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Modelling and forecasting interest rates during stages of the economic cycle: A knowledge-discovery approach☆

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ABSTRACT

Modelling the structure of risk-free rates and their relation to other economic and financial variables during different stages of the economic cycles has attracted much interest from both the theoretical and practical perspectives. The previous literature has emphasized the deployment of expert systems and knowledge-discovery approaches motivated by the need to address the limitations of the econometric models. However, it has failed to address the interpretability aspects and, more importantly, the need to provide methodological support that allows the deployment of such techniques in a more systematic way. This approach entails the definition of a process that includes the usual steps taken by experts to address similar problems and allows the relative merits of different techniques in relation to common goals and objectives to be gauged.

This paper addresses the interpretability and the lack of methodological support by proposing a knowledge-discovery methodology that includes a minimal common number of steps to model, analyse, evaluate and deploy different non-linear techniques and models. Furthermore, the interpretability is addressed through the use of open-box techniques, such as decision trees.

The proposed methodology helps to discover and describe hidden patterns, allowing for the study and characterization of economic cycles, and economic cycle stages, as well as the description of the historic relationships between interest rates and other relevant economic variables. These patterns can also be used in the forecasting of economic cycle stages, interest rates and other related variables of concern. The output of the methodology can provide actionable information for market agents, such as monetary authorities, financial institutions, and individual investors, as well as for the academic community, to increase further the knowledge and understanding of financial markets, thus enriching and complementing existing financial theories.

1. Introduction

In finance, expert systems are used to help practitioners with their decision making in relation to stock market, securities and commodities prediction. This task has been dealt with two main approaches, one that explicitly considers theory in relation to market characteristics (Cox, Ingersoll, & Ross, 1985; Diebold & Li, 2006; Estrella & Hardouvelis, 1991; Estrella & Mishkin, 1997, 1998; Svensson, 1994; Vasicek, 1977) and another that explores the existing patterns and relationships in the data without making explicit reference to financial theories (Araújo, Oliveira, & Meira, 2015; Cervelló-Royo, Guijarro, & Michniuk, 2015; Chang, Liu, Lin, Fan, & Ng, 2009; Guresen, Kayakutlu, & Daim, 2011; Kamo & Dagli, 2009; Svalina, Galzina, Lujić, & Šimunović, 2013),

One of the most significant problems in finance that relies on expert systems involves forecasting the future movements of interest rates (Enke & Thawornwong, 2005; Hong & Han, 2002; Ju, Kim, & Shim, 1997; Oh & Han, 2000). Part of the challenge has to do with the nonlinear and dynamic nature of interest rates, as well as their relationship to economic cycles and other economic variables. The latter relates to the fact that interest rates are part of the monetary policy of governments in order to control inflation and price stability.

Typically, authorities make use of the Monetary policy rate (MPR), which serves as an anchor and level for all other interest rates in the local market, as well as issuing risk-free debt at different maturities and denominations (Bank of England, 2015). The implicit

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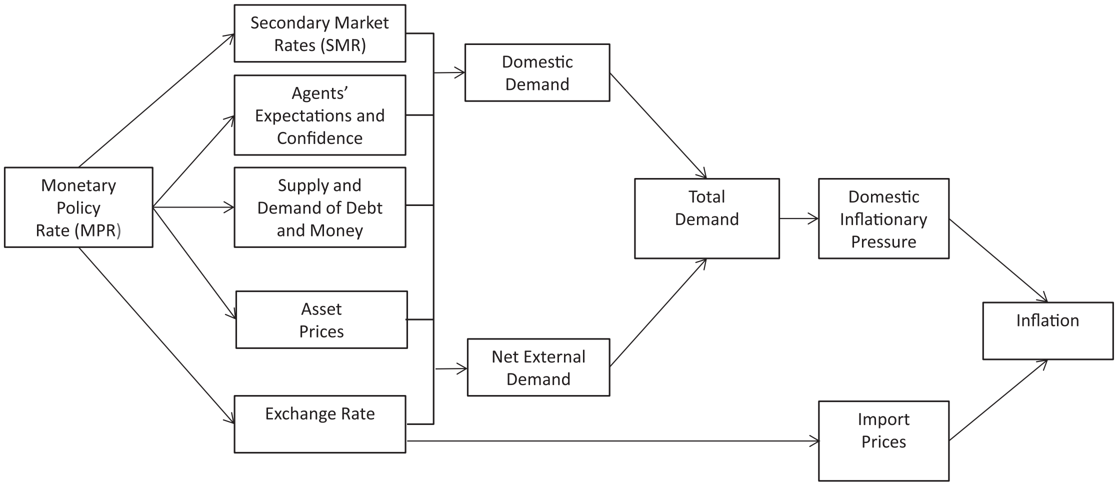

Fig. 1. The transmission mechanism of monetary policy [adapted from Bank of England (2015)].

zero-coupon rates on these emissions form the risk-free term structure that is usually represented as a graph known as the *Yield Curve* (Alexander, Sharpe, & Bailey, 2003), which corresponds to one of the most important economic indicators in existence. Its importance lies in the number of factors that are summarized on its shape, such as risk premium levels, investment expectations, real sector activity, and the balance between supply and demand for debt of different maturities in the future (Estrella, 2005; Estrella & Hardouvelis, 1991; Estrella & Trubin, 2006).

In order to determine the right levels of MPR and other risk-free debt rates, the monetary authorities adopt a continuous monitoring and review process of market conditions, during which they characterize the economic cycles through the analysis of several factors and the mechanisms by which monetary decisions impact inflation and economic activity (see Fig. 1). In a similar way, secondary market participants monitor economic cycles and the interactions between variables, and take trading decisions based on the expected evolution of such factors (Resnick & Shoesmith, 2002).

Understanding the dynamics of interest rates, and the relationship between the shape of the yield curve and the future economic cycle evolution is a problem that holds great interest for academia and market participants. In the literature, two main streams of research can be identified: theoretical and empirical. The theoretical stream attempts to explain the characteristics (such as the slope, level and curvature) of the yield curve on the basis of various financial theories (Alexander et al., 2003; Brown & Dybvig, 1986; Cox, Ingersoll Jr, & Ross, 1981; Heath, Jarrow, & Morton, 1992; Hicks, 1939; Ho & Lee, 1986; Nelson & Siegel, 1987; Svensson, 1994; Vasicek, 1977).

The empirical stream deploys the use of different econometric methods and knowledge-discovery techniques in order to model the structure and dynamics of the yield curve (Enke & Thawornwong, 2005; Chionis, Gogas, & Pragkidis, 2010; Gogas, Papadimitriou, Matthaiou, & Chrysanthidou, 2015; Jacovides, 2008; Ju et al., 1997; Kim & Noh, 1997; Oh & Han, 2000; Vela, 2013; Zimmermann, Tietz, & Grothmann, 2002). Recently, the use of knowledge-discovery techniques has gained popularity, mainly due to the fact that these are able to handle complex, non-linear relationships between variables, seasonality and the presence of structural breaks (Gogas et al., 2015; Jacovides, 2008; Ju et al., 1997; Kim & Noh, 1997; Oh & Han, 2000; Vela, 2013; Zimmermann et al., 2002). However, these are not exempt from limitations. Most noticeable is the difficulty of interpretation, bearing in mind that the deployed techniques can be considered "black-boxes", in which it is extremely hard to understand the abundant non-linear patterns that are taken into account for each prediction.

Furthermore, the deployment of knowledge-discovery techniques reported in the literature is carried out on an ad hoc basis that considers specific definitions of the problem, specific tools and special characteristics of the data sets. The task of understanding relationships in the context of interest rates and related economic variables would greatly benefit from the use of a methodological approach, as is the norm in other domains. This approach entails the definition of a process that includes the usual steps taken by experts to address similar problems, and allows for comparison between the different techniques in order to be able to gauge their relative merits in relation to common goals and objectives.

This paper addresses the lack of methodological support by proposing a knowledge-discovery methodology that includes a minimal common number of steps to model, analyse, and evaluate non-linear relationships between interest rates and the relevant related economic variables. In addition, the use of decision trees (Quinlan, 1990, 1993) when modelling interest rates is examined and compared with a wide range of statistical and knowledge-discovery techniques commonly mentioned in the literature. The comparison is carried out in terms of model accuracy, fitness and interpretability of its results. The proposed methodology is used to model and forecast risk-free interest rates, taking into consideration the stages of the economic cycles. Through the use of data-mining techniques such as clustering and decision trees, the proposed methodology addresses the limitations of previous work. To the best of our knowledge this is the first attempt to use decision trees as the tool to investigate and present in human, understandable form the non-linear patterns found in the relationships between interest rates and related economic variables.

The proposed methodology covers the complete lifecycle of a typical knowledge-discovery process, including the deployment of the resulting models in a simulated setting. Its use is demonstrated and evaluated through the characterization and analysis of the economic cycles and interest rate forecasting in relation to a specific secondary market bond. In addition to the novel application of these techniques in this context, the results show their appropriateness and benefits compared to existing econometric models, in relation to both the selection and ranking of variables at each stage of the cycle and to the prediction of movement of the interest rate.

The structure of the paper is as follows. Section 2 summarizes the relevant literature in terms of the different streams of research, highlighting the gaps and limitations addressed in this paper. Section 3 presents an overview of the proposed methodology in relation to its phases and the objectives pursued in each phase. Section 4 delivers a further description of the modelling and evaluation phases, giving details of the models and their results and how these are