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USE OF CALIBRATION METHODS IN ESTIMATING YIELD FIXED INCOME FINANCIAL INSTRUMENTS

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Abstract

Given that the temporal structure of interest rates is a highly debated and studied, the paper focuses on demonstrating how the evolution of the yield curve of government bonds in a given state can highlight a relationship of dependence or show a degree of influence over the trend observed at the level of another state. The estimation of the various parameters involved in the calculation and construction of this curve, by using the optimization models in this direction, Nelson-Siegel (NS) and Nelson-Siegel-Svensson (NSS), highlights the necessary specific information on the degree of curvature, or turning points, based on the theoretical-applicative basis of the parametric function between the time to maturity of the instrument and its yield. Finally, the degree of understanding of the mechanism given by the temporal structure is explained by the use of a series of correlational relations, which show various interdependencies between daily yields, estimated parameters or between spreads. The results of the research demonstrate the various dependencies at the level of European countries (i.e. Germany, Switzerland, Czechia, Norway, Poland, Hungary), as well as outside the European family (i.e. Malaysia and Vietnam). It is noteworthy that Germany and the Czechia have a high degree of correlation over most of the countries analyzed. As the result, the relevance of fixed income instruments and the theoretical intensification of the temporal structure of interest rates are given by the quantitative procedures of the models used.

Keywords: *Yield Curve, Parametric Models, Nelson-Siegel, Nelson-Siegel-Svensson, Correlational Relations, Predictability.*

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1. INTRODUCTION

This paper aims to demonstrate how the specific yields of fixed income financial instruments tend to ensure that the most accurate picture possible in financial markets, with the aim of informing about the investment decision-making act, and the way in which they are able to guide players in decision-making or investment processes. Starting from the way in which the term structure of interest rates is understood as the relationship between interest rates or bond yields and their different maturities (Vayonas and Vila, 2009), and the fact that it can reflect market participants' expectations about future changes in interest rates. Interest rates and the assessment of monetary policy conditions, it can be noted, based on a wide range of debates and important developments in the field under study, that a good indicator in this direction is given by the yield curve.

The motivation to study and analyze a series of specific features of these fixed income instruments is becoming increasingly important by notifying, identifying and providing a wide range of information on how to form their prices and the way in which the regulatory field plays a key role in the financial-banking world. Thus, with the help of the Svensson (1994) model, which is widely used for modeling the yield curve, being a parametric method for estimating the yields of these fixed income instruments, the basic research hypothesis is highlighted by the concentration and identification of plausible answers to how the government bond yield curve helps to predict events, as well as the existence of links between the obtained parameters. The importance of this useful financial indicator (Ananchotikul and Zhang, 2014) in the decision-making and investment process, seen as that lever with the role of information, but also of prediction or understanding of the fluctuating framework of financial markets, is justified by selecting the analyzed states, especially those in Central and Western Europe. Therefore, the fast – paced development of bond markets is an important condition in the development of research, as financial market players have to form a holistic picture of each impediment or more atypical situation in their pursuit of profit, the methods used highlighting the implications which the temporal structure of interest rates has, respectively the role of the yield curves of these fixed income financial instruments. At the same time, the aim is to capture the way in which these calibration methods and models are only the tools that can lead and help to understand the various interactions and relevant ways of guidance and they can be used to adapt and adopt those mechanisms designed to manage, monitor and prevent any changes or more difficult situations.

On the other hand, referring to the structure of the paper, it can be noted that *the first part* of the paper focuses on the thematic and systematic presentation of the main properties, characteristics and defining elements in the analysis of these financial securities. Most of the second part of the paper is focused on conducting a quantitative and empirical-conclusive analysis, by collecting between 2009-2019 data on government bond yields in different world countries grouped by region and economic potential. A first argument would be that less attention is paid to the possible applications of interest rate models to the financial markets specific to these European countries, the calibration models used being applied mainly to US bond markets, with different time intervals analyzed. A second aspect is the size of bond markets, which is generally smaller compared to Western markets, and the analysis of these European countries (i.e. Czechia, Poland, Norway, Denmark, Belgium, Switzerland and Germany) depended heavily on much of the availability of data. The research focus is on observing recent events, by capturing and signaling the links and relationships that can be established between this important predictor in the financial market, given the yield curve of fixed income instruments, but also on how to understand the series of interdependencies and connections identified.

2. LITERATURE REVIEW

2.1. The Models Used in Calibrating The Yield Curve

In the wide typological, diverse and dynamic palette of financial instruments with which economic agents operate, a main place is held by the particularities and multitude of fixed income financial instruments, from the different forms they take, being often integrated in econometric models established in financial practice (i.e.CAPM model, duration model, refinancing model etc.) as those instruments associated with the least risk, or even risk-free. A starting point in the scientific approach is given by the understanding and treatment in the research field of the link between government bond yields and their maturities, known as the temporal structure of the interest rate. The yield curve, also called the temporal structure of the interest rate, means the ordering of the yield given by these instruments fixed according to the time remaining until maturity or, in other words, until its maturity in a set time interval. The explanatory power of these government bonds is predominantly highlighted by both the temporal structure of interest rates and their yields to maturity, the literature confirming the premise that government bond yields are a relevant indicator of economic performance, which can be used to predict real economic activity, while having significant predictive power in international financial markets (Blomvall, 2017; Canto, 2008; Carruthers, 2013; Sambit,

2013).

The term structure demonstrates market expectations for future events. By understanding the structure of the term, it is possible to predict how changes in the underlying asset will affect the yield curve (Cox et al.,1985). Thus, it is found that managers, investors and other decision-making bodies would be extremely interested in obtaining that precise indicator of future interest rate levels, an idea formulated by the study conducted by Annaert et al. (2013). A first point of analysis regarding the shaping of the specifics of the bonds is mainly destined to their maturity, deriving from several points of view, such as:

i. specifies exactly the number of years of the loan and the characteristics of this category of financial instruments,

ii. shows a significant link with the bond yield (hence, the well-known yield curve of fixed income instruments is built in close dependence on their maturity),

iii. highlights the practical-applicative character that captures various forms of the yield curve, thus building a well-established theoretical basis about this dependence (i.e. term structures of interes rates),

iv. also suggests that influence on the price of the instrument, drawing attention also to the implicit relationship between price volatility and its maturity (one reason would be that a change in interest rates can generate a series of higher fluctuations over a longer period time compared to the closer term on the market price of the instrument),

v. allows investors or other relevant market players to guide their own path and the main decision-making acts related to the provisions of that instrument (eg. there are often provisions that allow for the change of time until the title expires or those privileged rights of withdrawal),

vi. implies a clear delimitation of the obligations according to the theoretical conventions in the financial field, in the short-term ones with maturities from 1 to 5 years; those on medium term up to 12 years, and those with a maturity of more than 1 year, already fall into the category of long-term instruments.

The graphical representation of this relationship between the interest rate and the maturity of the instrument (Fisher et al., 1994; Saunders and Cornett, 2018, pp. 200-230), suggests a number of changes in the investment sphere, so the main theories formulated in this direction are:

a) Theory of Expectations, a theory that states that long-term rates are a weighted average of expected short-term future rates. Based on the justification that forward interest rates are unbiased estimates of future sight rates, it can be said that only investors' expectations about future interest rates needs can create the shape of the yield curve, implying that the expected value of the returns obtained from holding securities over identical time periods are the same. Both this theory assumes the risks of inflation and the risks associated with the interest rate. According to the theory, based on this weighted average of interest rates that can lead to the elimination of high volatilities, the theory also supports the idea that short-term rates are more volatile than long-term rates. On the other hand, a weak point of expectation theory is that it cannot explain why long-term returns are normally higher than short-term returns. The theory attaches increasing importance to the expected values of future spot rates and states that bonds have a price, so that the default forward rates are equal to the estimated spot rate (spot rate).

b) Theory of Liquidity Preference, states that long-term bonds are a risky investment, making a first argument that risk aversion will cause forward rates to be systematically higher than anticipated sight rates, usually with an amount that increases with maturity. Investors also have a high aversion to risk, as a result, preferring short-term maturities, and if they engage in short-term securities, they will request one and receive it (Gibson, et al., 2001). Another valence of the theory presented draws attention to how longer-term interest rates not only reflect investors' future assumptions for interest rates, but also include that premium for holding these longer-term bonds, assert as long-term premium or liquidity premium, designating, in the latter case, the degree of risk-taking. At the same time, the theory acknowledges the importance of expected future sight rates, but attaches more importance to the effects of risk preferences of market participants. This assumption states that risk aversion will result in higher forward rates than expected rates at sight with an amount that increases with maturity, the value of the premium being given to investors to hold longer-term securities because they involve higher risk (Cox, et al., 1985). The theory also shows the main considerations regarding the way in which investors prefer cash, these being in accordance with the transactions in which we are involved (cash is used in the sale-purchase operations of goods and services), precautions (we want to have a buffer fund to get our hands on when needed), speculative reasons (cash is one of the assets held in its own asset portfolio).

c) Market Segmentation Theory, assumes that the markets for bonds with different maturities are completely segmented, the interest rate for each bond with a different maturity

being determined by the supply and demand of these fixed instruments. The theory, like the preferred habitat theory, supports the way in which the investment preferences of creditors and debtors depend on the maturity of the financial instrument, as there is no high risk premium level to induce investors in their preferred maturity range.

d) Partial Theory of Expectations (Favorite Theory A Habitat), represents that combination between the theory of market segmentation and the theory of expectations, because investors care about both the expected returns and the maturity of the securities held. In addition, because investors have different investment horizons and buy bonds with maturities outside their habitat, they need a significant premium. The theory allows market participants to trade outside their preferred maturity, if it is adequately compensated for the additional risk. However, the theory justifies that investors prefer short-term bonds to long-term bonds and never prefer a long-term bond, only if it offers the same expected return under short-term bonds. The theory explains why short-term investors are more widespread in the fixed income market, having as argument this temporal structure of the interest rate. The pure theory of interest expectations says that when investors buy a bond they look strictly at the return it offers, while the partial theory considers that investors look at maturity and yield simultaneously and compare different maturities with different yields. by bond classes (Gibson, et al., 2001). The way of understanding and observing the yield curve of these fixed instruments is an increasingly intense concern in the literature, most of the studies conducted addressing its various forms, which can be perceived with certain atypical situations or macroeconomic anomalies or even different stages that a state is going through on its way towards economic development (Cwik, 2004).

In this direction, the most visible forms are: (i) an inverted form of the yield curve, which can be interpreted as a situation of worsening economy or an economic slowdown, being observed the following situations of this kind, (ii) a form considered normal, which is inclined upwards and which validates the theory of the temporal structure of the interest rate, (iii) the hull-shaped curve, also known as the bell-shaped curve, and according to Vayonas and Vila (2009), such a shape may occur in response to a decrease in aggregate demand, signaling, as a result, a worsening or a downward slope of a state's economy. The thorough extension of the theoretical framework of the analyzed issues has allowed the establishment of certain schools and theoretical guidelines, in which different perceptions, statements and premises about the relevance of the temporal structure of interest rates are analyzed, according to the table below:

Table I. The main schools concerned with terms structure

TYPE OF SCHOOL	DESCRIPTION
BALANCE	It involves modeling the short-term interest rate through stochastic processes such as non-arbitrage and the equilibrium condition. Thus, the dynamics of the term structure are also provided, which is useful for studying the implications of interest rates for bond prices, but especially for option prices, where there are often closed-ended solutions.
INTERPOLATION AND BOOTSTRAPTING	Interpolation methods are characteristic of this type of school, helping build specific bond yield curve, as well as on swaps on interest rate.
PARAMATERIC	Describe this temporal structure by appealing to parametric functions. Using methods to minimize errors in estimating parameters, their modeling can lead to a lower interest rate risk, according to the concept presented by Blomvall (2017) and Vojtek (2004).

Source: Adapted from Hull (2018)

In other words, according to the study carried out by Gibson, et al. (2001), in the most detailed understanding of this raising interest in the specialist literature for the analyzed issues, and through the analytical-quantitative framework given by the elaboration of several models, one can identify a taxonomy of them, highlighting a series of characteristics and particularities:

[1] Continuous models, used in most cases, being extremely appropriate in terms of establishing a precise theoretical framework, valuable and with empirical explanatory power,

[2] Discrete models, specific to modeling as accurately as possible the dynamic processes and trends in current financial life, testing the effectiveness of interventionist decisions proposed by central banks in different countries of the world,

[3] Models based on the determination of the bond price, meant to determine the fluctuating rate and price dynamics of these fixed financial instruments,

[4] Models related to interest rates, having as main feature the modeling and highlighting the evolution of those short-term rates, being stochastic processes of Markov type (the future value of the interest rate depends on the current, historical value),

[5] Models that incorporate the entire time structure (yield curve) - a category that is intensifying lately, because it is based strictly on the dynamics of fixed instrument yields or on those forward interest rates.

[6] Single-factor models, which explain the temporal structure of the interest rate by using a series of factors or variables, their purpose being to show the different mutations in the yield curve, their analysis being done through complex statistical models,

[7] Multifactorial models, involve an extension of unifactorial models, the analysis of the structure being performed by adding several factors or independent variables, for example, often, the inflation rate,

[8] Calibration models of the yield curve (**fitted models**), based on empirical data, leading to a better understanding of these tools particularly relevant in the financial sphere. The models used in this paper are noteworthy, being extremely popular and used in this sphere of activity (applied by central banks), especially the model extended by Svensson (1994), which has a power to estimate a series of parameters that describe and explain the importance of this often debated financial indicator, namely, the yield curve of fixed income financial instruments,

[9] Non-arbitrage models, start from this essential condition and aim to model interest rates in a homogeneous and impartial process,

[10] Interest rate equilibrium models are in opposition to nonarbitrage ones, starting from the description and inclusion of the concave utility function of a representative investor, assuming this market equilibrium condition flows into the decision-making process, the price of assets, respectively on interest rates, being in the same theoretical direction announced by the theory of expectations or risk premiums.

2.2. Nelson Siegel and Nelson Siegel Svensson Models

The researchers have recently developed a series of application-theoretical models in estimating and calculating parameters arising from government bond yields. There is a clear delimitation between *dynamic models and static models* used in this direction, and according to Fabozzi et. al., (2006), static models having a raising use, because historical data represent that starting point in estimating the yield curve, and compared to dynamic models, they do not allow the volatility of interest rates to be incorporated into the model.

Thus, the model developed by Nelson and Siegel (1987) is a model of parametric analysis that highlights the estimation of the yields of these categories of financial instruments,

being often widely used and preferred by the central banks of various states of the world. Main extraction-modeling of the yield curve in an exponential threedimensional framework. Estimating the three factors and the exponential decomposition rate of the model proposed by Nelson and Siegel (1987) shows that not only the three factors can be interpreted as three latent values, but also the exponential decomposition rate is also a crucial factor which represents the fluctuating movement of the shape of the yield curves, also drawing attention to the essential feature of this indicator in the financial sphere, the explanatory power of forecasting.

At the same time, the flexible character of the optimization of the yield curve is highlighted, the most frequent resulting forms being in the form of "h" or "S", an aspect suggested from the detailed study made by Diebold and Li (2006), which brought new valences to the original model,by applying and establishing various econometric processes, from linear regression to the application of the autoregressive vector (VAR), showing both the dynamic side of the model and how the estimated parameters lead to the contouring of the yield curve as a function of time.

Also from the analysis elaborated by the American researchers, Diebold and Li (2006), reference is also made to the significance resulting from the estimation of the parameters of the model with three factors (β_0 , β_1 , β_3, τ_1), thus, β_0 represents the independent factor and specific to the long term, β_1 is interpreted as the short-term factor that leads to the contouring of the level of the respective curve, β_2, signifying its slope and degree of curvature, and through the exponential decomposition rate (τ_1), the finalization results coherently of the yield curve, the influence exerted by this last factor being extremely important in the optimization process, showing its use to build accurate long-term structural forecasts.

This prediction capacity was also exposed by Fabozzi et al. (2005) who show in the study how the Nelson - Siegel model can produce credible forecasts, being statistically validated, having an economic explanatory power, because they can be considered those levers that generate substantial profits in the investment and financial field.

A considerable revitalization of the three-factor model has been put forward by the Swedish researcher Svensson (1994), a model in the category of calibration of yields to maturity of the instrument being widely used by governments, central banks and financial institutions around the world. The model brings out new certain parameters (β_3 and τ_2), which by going through the same optimization function, explains and determines the various shapes

that the curve can have in different periods, highlighting the magnitude and direction of the curvature fence at its level. Svensson's in-depth model is able to capture many of the typically observed shapes that the yield curve can have over time, with substantial research efforts being dedicated to modeling and the ability to predict the temporal structure of yields in the future (Hladikova and Radova, 2012; Ibanez, 2016).

Considering the advantages and disadvantages of the models applied in the research, the literature refers to these aspects. Their main advantages are: (i) extremely popular in practice, (ii) extremely useful in shaping the yield curve, flexibility being one of the characteristics highlighted by the models, being suitable for evaluating yields for several bonds, for series of time yields, for a large number of countries, different time periods and for various bond classes, (iii) have a good ability to predict and make clear the resulting parameters (Marciniak, 2006), (v) used substantially to assess the structure of single-coupon bonds and forward interest rates (forward rates). However, the models have a number of disadvantages, such as: (i) a limited ability to adapt irregular shapes of the yield curve, (ii) the tendency to take extreme values at the bottom of the curve, (iii) relatively strong dependence on estimates from different or even non-adjacent segments of the yield curve (Marciniak, 2006).

2.3. Yield Curve and Monetary Field

The specialist literature shows the manner in which the yield curve represents that essential indicator from the point of view of the role played in the formulation of actions, measures related to the policy and the monetary sphere of the financial sector. Thus, in the wide range of the vast and complex field of finance, more precisely this concern and proactive attitude on the part of researchers and authorities to lead to the stability of the financial system, there is also a debate on how the monetary authority should focus on reducing imbalances (Adam, 2012; Andre et al., 2018; Gambacorta and Signoretti, 2014), by establishing a policy often analyzed and reflected in the last decade, known as "leaning against the wind".

This policy took off with the onset of the Great Financial Crisis of 2007, when central banks had to deal with and focus on these recurring imbalances and the fragility of the financial system, perceived as that form of systemic risk that contributes to various market imperfections, in the form of main causes from the information intensity, to the inter-temporal nature of financial transactions, to the high degree of interconnection and the existence of those links between financial intermediaries and markets, perceived as puzzle pieces. The policy is based on modeling financial cycles through an appropriate calibration process, which will reflect the tradeoff between the costs of this policy in the short term and the long-term

benefits of restoring the financial cycle, also referring to the manner in which the yield curve of fixed-income financial instruments plays an important role in the adoption and exercise of these new actions and the adaptive capacity of traditional monetary policy.

First, the policy analyzed is characterized by a new valence in the manner of application and understanding, so that if, before the onset of the crisis, central banks promoted a monetary policy based on that well-intentioned neglect, which may have a more beneficial effect than taking responsibility (benign neglect) on price stability (Caraiani and Călin, 2019; Svensson, 2016).

The new perspective highlighted by "leaning against the wind" (LAW) is suggested by a prudent attitude and considered to be, in general, an approach that allows awareness of the financial sector stability. Seen as those predictors of financial crises, modeling macroeconomic variables (i.e. production, exports, imports, private consumption, government consumption, trade balance, etc.) and highlighting the role of financial intermediaries in econometric models lead to highlight a variety of financial frictions that amplify economic shocks and exacerbation of business cycles, according to many researchers, such as: Sambit (2013), Borio and Lowe (2002) or Jorda et al., (2015). Moreover, the monetary policy transmission channel highlighted in this paper plays a prominent role in numerous theoretical and practical research, it can encourage banks to make higher gains since they take more risks in terms of policy and requirements of lending according to the asserption made by Borio and Lowe (2002).

Other considerations which have in view the manner of adopting such a loose policy reffers to the problem of bubbles (Asriyan et al., 2020; Filardo, 2004) that can be corrected suddenly, leading to investors' losses, rapid asset sales (intensification of the economic recession) or accelerating the activity of the unregulated banking system (shadow banking system) and increasing the fragility and instability of the financial sector, but also possible benefits from a lower probability or magnitude of an unpredictable situation that can lead to the outbreak of a future financial crisis, according to the beliefs of economists Adrian and Shin (2008) and Zacek (2018).

Many researchers thought that monetary policy should occupy a less important place, practically losing its size, thus increasing confidence in various macroprudential instruments, designed to increase the engineering behind the financial system. However, together with LAW, macro-prudential measures have the advantage of aiming at financial stability and

ensuring complementarity and efficiency at first sight in monetary policy (Asriyan et al., 2020; Zampolli, 2006). The way of resorting to LAW also involves noticing costs and benefits often highlighted in the literature, for example, the degree of measurement of financial imbalances, the cost of implementing this prevention policy on short-term variables or how much does credit change affect, the probability of a future financial crisis, aspects studied by Svensson (2016), Svensson (2017), and as the main advantage in favor of the policy. By evoking a proactive attitude which would respond to the recurring consequences and turbulence of financial instability, this policy shows the transition from the original area of the objective of the monetary policy (that of price stability by targeting inflation) involving an increasing concentration of the decision makers in this field of activity, somewhat the interest in the financial system being no longer considered and perceived as marginal action (Hagenbjork, 2019; Meyer et.al., 2017).

Stability in the financial sector remains an objective often analyzed and highlighted by those who deal with monetary policy decisions, the central banks being those promoters of price stability, but in most cases the orientation towards speculative bubbles remains a marginal activity. Also, the view that they become concerned and oriented towards the need for knowledge on movements in asset prices (more attention is paid to fixed income instruments, usually satt securities) or when the money market has negative effects on shocks, and through the multitude of models, processes and procedures, it becomes desirable, suggesting a more relevant and comprehensive representation of speculative bubbles (Ho and Lee, 1986; Hull and White, 1990).

Challenges to changes in conventional overall monetary policy actions, which were previously intended to stimulate economic activity, have led central banks to adopt certain sets of concrete actions and measures of measurement and protection in asset markets, constituting various instruments, econometric models that can encompasses a series of macroeconomic variables, noticing and creating different;forecasts and simulations on the issue in question (Toraman and Tuncay, 2017; Zampolli, 2006: Zacek, 2018). For these reasons, inflation targeting remains a complementary measure in this period increasingly characterized by the fragility of the financial system, the primary objective of the monetary authorities being to respond if and when a collapse in asset prices threatens the system and lead to situations of instability, together with the ability to manage the financial cycle, suggesting an increased concern towards the adoption of those macroprudential policies.

An important lesson derives from the fact that the modalities of monetary policy

transmission differ from state to state, from sector to sector (Gerdrup et al., 2017), although they do not provide any direct effect on speculative bubbles, policy revival allowing the management of unpredictable situations can have major significant effects for the entire economic sector, because instability and financial risks do not only come from these bubbles, the decision-making process being also extremely efficient and to be taken into account.

3. THE RESEARCH METHODS

A relevant part of this paper is highlighted by the methodology undertaken for the purpose of scientific demonstration of the research question previously formulated. The section represents the link between the theoretical framework given by the relevant literature in this direction and the scientific approach aimed at providing answers, solutions, suggestions, but also recommendations of the research question that leads the narrative thread of the paper. We used to collect in the period 2009-2019 data on government bond yields in various countries of the world grouped by region and economic potential, as follows:

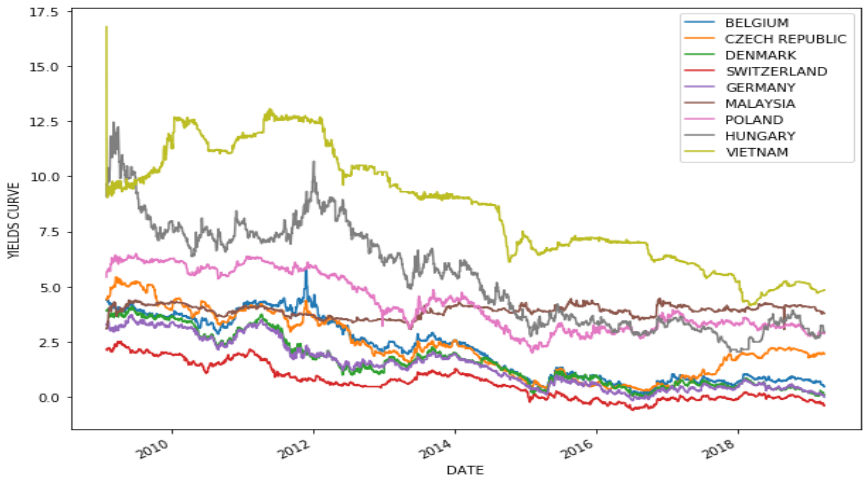
i. Developed countries in Central, Northern and Western Europe: Belgium, Czechia, Denmark, Switzerland, Germany, Norway.

ii. Developing / transition countries in the European area: Poland and Hungary.

iii. Countries in South-east Asia: Malaysia, Vietnam.

Thus, data on yields on mature government bonds starting up from 3 months to 10 years, were downloaded using the Bloomberg platform strategy used in their processing consisted in standardizing the data for each part and start from the same time interval: so that the analysis can lead to the conclusion of the scientific approach.

Chart 1: Evolution of government bond yields during 29.01.2009- 25.03.2019



Source: Author's Contribution

After this vital stage, the research methodology was structured in several parts, as follows:

[1] The first part of the methodology, based on the establishment of a code in Python (Christoffersen, 2011), it was highlighted how to form the yields of these fixed income tools, by resorting to a function that takes into account maturity and efficiency, which led to the highlighting of some key variables in the formation of these yields. We were able to use the estimation of each parameter in the daily yield of these instruments for each model, in the analyzed time interval, specific and characteristic for each country in the research. Running for each day of the proposed interval and for each state, this stage aimed at optimizing and obtaining the resulting parameters, providing information on the shape of the curve, its curvature, implicitly having meanings and implications in the financial field. The mathematical relations and the relevance of the parameters that are part of the model are:

a) The model formulated by Nelson and Siegel (1987) involves estimating the parameters that form the time curve of yields, according to the calculation formula and the following conditions to be taken into account:

$$y(t) = \beta 0 + \beta 1\left[\frac{1-e^{-\frac{t}{\tau 1}}}{\frac{t}{\tau 1}}\right] + \beta 2\left[\frac{1-e^{-\frac{t}{\tau 1}}}{\frac{t}{\tau 1}} - e^{-\frac{t}{\tau 1}}\right] \textbf{(1)}$$

b) The model deepened by Svensson (1994), which implies an extension of the basic mathematical relation, as well as the same conditions to be fulfilled, as follows:

$$y(t) = \beta 0 + \beta 1\left[\frac{1-e^{-\frac{t}{\tau 1}}}{\frac{t}{\tau 1}}\right] + \beta 2\left[\frac{1-e^{-\frac{t}{\tau 1}}}{\frac{t}{\tau 1}} - e^{-\frac{t}{\tau 1}}\right] + \beta 3\left[\frac{1-e^{-\frac{t}{\tau 2}}}{\frac{t}{\tau 2}} - e^{-\frac{t}{\tau 2}}\right] \textbf{(2),}$$ where**:**

y (t) = daily market yield of government securities for the period under review,

t = maturity of the fixed income instrument,

β_0 = measures the level of yield according to each maturity (the term independent of the time to maturity, considered to be the long-term term),

β_1 = measures the slope of the yield of the fixed income instrument according to each maturity, considered the short-term term,

β_2 = measures the degree of curvature and the hump of the yield curve of the fixed income instrument according to each maturity,

β_3= measures the degree of curvature and a second hump of the yield curve of the fixed income instrument according to each maturity,

τ_1 = decay factor, a factor that contribute to the best possible estimation of the parameters, based on the daily yield of these fixed income instruments,

τ_2 = decay factor, an additional factor that contributes to the best possible estimation of the parameters, based on the daily yield of these fixed income instruments.

[2] The last part of the methodolgy, consists in making several types of correlations which were based on previously estimated parameters. We used the way in which government bond yields, (implicitly their curve for each country and in the analyzed period) represents a certain degree of predictability and the way in which the temporal structure influences to a certain extent its evolution in another country, in other words, if there are connected and interdependent relations at terms of terms structure, drawing attention to the implications described by this mechanism.

The section of the research paper aims to draw attention to the various ways in which data processing, by using the multitude of deductible tools, quantifiable in clear and objective results, helps to underlyne the link between question formulation and hypotheses.

4. ANALYSIS AND DISCUSSION

Starting from the research hypothesis, described by the characteristics and particularities of fixed income instruments regarding their way of representing those points of support in guiding the various players in the financial markets, this section of the paper captures and provides interpretations of the results obtained, according to the theoretical - demonstrative framework used. We resorted to a division into several sub-points, regarding the review of the results according to their importance.

a) Establishing the diagram regarding the series of yields according to maturity, in order to show the evolution, trend and dynamic mode of the curve achieved in the analyzed interval 2009-2019, having the significance to explain the movements and various forms of the yield curve for each state separately.

This first stage, according to the followed methodology allowed the understanding and highlighting of the main trends and fluctuating movements noticed from the drawing of the yield curves in the targeted period and for the analyzed states. The predominant form explains and invalidates that purely theoretical and normative condition, according to which short-term yields are usually lower than long-term ones, which derive from the temporal structure of interest rates.

Chart 2. Yield curve in **Germany**

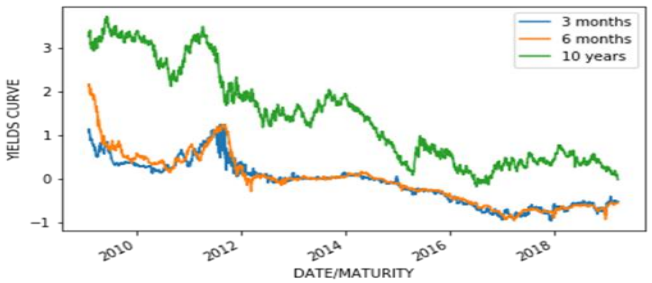


Chart 3. Yield curve in **Czechia**

Source: Author's Contribution

As a result, the form considered normal does not apply to existing and dynamic conditions in financial markets. The inverted curve has been growing since the beginning of the Great Financial Crisis and continues to persist for most of the analyzed states, interpreted as signaling possible atypical situations that affect the mechanism of financial markets. An extreme importance is highlighted by the fluctuations of the developed countries in Central Europe :Germany and the Czechia, in individual performance taking momentum from the years 2010, pointing out a continuous attempt to revive the mechanism of functioning of the markets of these countries, the strategies used being in balancing the undertaken policies, but also in controlling the imperfections of the financial markets being similar to the other states analyzed (i.e. Norway, Poland, Hungary, Denmark).

b) Estimation of the parameters resulting from the applied models, it is found how the use of optimization models by obtaining the parameters that are part of the yields of fixed income financial instruments was appropriate and representative for the time series analyzed. The development of the models aimed to draw attention to the methodological features that had the role of explaining the complex way of calculating the daily yield and the establishment of this dual relationship between maturity and yield to maturity.

Chart 4. The estimated parameters in **Czechia**

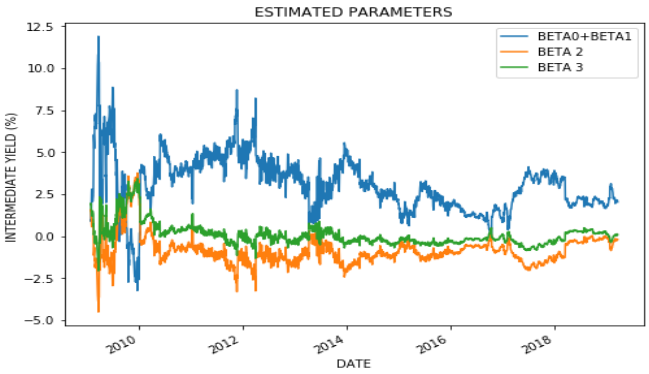
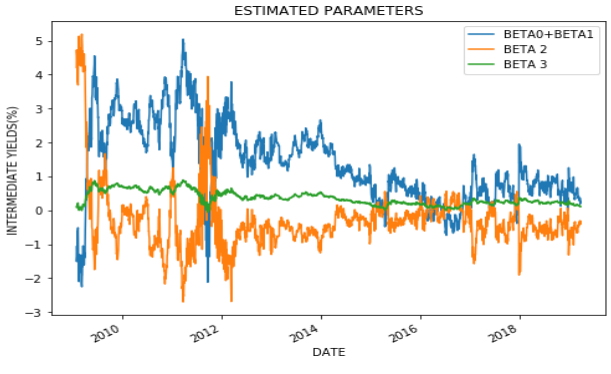


Chart 5. The estimated parameters in **Germany**



Source: Author's Contribution

The resulting parameters were intended to calibrate the various forms that the yield curve had in the period 2009-2019, showing both the level, the degree of curvature and the dependence on exponential decomposition rates (τ_1, τ_2). Also, the important role in estimating these rates was highlighted, as they led to a better accuracy of calculation of yields, as well as the highlighting of various turning points in the visualization given by the shape of the curve.

The two models had the ability to calibrate any yield according to its maturity (between 3 months and 10 years), particularly for each country, highlighting a number of advantages and disadvantages. Knowing these specific aspects and features of the models, we can rightly mention that the four-factor model (NSS) is indeed more efficient in terms of the broad degree of fit on any type of maturity. However, we can also emphasize the practical degree of the original model (NS), having the ability to provide extremely plausible results with a level of confidence of 99% in the calibration process. According to the graphs, it highlights the role that these parameters have in defining in a more accurate way the yield curve, for the states considered standard in the analysis: Germany and the Czechia.

c) Capturing those interdependencies and the way in which they have the capacity to lead to a better explanation of the situations that may have effects on the financial sector in these states. (Heat, et al., 1992). This could be achieved by carrying out several types of correlations:

i. Correlations at the level of each state between the maturities and the parameters obtained by applying government bond yield calibration models,

ii. Correlations that draw attention to the interdependence relations and the way in which the parameters in one country influence those in another country.

The first category is represented by the correlational analysis between yields, depending on maturity and the parameters that are part of them, performed for each state. By using the conditional formatting function, each correlation was highlighted by different colors, meant to show the various relationships, as follows:

Between 0.0-0.2, positive correlation of a low level (in red),
Between 0.2-0.5, positive correlation of a moderate level (in orange),
Between 0.5-1.0, positive correlation of a high level (in purple),
Between 0.0- (-0.2), negative correlation of a low level (in blue),
Between (-0.2) - (-0.5), negative correlation of a moderate level (in green),
Between (-0,5) - (-1.0), high negative correlation (in yellow).

Table II. Correlations between maturities and parameters estimated according to the NSS model in the case of the Czechia

MATURITY	3 years	5 years	10 years	beta0	beta1	beta2	beta3
3 years	1						
5 years	0,9825	1					
10 years	0,9517	0,97008	1				
beta0	0,5163	0,4658	0,65007	1			
beta1	-0,6073	-0,7423	-0,7574	-0,2487	1		
beta2	0,3024	0,3933	0,1907	-0,6212	-0,4821	1	
beta3	0,5765	0,6874	0,5510	-0,2561	-0,7939	0,9065	1

Source: Author's Contribution

Table III. Correlations between maturities and parameters estimated according to the NSS model in the case of Germany

MATURITY	3 months	6 months	10 years	beta0	beta1	beta2	beta3
3 months	1						
6 months	0,9493	1					
10 years	0,8947	0,8741	1				
beta0	0,6082	0,3825	0,7132	1			
beta1	-0,3973	-0,1806	-0,6014	-0,9622	1		
beta2	0,1039	0,4045	0,08002	-0,6414	0,7044	1	
beta3	0,6879	0,5364	0,8605	0,9574	-0,9242	-0,4166	1

Source: Author's Contribution

There are predominantly significant correlations at the level of Germany and the Czechia, shown in Tables II and III. The predominant type of correlation was a positive one with a high intensity (between 0.6 and 0.8), suggesting a high dependence on the estimated parameters, contributing to the explanatory power that the evolution of the yields of these bonds is influenced in directly by the time to maturity. Also, in the other states analyzed, there were mainly medium and low intensity relationships, depending on the applied models, explained by a dependence on maturity to a less extent, highlighting the importance of the parameters that determine the level, the curvature of the curve in estimating short-term yields.

The second category of analysis is intended for the correlational links that may occur between various parameters between countries. Based on the conditional formatting function, the correlations that have been developed by interpreting the way in which the yield curve is specific to a state, presents a degree of connection with the evolution of the yields of another state. It suggests the role of government policies adopted by each state, emphasizing an important action in the dynamics, orientation and support of the financial sector through the issuance of fixed income financial instruments.

The correlations captured in the tables IV and V focus on an important aspect, the main purpose being their degree of orientation, stability and confidence of financial players in various decision-making and investment processes, as well as increasing the share of fixed income instruments in finalizing market portfolios. Thus, there was a strong link between the specific parameters of Germany and those of the Czechia, confirming the strength and manner in which financial markets in these countries are true models of economic development and stability in the financial sector to follow.

Table IV. Correlations between the estimated parameters in the Czechia (NSS) and the other countries

PARAMETERS	*BETA 0*	*BETA 1*	*BETA 2*	*BETA 3*
BELGIUM	*-0,0107*	*-0,0201*	*-0,0026*	*-0,0045*
DENMARK	*0,2351*	*-0,0763*	*0,2408*	*-0,0047*
GERMANY	*0,3968*	*0,6506*	*0,0302*	*0,5427*
HUNGARY	*-0,0184*	*0,0229*	*0,0257*	*-0,0088*
POLAND	*0,2886*	*-0,3915*	*-0,4213*	*0,3973*
NORWAY	*0,1859*	*0,3703*	*-0,0545*	*-0,2725*
MALAYSIA	*-0,0418*	*0,0047*	*0,0002*	*0,0059*
VIETNAM	*0,1704*	*-0,1555*	*0,1862*	*0,0221*
SWITZERLAND	*-0,0333*	*0,0023*	*0,0088*	*0,0118*

Source: Author's Contribution

Table V. Correlations between estimated parameters in Germany (NSS) and other countries

PARAMETERS	*BETA 0*	*BETA 1*	*BETA 2*	*BETA 3*
BELGIUM	*0,0418*	*-0,0263*	*0,0134*	*-0,0611*
CZECHIA	*0,3968*	*0,6506*	*0,0302*	*0,5427*
DENMARK	*0,2492*	*0,1576*	*0,2456*	*0,2433*
POLAND	*-0,1438*	*-0,3670*	*0,1153*	*0,3067*
HUNGARY	*-0,0021*	*0,0385*	*-0,0411*	*0,0397*
NORWAY	*0,3398*	*0,3336*	*0,0267*	*-0,3951*
MALAYSIA	*-0,0201*	*-0,0114*	*0,0177*	*-0,0072*
VIETNAM	*0,0466*	*-0,1969*	*0,0743*	*0,1815*
SWITZERLAND	*-0,0603*	*0,0437*	*-0,0589*	*0,0306*

Source: Author's Contribution

The governmental authorities in these states support the tendency to stabilize or reduce the state debt, making these states the least indebted among the EU countries. The efficient liquidity management and the involvement of its available resources in covering the financing needs definitely contribute to stable economic growth. The budgetary policy represents an important component of the complex and ample framework of the decision-making process (Heat, et al., 1992; Volodin et al., 2017). This is mainly reflected in the yield curve of long-term government bonds and their high level leads to a continued attractiveness for investors in this direction, depending to some extent on the effects of the decisions taken at the level of the monetary policy.

Following the presentation and interpretation of the results, this paper draws attention to the useful, significant and directive nature of fixed-income instruments, in this case government bonds. The implications of the elaborated study closely concern the information that can be extracted from the correlational and parametric analysis characteristic of government securities. The recommendations that can target this area in full expansion and increase in relevance of government bonds are designed at the level of policies for each state, including: reducing the risk of debt refinancing, increasing the value of reference bond issues, closing small issues and low liquidity of marketable and non-marketable bonds, and last but not least, interest rate risk management. The government securities market can get a new value or direction to follow, being a source of relevant information from the perspective of monetary

policy: interest rate expectations, inflation rate, market uncertainty (Shea, 1985).The usefulness of the models developed in this research, drawing attention to the increasing global integration of financial markets, the increased sensitivity to the developments of bond markets in the economies of developed countries and the increased role of monetary policies, embodied in increasing liquidity management, and the relevance of domestic macroeconomic fundamentals, especially in periods characterized by increased global volatility.

Another contribution also refers to the way in which the types of correlations undertaken interact and propagate in different ways and degrees of intensity. In other words, given the novelty of the study it is essential to understand the plurality of connections that the yield curve has shown. Using the two methods of optimization, the results have also analyzed states less studied states in scientific research, such as: Malaysia and Vietnam, as well as, states in the Central European area, thus differing from the line preferred by the researchers who studied the specifics of the yield curves (McCulloch, 1971; Shea, 1985; Svensson, 1994), especially in the US markets.

It is surprising how the dynamics of the curve of the analyzed states is closely related to some states considered promoters of the development and well-being of the financial system (i.e. Germany). The relevance of the German government securities market is widely considered to be liquid, direct and clearly structured. At the same time, government securities are generally placed as single issues by auction and as a result, new issues with large volumes appear, especially on the capital market within it, helping to ensure a high level of liquidity, where the policy undertaken by the federal government is therefore shaped by the high interest in issuing securities continuously, with maturities that are spread across the entire spectrum between less than 12 months and over 10 years.

The main purpose of the scientific approach has been to draw attention to the fact that the parametric models targeting this sphere allowed a new valence and feature of the yields of these free- risk instruments, which shows the degree of connection between the analyzed states and the influences of the monetary policy adopted by government authorities. In this sense, the present study underlines the influence that the developed countries have mostly over other states in shaping the yield curve and the correlation between the estimated parameters. The obtained factors, the long-term one showing the level of the curve (β_0), especially the short-term one (β_1) and the exponential decomposition factors ($\tau_{1,2}$) lead to the relevance of correlational relations, validating the existence of these connections and interdependencies, where the curve yields increasingly occupy a central place in research in the field. Considering

the specifics of this study, we recomend a direction to be followed in further research to expand the number of countries to be analyzed which can highlight the benefits in a holistic manner the raising use of the fixed income financial instruments.

5. CONCLUSIONS

The paper has demonstrated through a quantitative approach, the particularities, characteristics, but also the implications that the yield curve of fixed income financial instruments propagates in the financial markets, characterized by dynamism, continues to concern associated risk management (from interest rate, market, foreign exchange, operational or political risk) and the various specific connections and interdependencies. Fixed income financial instruments, in this case, taking the form of government bonds, are growing in use, proving to be essential, especially in establishing and finalizing market portfolios, which amplify the understanding and perception of players in the market within these markets on the complex decision-making process. It is found, through the empirical study of the temporal structure of interest rates, but also through complex modeling and calibration procedures an important role of instruments, materialized in the explanatory power and predictability of the mechanism of operation in financial markets.

The models launched by Nelson - Siegel and Svensson are valuable in this regard and have a special contribution in estimating in a more accurate way the yield curves for each maturity and each state analyzed. In other words, the issue addressed also consisted in highlighting the interdependence relationships that the estimated parameters, following the applied models, have on the yield curve. Finally, it can be concluded that the Nelson - Siegel - Svensson model is a good model to replicate the behavior of the yield curve of government bonds applied in each country analyzed, being aware that this is a really powerful method to do compared to the yield curve, which is really useful for both researchers and financial market participants, thus helping to make decisions with more information. In this sense, it highlighted the role that developing countries (i.e. Germany, Czechia, Norway, Denmark) they have mostly other countries (i.e. Poland, Malaysia, Vietnam) in shaping the yield curve and the correlation between the estimated parameters.

Finally, the paper aimed to capture these relationships, especially the understanding and importance of fixed income instruments, along with the regulatory area, leading to the optimization of investment decision-making by players involved in the complex financial arena. Consequently, risk remains the key element, being often more important than the pursuit of profit, the risk being viewed from several angles, often this being equivalent to the

probability of creating an advantaje, an opportunity, which perceived carefully and thoroughly can lead to capitalize on a credible economic potential.

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