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Market turning points forecasting using wavelet analysis

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HIGHLIGHTS

- A model is proposed to forecast major turning points of stock markets.
- Our model employs the system adaptation framework and wavelet analysis.
- This model is successfully applied to the US, UK and China stock markets.
- This model could be extended to other economic time series or financial markets.

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ABSTRACT

Based on the system adaptation framework we previously proposed, a frequency domain based model is developed in this paper to forecast the major turning points of stock markets. This system adaptation framework has its internal model and adaptive filter to capture the slow and fast dynamics of the market, respectively. The residue of the internal model is found to contain rich information about the market cycles. In order to extract and restore its informative frequency components, we use wavelet multi-resolution analysis with time-varying parameters to decompose this internal residue. An empirical index is then proposed based on the recovered signals to forecast the market turning points. This index is successfully applied to US, UK and China markets, where all major turning points are well forecasted.

1. Introduction

Market cycles are the patterns that the price level of market repeats its upward and downward movements over some specific time scales. In financial markets, financial time series always show cycle patterns at all-time scales [1,2], varying from long term cycles to high frequency fluctuations. However, cycle does not imply any regularity in timing or durations. According to duration, market cycles can be classified into three categories: primary cycles, intermediate cycles and short-term cycles [3]. The average length of primary cycles is three to seven years, which are driven by both economic environment and the sentiment of investors [4–6]. Intermediate cycles typically last three to eighteen months, while short-term cycles last six to twelve weeks, which are usually driven by unpredicted news or random events. This kind of short-term fluctuation is inevitable in every financial market. This study mainly focuses on the identification of primary cycles and the forecasting of their turning points.

In terms of the market cycle structure, cycles generally include three phases: uptrend, downtrend, and sideways [7]. Successfully identifying the transition period between two phases is extremely critical in the investment. There are mainly

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two groups of market forecasting methods: fundamental analysis and technical analysis. Fundamental analysis aims to determine the intrinsic value of securities by studying all factors related to the company, e.g. the balance sheet, financial statement and operating environment [8]. When applied to the market index analysis, related macroeconomic variables are studied to understand the main market situations [9,10]. Technical analysis is to study the market data, such as price and volume, to forecast the future price movements [11]. It is believed the past data patterns will repeat themselves, and their statistical characteristics would imply the future activity.

The large quantities of noises is a big challenge to the technical analysts when they study the primary cycles. There are intermediate and short-term cycles, and high-frequency volatilities within the primary cycle ranges. All of these cause interference to the primary cycle recognition and forecasting. The moving average (MA) method is commonly used to filter such noises and highlight the long-term trends. Based on the MA, a moving average convergence/divergence (MACD) indicator is developed to forecast the market turning points. These methods are widely used in the financial industry. However, the MA introduces lags to the data analysis. Instead of identifying the cycle patterns, another technical analysis method, the momentum index, tries to find turning signals from the change rate of price [3,12]. It calculates the price differences between the current market price and the price of some days ago. Once the momentum crosses zero it generates a trading signal. The momentum method is mostly used for the short-term trend analysis. Benefiting from the momentum concept, a group of indicators, e.g. stochastic oscillators and relative strength indices, are developed for the forecasting of price movements [13].

In engineering, there are many advanced methodologies for signal processing and pattern recognition. Known as a "mathematical microscope", the wavelet method is a powerful time–frequency analysis tool in this field. By using wavelet multiresolution analysis (MRA), a signal can be split into multiple time scales, including large-scale approximation and finer-scale details. It allows us to focus on specific time scales where cycle patterns are critically concerned, and it does not introduce any lags. The development of this method has attracted extensive attentions from economic researchers [14,15]. By using wavelet to investigate the high-frequency data of the Nikkei stock index, Capobianco [16] revealed the hidden periodic components. Yamada and Honda [17] applied the MRA of the discrete wavelet transform (DWT) to Japanese stock prices to retrieve the middle-frequency signals, which were found to contain predictive information of Japanese business turning points.

The maximal overlap discrete wavelet transform (MODWT) is a non-decimated form of the DWT, which applies high and low pass filters to decompose a signal [18]. One of its main advantages is the translation invariance, meaning that a shift in the signal does not change the wavelet and scaling coefficients. Therefore, it is not sensitive to the starting point of a signal. Xue et al. [19] applied the MODWT to extract the multi-frequency components from the intraday equity prices, in which the jump dynamics of equity prices were found to be sensitive to the data sampling frequency. Their results revealed that the high frequency bands contain more jump points than that in the low frequency bands. Based on a MRA of the MODWT, Gençay et al. [20] proposed a method to extract the intraday seasonality which was simple to calculate and free of model selection parameters. Similarly, the MODWT is employed in analyzing the business cycle and growth cycle, see Refs. [21,22]. The multi-scaling extraction of wavelet has also been applied to the volatility analysis, risk hedging and portfolio allocation [23–25]. In recent years, although wavelet methods have been widely used in financial time series analysis, the literature in forecasting market turning points still lacks.

In this paper, we propose a model to forecast the market turning points using wavelet analysis. The model is based on our previous system adaptation framework [26,27], in which the financial market is considered to be a complex dynamic system, see Fig. 1. One of the advantages of this system adaptation framework is its structure, within which not only quantitative relationships between the market and external influences can be modeled, but also the market dynamics and behaviors are well captured. Our study found that the residue of the internal model contains predictive signals on the market cycles [27]. This paper first applied the internal model to the stock prices to generate a signal-rich residue series. The wavelet MRA with time-varying parameters is then applied to decompose the internal residue and retrieve concerned signals, based on which an empirical index for forecasting market turning points is proposed.

The following of this paper is organized as below. Section 2 briefly reviews our system adaptation framework and the internal model used in this paper. Section 3 gives our turning points forecasting methods with an introduction of wavelet analysis. Section 4 presents the empirical results from US, UK, and China stock markets. Section 5 concludes the paper.

Throughout this paper, the notation $\mathbb{R}$ and $\mathbb{Z}$ denote the set of real numbers and integers, respectively. $\mathcal{L}^2(\mathbb{R})$ denotes the vector space of measurable, square-integrable one-dimensional function $f(x)$.

2. Modeling the market: a system adaptation framework

Modeling financial markets in our system adaptation framework is considered as a system identification problem. The real financial market is treated as an unknown plant S whose dynamic behavior is mathematically described by the identification model $\hat{S}$, see Fig. 1. The market in our models is considered to have slow and fast dynamics, which are respectively captured by the internal model I and adaptive filter A. The input r is consisted of external influences and the output $\hat{p}$ is the estimated security price. The actual security price p is the output of the real financial market S.

In this paper, we focus on the internal model, and for the readers who are interested in the detail of our system adaptation models or the design of adaptive filter, please refer to our previous publications [26,27]. To capture the slow dynamic properties, the internal model works as a price trend generator, which makes the estimated prices have the same trends as