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THE POSSIBILITY OF IDENTIFYING FACTORS INFLUENCING THE DYNAMICS OF THE YIELD CURVE IN THE CROATIAN FINANCIAL MARKET

MOGUĆNOST IDENTIFIKACIJE FAKTORA SISTEMATSKOG RIZIKA KOJI UTJEČU NA KRETANJE KRIVULJE PRINOSA NA HRVATSKOM FINANCIJSKOM TRŽIŠTU

SAŽETAK: Analiza glavnih komponenata korištena je za identifikaciju faktora koji utječu na dinamiku kretanja krivulje prinosa na hrvatskom financijskom tržištu. Analiza je provedena korištenjem nul-kupon prinosa koji su procijenjeni na temelju parametara Nelson-Siegelova modela. Navedeni prinosi procijenjeni su za uzorak državnih vrijednosnih papira s valutnom klauzulom te za uzorak bez valutne klauzule od travnja 2006. do prosinca 2022. Rezultati pokazuju da su dovoljna tri faktora za objašnjenje kretanja dinamike krivulje prinosa, a to su razina, nagib i zakrivljenost, **što** je u skladu s rezultatima za tržišne prinose na obveznice bez kupona i provedenim istraživanjima. Ovi rezultati potvrđuju mogućnost primjene analize glavnih komponenata u analizi kretanja krivulje prinosa i to za tržišta koja karakterizira slabija likvidnost i razvijenost. Rezultati su pokazali da su iznimno bitna dva faktora, razina i nagib prilikom opisa kretanja krivulje prinosa. Zaključno, dobiveni rezultati pridonose boljem razumijevanju hrvatskog financijskog tržišta i njegovih implikacija za analizu kretanja krivulje prinosa.

KLJUČNE RIJEČI: analiza glavnih komponenti, krivulja prinosa, hrvatsko financijsko tržište, tržišta u nastajanju

JEL KLASIFIKACIJA: G12, G15

ABSTRACT: This study employs principal component analysis to identify factors influencing yield curve dynamics in the Croatian financial market. Zero-coupon yields used for the analysis are estimated based on parameters from the Nelson-Siegel model for

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government securities with and without currency clauses from April 2006 to December 2022. Results indicate that three factors, level, slope, and curvature, adequately explain yield curve movements, aligning with findings for market zero-coupon yields and existing literature. Obtained results showed it is possible to apply principal component analysis in context of yield curve in less developed and less liquid financial market. The results are consistent with findings from developed financial markets, where the level and slope are main factors used to explain yield curve movements.

KEY WORDS: principal component analysis, yield curve, Croatian financial market, emerging market

JEL Classification: G12, G15

1. INTRODUCTION

The yield curve is an important tool for both macroeconomists and investors, as well as policymakers. Knowing the shape of the yield curve tells a lot about the market situation and what can be expected in the near future. Firstly, the yield curve was analyzed in developed economies and then in less developed. Today, many papers deal with the topics connected to yield curve in developed financial markets, but there are fewer for less developed, though the number is increasing.

Earlier research conducted on developed and less developed markets shown that there are no more than three factors that are needed to explain yield curve variability. Those factors were identified as level, slope and curvature of the yield curve where principal component analysis (PCA) has proven to be the most effective method for extracting them. One of the earliest papers in this field is the work by Litterman and Scheinkman (1991), who concluded that the level, slope and curvature factors are sufficient to explain movements in the U.S. yield curve. Later research confirmed these findings, with similar conclusions for developed financial markets, where the first factor, level, explains the most variability in yield curves. Research on less developed markets, including Hungary, Slovenia, and Romania, further provides evidence for the applicability of PCA. However, the Croatian financial market remains underexplored in this context.

For this reason, this paper analyses yield curve dynamics in Croatia using data from April 2006 to December 2022. Until 2022, the main currency in Croatia was the kuna, but the market was also heavily depended on the euro. Therefore, two samples were observed: one consisting of government bonds with currency clauses (euro sample) and the other without (kuna sample). It is important to analyze these two samples separately, as they are exposed to different types of risk. The results showed that no more than three factors are needed to explain yield curve movements, with the first two factors contributing the most.

This study contributes to existing literature in several ways. It is the first paper on the Croatian financial market addressing this topic. The analysis was conducted on samples of bonds with and without currency clauses, highlighting the importance of accounting for such distinctions in similar economies. Because of this, these findings may therefore be applicable to other less developed and less liquid markets, such as Croatia. The results provide practical implications for policymakers and investors, who can use the identified factors to develop strategies and manage risks in less developed financial markets.

2. LITERATURE REVIEW

The literature review can be divided into two main parts. The first group of papers focuses on identifying the number of factors affecting the variability of the yield curve in developed markets. The second group addresses the same topic but focuses on less developed markets.

The most important work in the context of examining the factors that influence the variability of the yield curve is the study by Litterman and Scheinkman (1991). They applied PCA to zero-coupon government bond yields and were among the first to show that three factors are sufficient to explain most of the fluctuations in U.S. yield curves. These factors were defined as the level, slope, and curvature of the yield curve, with level explaining 90%, slope 8%, and curvature 2% of the fluctuations. Following their research, numerous studies have investigated the same topic across different financial markets, initially in developed, and later in less developed markets.

Stangol (2019) examined how many factors influence the variability of the yield curve for a group of developed markets (Australia, Canada, United States, Germany, France, United Kingdom, Italy, Japan, and Sweden). The results showed that the level factor accounts for most of the variability, at around 86%. This was followed by the slope factor, which explained approximately 11% of the variability, while the curvature factor made only a minimal contribution to yield curve fluctuations. Sekyere Asara (2019) showed that, for the Canadian market during the period from 2004 to 2018, three components explain 90% of the variability in government bond yields. In addition, Driessen et al. (2003) showed that in the U.S. market, the first factor explains 96.9% of the variation in yields, while the second and third factors make only a small contribution. Their analysis also revealed that in Germany and Japan, the second and third factors account for a larger proportion of variability than in the U.S.

Since developed markets have been extensively studied and have confirmed the significance of the three factors, there is growing interest in examining how less developed markets behave in the same context. Oprea (2022) studied the Romanian market and found that the first three factors were sufficient for 96% of the bond yield variability in the period from March 2019 to March 2022. Similarly, Dittmar and Yuan (2005) examined the Slovenian market and found that the first factor explained 88%, the second 11% and the third only 1% of the variability in bond yields from January 1996 to November 2000. In contrast, Reppa (2009) examined the Hungarian financial market and showed that two factors were sufficient to describe 99.45% of the variability in yields in the period from December 2001 to June 2008. In addition, Kopany (2010) examined the Hungarian market from 1998 to 2008 and showed that the first three factors explain 95.71% of the variation in yields when looking at the first difference between the observed yields. However, if the yields were observed in levels, only two factors were necessary to explain 99.33% of the variability.

The consistency observed in the mentioned research has led to the exploration of strategies based on traditional yield curve factors. Given that both developed and less developed financial markets show a predominant explanation of yield variability by the level and slope factors, while curvature plays a minor role, this has led to the precise formulation of strategies based primarily on the level and slope factors.

3. THEORETICAL BACKGROUND

PCA has been used to examine a number of factors that influence the movement of the yield curve. It is a method of multivariate analysis that is performed to reduce the dimensionality of a data set in which there are a large number of correlated variables (Pasini, 2017). It is a method that uses a linear transformation to turn a set of extremely related variables into a set of variables, i.e. components that are not correlated with each other (Sekyere Asare, 2019).

The data set is in a matrix $\boldsymbol{X}$ of size $I \times J$, where I stands fro the rows of the matrix ($i = 1, 2, ..., I$) and J for the columns of the matrix ($j = 1, 2, ..., J$). In the matrix $\boldsymbol{X}$ defined in this way the columns represent variables that can be written as $\boldsymbol{x}_j$ and represent vectors in I - dimensional space. It follows that the linear combination of $\boldsymbol{x}_j$ variables can be written as follows (Bro and Smilde, 2014):

$$\boldsymbol{t} = w_1 \times \boldsymbol{x}_1 + \cdots + w_J \times \boldsymbol{x}_J, \tag{1}$$

where $\boldsymbol{t}$ represents the new vector of variables. In addition, the given expression can be written as a matrix:

$$\boldsymbol{t} = \boldsymbol{X} \times \boldsymbol{w}. \tag{2}$$

The vector $\boldsymbol{w}$ contains the values w_i which represent the coefficients of the included variables and are referred to as eigenvalues. The first coefficient w_1 was estimated such that the first component explains the maximum variance from the data, the second coefficient w_2 such that the second component explains the maximum variance left unexplained by the first, and so on up to the number of variables included in the analysis (Gemperline, 2006). The problem of PCA is therefore to maximize the variance of the data set so that the optimal values of the w_i coefficients are selected:

$$maxvar(\boldsymbol{t}) \tag{3}$$

with the condition that the sum of the squares of the coefficients w_i is equal to 1. When calculating and maximizing the variance $\boldsymbol{t}$, it is necessary to determine how representative the matrix $\boldsymbol{t}$ is with regard to the replacement of the matrix $\boldsymbol{X}$, which can be tested using the regression equation (Bro and Smilde, 2014):

$$\boldsymbol{X} = \boldsymbol{t} \times \boldsymbol{p}^T + \boldsymbol{E}, \tag{4}$$

where **p** is the vector of regression coefficients and corresponds to the values of the vector $\boldsymbol{w}$, and $\boldsymbol{E}$ is the matrix of residual values. From all the above, the general explanation of the variance using the components, i.e. the maximization of variance, can be written as follows (Bro and Smilde, 2014):

$$\|\boldsymbol{X}\|^2 = \left\|\boldsymbol{t_1} \times \boldsymbol{p_1^T}\right\|^2 + \ldots \left\|\boldsymbol{t}_k \times \boldsymbol{p}_k^T\right\|^2 + \|\boldsymbol{E}\|^2, \tag{5}$$

$\|.\|^2$ represents the norm of the vector, i.e. the sum of the squares of the values. The first part of the equation $\left\|\boldsymbol{t_1} \times \boldsymbol{p_1^T}\right\|^2$ shows how much of the variance is explained by the first component and so on up to R components.

There are two methods most commonly used in the selection of the number of components by PCA, namely the Kaiser-Gutman rule and the cumulative percentage of variance (Pasini, 2017). In the Kaiser-Gutman rule, the components whose eigenvalues are greater than 1 are retained. All components that have an eigenvalue of less than 1 contain less important information than the original variables, which is why it is not necessary to include them in the further analysis according to the specified criterion. According to Jolliffe (2002, p. 115), the threshold value of the Kaiser-Gutman rule must be corrected and reduced to a value of 0.7. Therefore, all components whose eigenvalues are greater than 0.7 must be considered in the further analysis. When using the cumulative percentage of variance to select components, the range of 70% to 90% of the variance explained by particular components is usually used, but the thresholds may be higher or lower depending on the nature of a particular data set (Jolliffe, 2002, p. 113).

4. DATA

For the empirical analysis, we used the estimated parameters of the Nelson-Siegel model for the period from April 2006 to December 2022. These parameters, including level, slope, curvature and lambda, were derived from the monthly prices of government securities on the Croatian financial market. Based on the estimated parameters, zero coupon yields are estimated and used for further analysis. Until the end of 2022, the official currency in Croatia was the kuna and the government bonds were issued in domestic currency, i.e. they were issued without a currency clause. Croatia also issued bonds in foreign currency, mostly in euros, and these were issued with a currency clause. Since different currencies carry different risks, it is important to analyze these two samples individually. Therefore, in this study, the estimated level, slope, curvature and lambda parameters were used for both samples, with and without a currency clause, to estimate the zero-coupon yields for both.

Following Litterman and Scheinkman (1991), zero-coupon yields with maturities of 3 and 6 months and for 1, 2, 5, 8, 10, 14 and 18 years were used. Litterman and Scheinkman (1991) used standard zero-coupon yields, that are known for developed financial markets. Since Croatia is a less developed financial market, there are no continuous series of zero-coupon yields for all these maturities. In Croatia, it is only possible to perform an analysis of market zero-coupon yields for the period from April 2006 to December 2015, as zero-coupon yields for maturities of 3, 6 and 12 months are known for the sample without a currency clause. For this reason, the main analysis was carried out on the basis of the estimated zero coupon yields for the sample with and without a currency clause.

In the Table 1, descriptive statistics of analyzed zero-coupon yields are presented. Panel A displays estimated zero-coupon yields based on level, slope, curvature and lambda parameters for the sample of government securities without currency clause, while Panel B includes estimated zero-coupon yields based on these parameters as well but for the sample of government securities for a sample with currency clause. In Panel C are presented market zero-coupon yields in Croatian financial market.

Table 1: Descriptive statistics of three analyzed samples

Panel A: Zero-coupon yields for sample of government securities without currency clause				
	Mean	**Standard deviation**	**Minimum**	**Maximum**
3 months	4.32	2.14	0.22	9.50
6 months	4.73	2.07	0.30	9.73
1 year	4.99	2.01	0.88	9.85
2 years	5.14	1.98	0.96	10.00
5 years	5.24	1.99	1.00	10.14
8 years	5.26	2.01	1.01	10.37
10 years	5.27	2.01	1.02	10.48
14 years	5.28	2.00	1.02	10.26
18 years	5.28	2.00	1.02	10.21
Panel B: Zero-coupon yields for sample of government securities with currency clause				
	Mean	Standard deviation	Minimum	Maximum
3 months	3.20	2.16	0.00	9.57
6 months	3.53	1.74	0.58	8.56
1 year	4.07	1.70	0.51	8.79
2 years	4.46	1.70	0.37	8.90
5 years	4.71	1.76	0.28	8.97
8 years	4.77	1.79	0.26	8.99
10 years	4.79	1.80	0.26	9.00
14 years	4.81	1.81	0.25	9.00
18 years	4.82	1.81	0.24	9.01
Panel C: Market zero-coupon yields				
	Mean	Standard deviation	Minimum	Maximum
3 months	2.87	2.10	0.28	7.60
6 months	3.38	2.04	0.46	7.70
1 year	3.93	1.81	1.45	7.87

Source: author's calculations

Table 1 shows that the estimated and market zero-coupon yields for shorter maturities are lower than the yields for longer maturities, which is consistent with the expectations theory of the term structure. In addition, short-term interest rates are in most cases less volatile than long-term interest rates, which is also consistent with the results. These results also indicate that the normal shape of the yield curve prevailed on average over the observed period.

5. RESULTS & DISCUSSION

The results of the analysis of the principal components on the sample of government securities without a currency clause, as well as for the sample with a currency clause, are presented in Table *2*.

Table 2: Results of PCA based on estimated zero-coupon yields in levels

	Government securities without currency clause				**Government securities with currency clause**			
Number of observations	189				177			
Components	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Eigenvalue	8.67	0.30	0.03	0.002	8.02	0.71	0.27	0.004
Proportion	96.32%	3.36%	0.30%	0.02	89.15%	7.81%	2.99%	0.04%
Cumulative	96.32%	99.68%	99.98%	100%	89.15%	96.97%	99.96%	100%

Source: author’s calculations

According to the Kaiser-Gutman rule, for a sample without a currency clause, one factor is sufficient to describe the variability of the yield curve, because its eigenvalue is 8.67, so it is greater than 1. According to the cumulative percentage of variance, the first factor explains the largest part of the variability, as much as 96.32%, while the second and third only slightly. For the sample of government securities with a currency clause, the first factor has an eigenvalue greater than 1, from which it follows that the basis of the Kaiser-Gutman rule is the only one necessary to explain the variability of the heh yield curves. If we take into account Jolliffe’s (2002) assumption that those factors whose eigenvalues are greater than 0.7 are needed it can be concluded that the second factor for the sample with the currency clause has a significant influence on the explanation of the variability of the yield curve. The conclusion can also be connected with the cumulative percentage of variance according to which two factors explain 96.97% of the variability of the yield curve, which is an approximate value equal to the selection of one factor for the sample without the currency clause. Also, the results indicate that the inclusion of the third and fourth factors for the sample with the currency clause contributes only slightly to the overall explanation of the variability of the yield curve.

In addition, a PCA of standard market zero-coupon yields was carried out for the period from April 2006 to December 2015. It was performed for zero-coupon yields with maturities of 3, 6 and 12 months without a currency clause, as only such standard market zero-coupon yields are available. PCA was performed and the results can be found in the Table 3.

Table 3: PCA results based on market zero-coupon yields without currency clauses in levels

Number of observations	114		
Components	**1**	**2**	**3**
Eigenvalue	2.9676	0.0244	0.0079
Proportion	98.92%	0.81 %	0.27%
Cumulative	98.92%	99.73%	100.00%

Source: author's calculations

In a sample of standard market zero-coupon yields without a currency clause according to the Kaiser-Gutman rule, one factor is sufficient to explain the variability of the yield curve. The influence of the second and third factors is significantly less than that of the first factor. The results obtained for the standard market zero-coupon yields are consistent with the results obtained for the estimated zero-coupon yields. However, when comparing the two samples mentioned, it should be borne in mind that the standard market zero-coupon yields are only known for 3, 6 and 12 months. The medium and long end of the yield curve is therefore not included in the analysis, as such standard market zero-coupon yields do not exist on the market and the results on this basis cannot provide any information about the dynamics of the entire yield curve. Furthermore, the sample of standard market zero-coupon yields in our analysis is not fully comparable with the estimated zero-coupon yields.

In their work, Lardic et al. (2003) analyze the methodology in the selection of inputs for conducting the PCA and examine whether the choice of methodology influences the final results. The main objective of the mentioned research is to show whether PCA should be performed based on zero-coupon yields defined in levels or whether it is more appropriate to use the first difference of zero-coupon yields. They concluded that it is more appropriate to use zero-coupon yields defined in the form of differences, as such time series of zero-coupon yields are stationary series that do not contain any trend or seasonality. The studies by Parashar (2021), Sekyere Asare (2019), Mota Aragón and Mata Mata (2018), Nath (2012) are also based on changes in zero-coupon yields. Therefore, an analysis of the principal components for differentiated zero-coupon yields was also carried out as part of this study. The results are shown below in Table 4.

Table 4: Results of PCA based on zero-coupon yields in first differences

	Government securities without currency clause			
Number of observations	188			
Components	**1**	**2**	**3**	**4**
Eigenvalue	7.78	1.13	0.08	0.005
Proportion	86.41%	12.60%	0.93%	0.05%
Cumulative	86.41%	99.02%	99.94%	100%
	Government securities with currency clause			
Number of observations	176			
Components	**1**	**2**	**3**	**4**
Eigenvalue	7.82	0.79	0.38	0.01
Proportion	86.88%	8.82%	4.25%	0.06%
Cumulative	86.88%	95.70%	99.94%	100%
	Market zero-coupon yields without currency clause			
Number of observations	113			
Components	**1**	**2**	**3**	-
Eigenvalue	2.52	0.35	0.13	
Proportion	83.88%	11.81%	4.31%	
Cumulative	83.88%	95.69%	100.00%	

Source: author's calculations

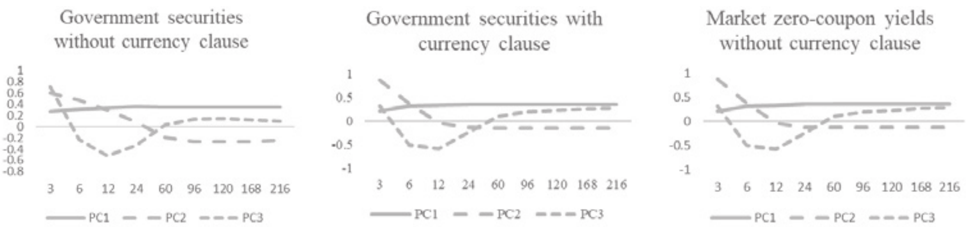
Using PCA, the Kaiser-Gutman rule was applied, as defined by Jolliffe (2002), to elucidate the dynamics of the yield curve for samples both with and without the currency clause. Two significant factors are identified for both samples, as indicated by eigenvalues exceeding 0.7. Additionally, the rule of the cumulative percentage of variance supports this finding. Specifically, for the sample without the currency clause, 99.02% of the yield curve variability is explained by two factors, while for the sample with the currency clause, 95.70% is explained by the same number of factors. However, the inclusion of a third factor is possible, as it contributes 4.57% to the explanation of variability. Conversely, third and fourth factors in the sample without the currency clause each contribute less than 1% to the variability, rendering their contribution negligible.

The analysis conducted on market zero-coupon yields yields divergent conclusions when applying the Kaiser-Gutman rule and cumulative percentage variance. While the Kaiser-Gutman rule suggests that one factor is sufficient to explain the dynamics of the yield curve, the cumulative percentage variance indicates the possibility of including at least one additional factor for a more comprehensive explanation. Furthermore, incorporating a third factor, which accounts for 4.31% of variability, could significantly enhance the accuracy of interpreting yield curve movements. It's important to note that this part of analysis focuses solely on the short end of the yield curve. Therefore, while one factor is deemed necessary for explaining variability at this end, there's potential to include up to two additional factors to provide a more understanding of the dynamics involved.

According to Martellini (2003, p. 72), the first factor or component in explaining the variability of the yield curve is related to the traditional level factor. The level parameter is related to parallel shifts in the yield curve and can be interpreted as an average value calculated on the basis of short- and long-term interest rates. The second factor is related to the position of the yield curve, which determines the slope or steepness of the yield curve, and the parameter is called the slope. The third factor is related to the curvature parameter and has a different influence on the short, middle and long ends of the yield curve, which determines the concavity of the yield curve. The previously described factors in the existing literature are accepted as a consensus that they are the level, slope and curvature factors that can be used to describe the yield curve. The best known work in the context of determining the number of factors that influence the dynamics of the yield curve in the US market is the work of Litterman and Scheinkman (1991), who were one of the first to show that three factors are sufficient to describe the movement of the yield curve. The first factor is the most important and explains 90 % of the variability, followed by the second factor with 8 % and only 2 % explained by the third factor. For certain developed financial markets, it was found that the level parameter explains at least 60% of the variability of the yield curve, the slope parameter between 5% and 30% and the curvature parameter has the least influence and its share is between 0% and 10% (Martellini, 2003, p. 72).

Given that the results for the Croatian market indicate no necessity to include more than three factors, consistent with Litterman and Scheinkman (1991), the Figure 1 illustrates the shape of the eigenvectors corresponding to the first three principal components for the zero-coupon yields defined in first differences.

Figure 1: Eigenvectors of PCA for zero-coupon yields in first differences



Value on horizontal axis is maturity in months, value on vertical axis is factor loadings

Source: author's calculations

Figure 1 illustrates that the dynamics of the three components across the three analyzed samples are highly similar, with minor deviations. The first principal component (PC1) is represented by a horizontal line for all maturities, indicating that PC1 impacts all rates with the same magnitude. This suggests that PC1 can be defined as the level of the yield curve. Examining the second principal component (PC2), it is evident that for shorter maturities, PC2 has a positive impact, while for longer maturities, it has a negative impact on rates, consistent with the definition of the slope factor of the yield curve. Similarly, the third principal component (PC3) demonstrates a positive impact on short and long rates, while intermediate rates exhibit a negative effect, aligning with the definition of the curvature factor of the yield curve. The interpretation and dynamics of the first three components are consistent with conclusions presented in the literature regarding the application of PCA on the yield curve.

The results achieved for Croatian financial market can be compared with similar, less developed markets. Kopányi (2010) has shown for the Hungarian market that when looking at zero-coupon yields by level, the first factor explains 94.70% of the variability and the second 99.33%, which can be linked to the analyzed sample of government securities without currency clauses. When he based his analysis on the differences in zero-coupon yields, he concluded that three factors explain 95.71% of the variability. The results for the Croatian financial market support the findings of Kopányi (2010), as it was shown that the use of differentiated zero-coupon yields as input in the analysis increases the number of factors needed to explain the dynamics of the yield curve. In this sense, when describing the dynamics of the yield curve, the level and slope parameters have the greatest importance and the curvature parameter only a minor one. Reppa (2009) has shown that the first factor explains 95.74% and with the addition of the second factor 99.45% of the variability of the yield curve on the Hungarian market by analyzing the zero-coupon yields in levels, which also fits with the results described.

The results obtained for the sample of government securities with currency clauses for the Croatian market can be related to the research conducted by Dittmar and Yuan (2005) for the Slovenian market, which showed that the first factor explained 88%, the second 11% and the third factor only 1% of the variability of the yield curve. Similar explanatory values for variability were also found for zero- coupon yields when defined in terms of differences. Similar results for the Romanian market were presented in the work of Oprea (2022), in which it was shown that the first factor explained 80.83%, the second 11.09% and the third 4.95%. From all the above, it can be concluded that the results for the sample without currency clause and for the sample with currency clause are in line with the results obtained for less developed financial markets.

6. CONCLUSION

PCA is often used to examine the number of factors that influence the dynamics of the yield curve. Previous research has shown that a maximum of three factors are sufficient to describe the movement of the yield curve. Since this topic is largely studied for developed markets, there is not much research for less developed and less liquid markets. Since the Croatian market belongs to the group of countries with the characteristics of less developed and less liquid markets, the aim of this paper was to check whether the results of the literature review also apply to the Croatian market. To the author's knowledge, there is no work that deals with this topic on the Croatian financial market.

The PCA for a sample of government bonds without currency clauses has shown that one factor is sufficient to describe the movements of the yield curve if the estimated zero-coupon yields and the levels of market zero-coupon yields are analysed. However, when the first differences of yields are analysed, two factors are required to explain the movement of the yield curve. For the currency clause sample of bonds both for levels and first differences of yields, two factors significantly influence the dynamics of the yield curve. The results of the study show that no more than two factors are needed to explain the movments of the yield curve in the Croatian financial market. Moreover, these two factors can be related to the level and slope of the yield curve, which is illustrated by the values of the eigenvectors whose shape corresponds to the definition of the two mentioned factors of the yield curve.

The limitations of this study can be seen in the characteristics of the Croatian financial market. Compared to developed markets, where it is possible to extract market zero-coupon yields, in the Croatian financial market these yields are only known for a short period of time and for some maturities. Until the end of 2022, this data scarcity also had to be split into two samples, as the bonds were issued in different currencies. As Croatia adopted euro in January 2023, it would be possible to investigate this problem for Croatia in a single sample. This opens up the possibility of including eurozone countries and comparing the results with the Croatian market. In addition, Croatia has issued some government bonds with shorter maturities in 2023 and 2024, which will fill in the data of the current sample with market zero coupon yields.

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