - ROE and ROA, are analytically modeled as factor-dependent on nine key macroeconomic indicators. The sample size includes quarterly and monthly data for the recovery period of the banking system after its restructuring in 2014. The empirical results of the VECM form two similar models, which are distinguished based on dependent variable ROA and dependent variable ROE. They show the significance of the established results at high degrees of determination and minimal degrees of standard errors of the cointegration vectors.

The analysis of bank profitability has been refined using the SVR methodology, but the optimization of the hyperparameters does not confirm high significance. It is concluded that with increasing regulatory requirements for the formation of buffers against macroprudential risks, banks report a relatively neutral dependence in ROA and ROE on the impact of macroeconomic factors, which is logically offset by effective management decisions and innovations in interbank competition.

Keywords: commercial banks in Bulgaria, bank profitability, VECM, SVR

JEL: C58, E62, G21

Introduction

In recent years, commercial banks have faced challenges to financial stability due to dynamic changes in macroeconomic indicators. The paper focuses on examining and analyzing the relationship between the main indicators of bank performance return on equity and return on assets, analyzing them in the context of the impact of the key macroeconomic indicators inflation, GDP, imports, exports, exchange rate, unemployment rate, interest rates on loans, interest rates on deposits. On this basis, the

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research area is defined as the profitability indicators of commercial banks. **The research problem** is formulated as the identification and metrification of the macroeconomic drivers of bank profitability of Bulgarian banks for a 7-year period. **The purpose** of the study is to establish the relationship between the macroeconomic factors and indicators measuring the financial performance of the banks in the country using iterative testing methodology of VECM and SVR. The main research **hypothesis** is based on the idea that with increasing regulatory requirements for the formation of buffers against macroprudential risks, banks report dynamics in the profitability indicators ROA and ROE to a relatively moderate extent to the influence of macroeconomic factors, offset by effective management decisions in interbank competition. The above described research area, research problem, purpose and research hypothesis characterize the conducted study as relevant and significant.

continuously attracted research attention since the establishment of the first commercial banks in Italy in the early 16th century. Six hundred years later, one of the greatest economic considerations remains having a stable and profitable banking system as the foundation of any economy. Practice shows that countries with a stronger financial sector and a particularly stable banking system absorb external shocks more smoothly and recover faster. In this sense, the greater openness of financial markets can positively affect the economic growth, in case the banking system is sufficiently stable and able to respond to high competition and potential negative impacts associated with access to foreign capital.

The financial sector is unique in its kind due to the presence of risk and uncertainty for both savers and investors. The impact of the financial sector on economic activity is of particular importance. According to (Kalchev, 2014), it consists of the banking system and capital markets, and is the basis of the financial system developed in concert with the corporate sector and the industrial and entrepreneurial sector, as strategic decisions taken affect the financial markets. The financial system can be structured as follows:

1. Theoretical background

1.1. Commercial banks in the structure of the financial sector

The role of the financial sector in the process of economic development has

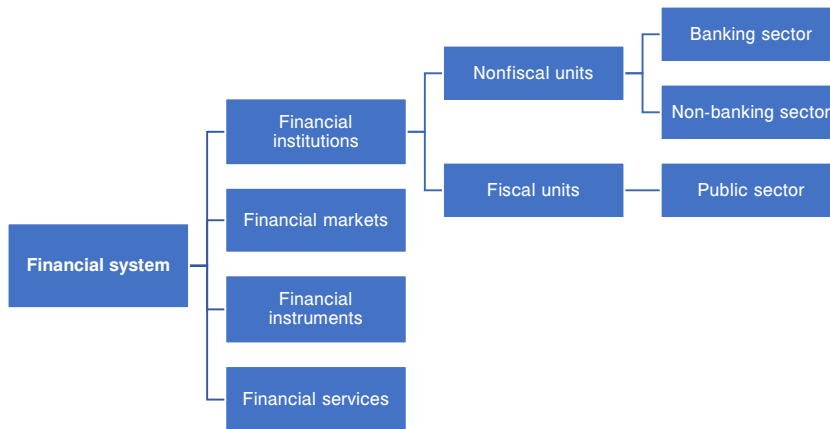


Figure 1: Structure of the financial system and positioning of the banking sector

The challenges posed by the economic disruptions in the sector in recent years have sparked a discussion on a number of important issues. The exploration for key economic relationships to regulate their impact on the assessment of the banking sector reveals the problems, the challenges (Prodanov & Naydenov, 2020) and the good examples in public finance (Sabitova, Shavaleyeva, Lizunova, Khairullova, & Zahariev, 2020b) and banking. The role and the importance of the banking sector should not be underestimated. It is as important for the development of the national economy as any other sector. Banks, as its main component, most often operate as intermediaries between investors and users of borrowed capital, mediating numerous business relationships, and it is not by chance that they are considered the “core” of the financial sector. As one of the main sources of financing for economic activities, commercial banks can also influence business cycles. The relationship between business cycle fluctuations (Albertazzi & Gambacorta, 2009) and the profitability of the banking sector, as well as the impact of the institutional and structural characteristics of the environment in which the sector develops, constitute an important element of macroprudential analysis. A strong and profitable banking system (Gerlach, Peng, & Shu, 2005) is a prerequisite for financial stability, increasing the resilience of the economy to adverse macroeconomic shocks. At the same time, the changes in the macroeconomic conditions affect the financial results of the banks, resp. their financial condition. It is therefore important that the authorities (Mohanty, 2014) responsible for maintaining financial and monetary stability in the national economy determine (using quantitative indicators) the link between macroeconomic development

and the banking sector. On the other hand, at present, 24 banks operate on the territory of Bulgaria (BNB, 2020b) - 18 commercial banks licensed in Bulgaria and 6 branches of foreign banks. Identifying the relationship between Bulgaria’s banking system and key macroeconomic indicators could help maintain the stability of each of the banks, as well as of the overall financial system of the country.

In Bulgaria, the presence of commercial banks is dominant in the financial system, compared to other financial institutions, due to the identification of the relationship between the bank profitability and the macroeconomic growth of the country. The cumulative impact of macro-variables on the overall performance of commercial banks is also a matter of major importance. The time period 2014 - 2020 is characterized both by stabilization of the banking system of the country after the critical moments of 2014, and a number of political and economic challenges in national and international scope. One of the most severe tests of the banking stability of the country was in 2014 with the Corporate Commercial Bank (CCB) crisis (Zahariev, et al., 2020b). What was positive for the period was that the functionality of the banking sector (Trifonova & Kaneva, 2016) was not completely disrupted, the situation having proven the need for more effective banking supervision in the country, supported by adequate measures and reliable tools. It has been proved that **commercial banks** by themselves are essential for the economic development and distribution of economic resources in the country. This, on the one hand, and on the other - they are also influenced by macroeconomic conditions and contribute to the economic growth, providing for borrowed capital for investors and a variety of services that facilitate business processes.

For F. Mishkin (Mishkin, 2001) banks are important institutions and a major source of funds for the external financing of business in almost all countries, and in recent years they have been facing the challenges to maintain their financial stability in the context of the dynamic changes in the economic indicators of the environment.

1.2. Determinants of commercial bank profitability

The results of the ongoing processes in the banking sector can be measured and evaluated based on statistical and econometric tools. The individual indicators have an independent informational significance, but studied together, as a system, **they allow for an in-depth analysis of the conditionality “macro-indicators - bank results”, including at the sectoral level.** The measurable indicators of interest for the assessment of the banking sector include several that measure bank profit and the factors that influence it. **Profitability**, defined by (Rose, 1999), is the net income of banks after tax, usually measured by return on assets and return on equity. It can also be measured as the ratio of net interest income to total assets. The first indicator shows the weight of total bank assets in the formation of net bank income and can be considered as a measure of financial results. For the banking sector, it is highly influenced by the management decisions made by each individual commercial bank, as well as by external factors related to banking regulations and economic conditions. The second indicator (**ROE**) shows how effectively the organisation manages to convert shareholders' equity into net returns. The higher the ratio, the better for banks, because investors will be interested in it before investing in the financial sector. ROA is an indicator of the bank's operational

efficiency, while ROE is considered a measure of the return on equity holders and the potential growth of their investments. Optimal values of the determinants are considered (Vatev, 2015) to range from 0.5% to 2% for return on assets (ROA) and between 10% and 20% for return on equity (ROE). The higher values of the two metrics reflect the higher management efficiency of the bank and vice versa. An early research of the efficiency of the Bulgarian banking system for the period 1999-2006 reveals five major impacting factors (Nenovsky, Chobanov, Mihaylova, & Koleva, 2008), including the structure of bank assets and liabilities.

There are a number of various factors that influence and determine the profitability of banks. Different studies classify them differently, but in the most general case they can be classified in one of two main groups. **The first group** is constituted of determinants of profitability specific to every individual bank or banking system, and in most cases a direct result of management decisions and regulations. **The second group** of indicators includes factors related to the macroeconomic environment in which the banking system operates, such as openness of the economy, inflation, exchange rate and others.

The results of commercial banks are influenced by internal and external factors, which can be classified into specific for the bank and the banking system (internal) indicators and **macroeconomic variables (external indicators)**. The internal factors are determined by the specific banking characteristics that influence the work of the individual banks and the established banking system, as these factors are mainly influenced by the internal management decisions of the banking management. External factors are those that shape the entire sector in the

national economy, they are outside the control of the bank but are relevant to its financial performance.

Macroeconomic variables are factors that shape the banking sector, which, however, cannot be controlled by any banking management. Stable macroeconomic conditions (Kanngiesser, Martin, Moccero, & Maurin, 2020) form a positive environment for the development of the banking activity, while unfavorable ones can affect market and credit risk, which in turn can compromise banking performance. Likewise, socio-economic stability at the national (global) level also has an impact on the stability of the banking sector.

External shocks, such as the financial crisis, the global pandemic (COVID-19) and the global recession, influence the macro situation in the country, which in turn affects banking institutions. The assessment of the position of commercial banks is most often based on the profitability and the price / income ratios (Burger & Moormann, 2009). It is believed that these are shaped by many factors, including the development of the stock markets, the political situation, the taxation, the financial structure, the macroeconomic tendencies and others. As far as macroeconomic variables are concerned, the key ones are economic growth, inflation, the foreign trade balance, the exchange rate of the national currency, the unemployment rate. **The gross domestic product** is used to measure the overall economic activity in the country. High activity is a prerequisite for high economic development, which is usually reflected in the indicators of bank profitability, shifting them upwards. On the other hand, the presence of strong interbank competition may reduce bank profits, which will affect the correlation "economic growth - financial

result". The impact of **inflation** on bank performance depends on the expectations of the management of the bank, assuming that banks can properly adjust interest margins and thus increase their profits. On the other hand, unanticipated inflation can lead to incorrect adjustment of interest margins, lower profits or a negative financial result. As for the money supply, it depends on the policy pursued by the Central Bank. Excessive growth of money supply (Were & Wambus, 2014) boosts inflation and negatively affects savings in the form of deposits, respectively decreases the level of income of banks. **Employment rates** can also affect bank profitability. On the one hand, the higher employment rate allows banks to pursue a flexible and active banking policy and on the other hand, the lower unemployment rate enables employees to negotiate better working conditions. In this sense, the changes in the employment and the unemployment rates may be important for the ability of banks to control their performance. **The foreign trade balance (the volume of exports and imports)** can be considered significant in the study of the relationship between the banking and macroeconomic sectors due to the direct impact of the financial effects of the two processes on the banking system through money transfers related to exchanges of goods (Laktionova, Dobrovolskyi, Karpova, & Zahariev, 2019) and services outside the national borders. This includes the exchange rate, which is a function of a number of factors, including interest rates, inflation, political agreements. Given this, the analysis of **the exchange rate of the national currency against** a widely used currency, such as the US dollar could be indicative. The decline of **interest rates (on loans and deposits)** is also relevant to the banking system. For

example, high interest rates on loans reduce the interest of borrowers, while high interest rates on deposits encourage people to save their money in banks.

2. Literature review

A number of studies identify **the internal and external determinants of bank valuation**. In-depth research on the topic is made by: (Narusevicus, 2018), who investigates the relationship between the profitability of the Lithuanian banking sector and its external and internal determinants. To achieve the goals, the author uses a panel error correction model to assess long-term and short-term determinants of bank income. The study considers various variables as short-term and long-term determinants. The results of the assessment show that bank size and real GDP are the main determining factors in the long run. The method used allows the compilation of a better picture of the Lithuanian banking sector and the determining factors for its revenue and expenses. (Kanwal & Nadeem, 2013) examine the significant contribution of commercial banks to the economic progress of Pakistan by investigating the impact of macroeconomic variables on the profitability of commercial banks in Pakistan between 2001 and 2011 with the Pooled Ordinary Least Square (POLS) method. The latter is used to examine the effect of 3 major external factors - inflation rate, real gross domestic product and real interest rate on profitability, return on assets, return on equity and equity multiplier in 3 separate models. Empirical findings show a strong positive relationship between the real interest rate and ROA, ROE and EM. Real GDP has a negligible positive effect on ROA and a negligible negative effect on ROE and EM. There is a negative

relationship between the inflation factor and the three profitability indicators. As a result, it was found that the selected macroeconomic factors have a negligible impact on the commercial bank indicators in the country. (Kiganda, 2014) examines the effect of macroeconomic factors on the profitability of banks in Kenya to identify the characteristics specific of the country and the banks. The specific objectives are based on a study and assessment of the effect of economic growth, inflation and the exchange rate on the profitability of banks in the country. The author models the study on the theory of production and bases it on the correlation research design. To obtain relevant results, he employs the Ordinary Least Squares (OLS) methodology. The findings indicate that the internal factors related to bank management have a more significant impact on the profitability of banks in Kenya. (Lutf & Omarkhil, 2018) focuses on the impact of macro-determinants and internal indicators on the performance of conventional and national banks in Pakistan. The author evaluates the differential effects of the macroeconomic variables and the bank-specific variables in two separate models - return on assets and return on equity. The main purpose of the study is to find how the banks operate in the country. The author arrives at the conclusion that in the long run GDP and inflation have a positive impact on banking performance, while interest rate has no effect on the country's banking sector. (Aviliani, Siregar, Maulana, & Hasanah, 2015) analyze the impact of macroeconomic indicators - production index, inflation, bank rate, stock index, exchange rate and crude oil price on the performance of the state-owned banks in Jakarta. They apply the Vector Error Correction Model (VECM). The

main conclusion they reach is that of all macroeconomic variables, the exchange rate has the greatest impact.

Based on the presented literature review and main characteristics of the considered macroeconomic indicators, the study of the relationship and interactions between them and the profitability of banks and the banking sector is defined as essential for their optimal development. The study of the degree of influence of external and internal determinants on the banking sector can be a factor for increasing management efficiency, as well as for achieving higher financial results.

3. Methodology

The commercial banks in Bulgaria are assigned by (BNB, 2020a) into one of three structural groups, based on the size of their assets as of the end of each reporting period. Given this, the first group consists of the 5 largest banks in the country, the second – all the remaining banks operating in the country and the third group comprises the branches of foreign banks in Bulgaria.

The present study focuses on examining and analyzing the relationship between the main indicators of bank performance: return on equity (ROE), return on assets (ROA), analyzing them in the context of the impact of key macroeconomic indicators: inflation (ICP), the Harmonized Index of Consumer Prices (HICP), gross domestic product (GDP), imports (Import), exports (Export), exchange rates (Exchange Rate), employment rate (Employment), interest rates on loans (L% Credit), interest rates on deposits (L% Deposit). The sample size includes data on a quarterly and monthly basis, covering the period 2014 - 2020, which is defined as a period of recovery of the Bulgarian banking

system after its restructuring in 2014 due to the bankruptcy of one of its structural units – the Corporate Commercial Bank (CCB). The data has been retrieved from reliable information databases - the Bulgarian National Bank (BNB), the National Statistical Institute (NSI), the European Central Bank (ECB) and the Federal Reserve Economic Data.

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The study uses the following methodological framework: descriptive statistics, correlation matrix, VECM (Vector Error Correction Model) and SVR (Support Vector Regression). The first method is used based on the assumption (Dalina & Liviu, 2014) that the application of the model is valid and the relationship between the indicators is derived. In support of the assumptions offered by extant literature, the construction of a mechanism for correction of errors for modeling dynamic relationships surpasses other methodological options in that VECM (Mishra, 2011) has cointegration relationships built into the specification, which serve to limit long-term behavior of endogenous variables. This aims at correcting possible long-term errors through preliminary short-term adjustments at the methodology level. This makes the use of VECM in this case more useful than other available models.

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SVR (Support Vector Regression) (Zahariev, et al., 2020a) is considered as a method of more serious identification of causal relationships in case the former does not meet expectations. The use of this methodology provides for the optimality of the obtained data and minimizes the possibilities for statistical error. Its applicability is also related to the fact that the opportunities for

the flexible application it offers are equally useful for working with both linear and non-linear data. This reduces the possibility of inconsistencies in the model based on incorrectly structured data.

4. Empirical analysis

The results of the performed descriptive statistical analysis of the macroeconomic observations are systematized in Table 1.

Table 1: Descriptive indicators of the macroeconomic observations

	Average	Median	StD	Min	Max
ICP	1.052	1.265	1.803	-2.300	3.800
HICP	0.486	0.750	1.780	-2.000	3.592
Exchange Rate	1.694	1.735	0.107	1.415	1.855
GDP	23719.145	24117.554	3055.091	17414.626	28473.766
Employment	3482.273	3477.603	146.163	3259.568	3716.850
L% Credit	5.289	4.690	1.500	3.307	9.500
L% Deposit	0.804	0.296	0.883	0.071	3.100
Import	4782.584	4828.553	457.696	3935.717	5499.990
Export	4249.918	4235.350	486.180	3193.675	4920.086

Source: Computed by the authors

The maximum value of ICP is 3.8%, reached in the fourth quarter of 2019, the third quarter of 2018 peaks in the values of the HICP - 3,592, the highest exchange rate in US dollars is observed in the fourth quarter of 2016 - 1,855, the maximum value of GDP (28473.766) is observed in the fourth quarter of 2019, the highest value of the employment rate (3716.85) is observed in the third quarter of 2017, the maximum interest rate on loans - 9.5% was established in the first quarter of 2015, and the maximum interest rate on deposits - 3.1% in the first quarter of 2014. In the first quarter of 2014 the ICP values were minimum at -2.3%, HICP - -2, the exchange

rate in US dollars - 1.4147, GDP - 17414.626. At the end of 2014, the lowest employment rate was reported (3259.568), and in 2020 the lowest levels of interest rates on loans were observed – 3.307, respectively interest rates on deposits - 0.071.

Table 2 shows the correlations between the variables in the conducted research. For the purposes of the analysis, the macroeconomic indicators with the corresponding abbreviations were used, which at a later stage will be used as independent variables in the construction of the models, together with the level of ROA and ROE.

Table 2: Correlation matrix between the variables in the study

	ROA-F	ROE - F	ROA -1	ROE -1	ROA -2	ROE -2	ROA -3	ROE -3	ICP	HICP	Exchange Rate	GDP	Employment	L%-Credit	L%-Deposit	Import	Export
ROA-F	1.000																
ROE - F	0.995	1.000															
ROA -1	0.968	0.965	1.000														
ROE -1	0.971	0.972	0.996	1.000													
ROA -2	0.922	0.923	0.822	0.825	1.000												
ROE -2	0.912	0.917	0.804	0.810	0.997	1.000											
ROA -3	0.523	0.550	0.363	0.385	0.659	0.702	1.000										
ROE -3	0.384	0.406	0.240	0.274	0.430	0.471	0.812	1.000									
ICP	0.256	0.274	0.066	0.101	0.426	0.477	0.641	0.565	1.000								
HICP	0.241	0.263	0.054	0.095	0.403	0.459	0.669	0.610	0.980	1.000							
Exchange Rate	0.245	0.244	0.177	0.179	0.304	0.300	-0.004	0.078	0.361	0.253	1.000						
GDP	0.863	0.852	0.779	0.804	0.781	0.782	0.632	0.582	0.420	0.422	0.169	1.000					
Employment	0.126	0.107	0.044	0.058	0.195	0.190	0.182	0.284	0.217	0.229	-0.036	0.256	1.000				
L% Credit	-0.312	-0.303	-0.126	-0.165	-0.398	-0.424	-0.564	-0.586	-0.650	-0.696	-0.205	-0.589	-0.120	1.000			
L%Deposit	-0.260	-0.265	-0.068	-0.108	-0.400	-0.425	-0.459	-0.542	-0.750	-0.732	-0.598	-0.478	-0.212	0.804	1.000		
Import	0.141	0.165	-0.025	0.019	0.262	0.313	0.620	0.600	0.875	0.876	0.213	0.399	0.093	-0.705	-0.712	1.000	
Export	0.057	0.061	-0.140	-0.101	0.239	0.272	0.511	0.580	0.784	0.788	0.302	0.337	0.486	-0.682	-0.801	0.807	1

Source: Computed by the authors

The profitability indicators are designated as follows: -F is added to the name of the indicator, which refers to the entire banking system, -1 – for the first group of banks, -2 – for the second group, -3 – for the third one. It is evident from the table that the correlation between the measures of profitability in the banking system of the country and the first and the second group of banks is the strongest. GDP correlates significantly with the ROA and ROE of the banking system, the first group and the second group and to a lesser extent with the third group of banks. The country's imports and exports have the highest correlation with ROA-3, ROE-3 and the indicators of inflation. A negative correlation is found in the interest rates on loans and deposits, compared to all analyzed indicators. All other combinations of determinants show a weaker correlation. Given the results of the correlation analysis and the divergent results within the modeling

of the relationships between profitability and macroeconomic indicators, the variables are kept to test their significance and relationship.

Tables 3 and 4 present in a systematized and summarized form the sample data and the empirical findings from the performed Vector Error Correction Model (VECM) for the dependent variable ROA (table 3) and dependent variable ROE (table 4). In both constructed models, significance of the performed calculations at high degrees of determination and minimal degrees of standard errors of the cointegration vectors is observed. The coefficient of determination usually has values between 0 and 1, a model being considered robust when the coefficient of determination approaches 1. In this case, in both variables they are as close as possible to completion, except for the third group where nearly 11% of factors are taken into account in ROA calculations and almost 14% in ROE.

Table 3: Sampling data and empirical findings of VECM in dependent variable ROA

ROA								
	Banking system		First group		Second group		Third group	
Coefficient of determination	0.992106		0.976311		0.958004		0.893802	
Standard errors of cointegration vectors	0.000000		0.000000		0.000000		0.000000	
	<i>Coefficient</i>	<i>p-value</i>	<i>Coefficient</i>	<i>p-value</i>	<i>Coefficient</i>	<i>p-value</i>	<i>Coefficient</i>	<i>p-value</i>
ICP	-0.0260	0.0210	-0.0366	0.0530	-0.0121	0.4800	-0.5034	0.0920
HICP	0.0360	0.0080	0.0380	0.0860	0.0120	0.4290	0.2660	0.3560
Exchange Rate	0.3240	0.0080	0.0700	0.5220	0.1910	0.0570	1.3720	0.2570
GDP	0.0000	0.0560	0.0000	0.4950	0.0000	0.7800	0.0000	0.1870
Employment	0.0000	0.0030	0.0000	0.2620	0.0000	0.0640	0.0020	0.1010
L%Credit	-0.0157	0.1200	0.0080	0.5290	0.0110	0.3000	0.2040	0.0630
L%Deposit	0.0260	0.2230	0.0180	0.6800	-0.0202	0.5580	-0.3486	0.3740
Import	0.0000	0.0750	0.0000	0.6830	0.0000	0.6840	0.0010	0.1640
Export	0.0000	0.2550	0.0000	0.8880	0.0000	0.9660	0.0000	0.9840

Source: Computed by the authors

Table 4: Sampling data and empirical findings of VECM in dependent variable ROE

ROE								
	Banking system		First group		Second group		Third group	
Coefficient of determination	0.991224		0.978297		0.956440		0.866185	
Standard errors of cointegration vectors	0.016143		0.011922		0.008495		0.001077	
	<i>Coefficient</i>	<i>p-value</i>	<i>Coefficient</i>	<i>p-value</i>	<i>Coefficient</i>	<i>p-value</i>	<i>Coefficient</i>	<i>p-value</i>
ICP	-0.0260	0.0210	-0.0366	0.0530	-0.0121	0.4800	-0.5034	0.0920
HICP	0.0360	0.0080	0.0380	0.0860	0.0120	0.4290	0.2660	0.3560
Exchange Rate	0.3240	0.0080	0.0700	0.5220	0.1910	0.0570	1.3720	0.2570
GDP	0.0000	0.0560	0.0000	0.4950	0.0000	0.7800	0.0000	0.1870
Employment	0.0000	0.0030	0.0000	0.2620	0.0000	0.0640	0.0020	0.1010
L%Credit	-0.0157	0.1200	0.0080	0.5290	0.0110	0.3000	0.2040	0.0630
L%Deposit	0.0260	0.2230	0.0180	0.6800	-0.0202	0.5580	-0.3486	0.3740

ROE								
	Banking system		First group		Second group		Third group	
Import	0.0000	0.0750	0.0000	0.6830	0.0000	0.6840	0.0010	0.1640
Export	0.0000	0.2550	0.0000	0.8880	0.0000	0.9660	0.0000	0.9840

Source: Computed by the authors

To be considered as significant metrics theoretically at a confidence interval of 95%, we take into account that $p\text{-value} < 0.05$ and therefore the lower and close to zero the $p\text{-value}$ is, the greater the statistical significance of the observed difference. The Akaike information criterion, the Schwartz BIC criterion and the Hanan-Quinn test give relatively low values (including negative ones) and support the choice of a model.

Despite the conclusions about the significance of the models, the interpretation of the coefficients and $p\text{-value}$ of the variables lead to the following conclusions:

- the return on assets in the banking system is minimally affected by the HICP, the US dollar exchange rate and employment;
- the return on assets of banks in the third group are influenced by GDP and inter-

est rates on loans, but their ROA ratio is within the critical minimum;

- in the study of the dependence of the return on equity of banks (ROE) in Bulgaria and the macroeconomic measures the determinants inflation, HICP, the exchange rate in US dollars and employment show theoretical dependence, but their importance for return on equity is defined as poor.

In view of the above results obtained using VECM, a more detailed study with the applied vector regression (SVR) methodology was conducted. In the specific interpretation, for modeling purposes, data on a monthly basis for the same period of time were used. The final presentation of the data in the optimization of the hyperparameters is:

$$\text{parameters} = \{ 'C': [1, 2, 3, 4, 5, 10, 20, 30, 40, 50, 100, 150, 120, 180, 200], \\ 'gamma': [0.0001, 0.001, 0.1, 1], 'epsilon': [0.00001] \}$$

As a consequence, there is again a lack of significance between the dependent variables - ROA and ROE of the banking system and the three groups of banks and the independent

variables - the investigated macroeconomic indicators, given the obtained coefficients of determination:

Table 5: Determination coefficients in the application of the SVR model

Banking system		Group 1		Group 2		Group 3	
ROE	ROA	ROE	ROA	ROE	ROA	ROE	ROA
0.1880	0.1759	0.2720	0.2751	0.1030	0.1482	0.5542	0.0438

Source: Computed by the authors

Due to the low values of significance, it is not viable to perform any subsequent optimization processes and other in-depth detailed consideration of the established model.

The results obtained in the study imply that the investigated macroeconomic determinants do not significantly affect the ROA and ROE of the banks in Bulgaria. Given this, it is necessary for the Bulgarian banks to commit to elaborating the internal banking policies in order to improve the banking and interbank climate. On this basis, the study recommends that banks in Bulgaria adopt policies that lead to increased management efficiency to achieve higher financial results and optimal risk-acceptable levels of return on assets and equity of banks, complemented by effective management decisions and innovations in interbank competition. Similar illations by contemporary studies on the efficiency, profitability (Kazandzhieva, 2019) and DCF valuation (Ralinska, 2019) of the Bulgarian banks support our research hypotheses but from the point of view of a stochastic modelling.

Conclusion

The aim of the study was to model the relationship between the main indicators of bank performance - return on equity (ROE) and return on assets (ROA), as factor-dependent on nine key macroeconomic measures: inflation (ICP & HICP), gross domestic product (GDP), imports (Import), exports (Export), exchange rate (Exchange Rate), employment rate (Employment), interest rates on loans (L% Credit), interest rates on deposits (L% Deposit). The sample size includes data on a quarterly and monthly basis, covering the period 2014 - 2020. The sample data and empirical findings from the

performed Vector Error Correction Model (VECM), divided into dependent variable ROA and dependent variable ROE form two models in which there is significance of the performed calculations at high degrees of determination and minimal degrees of standard errors of the cointegration vectors. The interpretation of the coefficients and p-value of the variables in the VECM lead to three main conclusions: (1) ROA in the banking system is minimally affected by the HICP, the US dollar exchange rate and employment; (2) the ROA of banks in the third group is influenced by GDP and interest rates on loans, but their ROA ratio is within the critical minimum; (3) in the study of the dependence of the return on equity of banks (ROE) in Bulgaria and the macroeconomic measures the determinants inflation, HICP, the exchange rate in US dollars and employment show theoretical dependence, but their importance for return on equity is defined as low.

The analysis with data for the system of commercial banks in Bulgaria on a monthly basis is refined using the methodology of Support Vector Regression (SVR) (84 observations). When optimizing the hyperparameters through SVR, the significance between the dependent variables - ROA and ROE for the banking system as a whole and for the three groups of banks is not confirmed. Therefore, for the 7-year study period, bank profitability in Bulgaria shows a relatively neutral dependence on the macroeconomic environment, which is offset by the internal banking policies aimed at management efficiency, optimal risk-acceptable levels of return on assets and equity and innovation in interbank competition.

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