Journal of Economic Dynamics & Control 80 (2017) 34–53

Contents lists available at ScienceDirect

Journal of Economic Dynamics & Control

journal homepage: www.elsevier.com/locate/jedc

On the bimodality of the distribution of the S&P 500's distortion: Empirical evidence and theoretical explanations☆

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ARTICLE INFO

Article history:
Received 2 August 2016
Revised 30 January 2017
Accepted 2 May 2017
Available online 9 May 2017

JEL classification:
G12
G14
G17

Keywords:
Stock market dynamics
Bubbles and crashes
Chartists and fundamentalists
Nonlinear dynamics
Bimodality tests
Time series analysis

ABSTRACT

After showing that the distribution of the S&P 500's distortion, i.e. the log difference between its real stock market index and its real fundamental value, is bimodal, we demonstrate that agent-based financial market models may explain this puzzling observation. Within these models, speculators apply technical and fundamental analysis to predict asset prices. Since destabilizing technical trading dominates the market near the fundamental value, asset prices tend to be either overvalued or undervalued. Interestingly, the bimodality of the distribution of the S&P 500's distortion confirms an implicit prediction of a number of seminal agent-based financial market models.

1. Introduction

The goal of our paper is twofold. We first present empirical evidence indicating that the distribution of the S&P 500's distortion, i.e. the log difference between its real stock market index and its real fundamental value, is bimodal. While the S&P 500 fluctuates in an intricate manner around its fundamental value, we show that it spends relatively more time in bull and bear markets than in the vicinity of its fundamental value.[1] The distribution of the S&P 500's distortion is thus – contrary to what one would expect – not unimodal but possesses a bimodal shape. We then demonstrate that this puzzling observation may be explained by agent-based financial market models. Since speculators rely within these models on technical and fundamental analysis to predict asset prices, their dynamics depends on two competing forces. As we will see, it is the repeated comeback of destabilizing technical forces near fundamental values that tends to keep markets distorted. We would like to stress that the bimodality of the distribution of the S&P 500's distortion, as documented in our

☆ We thank Mikhail Anufriev, Te Bao, Reiner Franke, Florian Herold, Hajo Holzmann, Cars Hommes, Blake LeBaron, Christian Menden, Valentyn Panchenko, Christian Proaño and Jan Tuinstra for their encouraging, constructive and valuable feedback. Our paper also benefitted from helpful comments made by two anonymous referees and the handling editor, Tony He.

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[1] We follow Day and Huang (1990) and classify a market as a bull (bear) market when prices are above (below) fundamental values.

http://dx.doi.org/10.1016/j.jedc.2017.05.002
0165-1889/

paper, confirms an implicit prediction of a number of seminal agent-based financial market models that, until now, has been largely neglected.

The empirical part of our paper rests on Shiller's (2015) proposal on how to compute the S&P 500's fundamental value. His unique historical dataset from January 1871 to December 2015 gives us access to 1740 monthly observations of the real S&P 500 and its real dividend payments. In his Nobel Prize Lecture, Shiller (2015) determines the real fundamental value of the S&P 500 by discounting its real dividend payments, assuming a constant real discount rate and a constant real growth rate of the last observed real dividend. We define the S&P 500's distortion as the log difference between the real S&P 500 and its real fundamental value. Visual impression as well as Silverman's (1981) statistical mode test indicate that the distribution of the S&P 500's distortion is bimodal, i.e. the S&P 500 spends relatively more time in bull and bear markets than in the neighborhood of its fundamental value. In our view, this is very surprising since the distribution of the S&P 500's distortion possesses a local minimum at the very place where one would expect to find a global peak.

As is well known, standard linear time series models do not give rise to such a bimodal distribution. However, in order to rule out the S&P 500's bimodal distributed distortion being due to finite sample effects, assuming that the true distribution is unimodal, we conduct a simple simulation study in which we hypothetically assume that standard linear time series models represent the true data-generating process of the S&P 500's distortion. We can thus compare the magnitude of the dip in the bimodal distribution of the S&P 500's distortion to those one may encounter in simulated distributions derived from such models. Searching within a large class of standard linear time series models, common model selection criteria favor an ARMA (2,2) model as the true data generating process. Although simulated time series resemble the path of the S&P 500's distortion, at least at first sight, our simulation study reveals that the dip we observe empirically is very unlikely to occur in an environment in which the true data-generating process is given by standard linear time series models such as an ARMA (2,2) model. From this perspective, we can furthermore conclude that linear economic dynamic models are unable to explain the bimodality of the distribution of the S&P 500's distortion. Or, in other words, our simulation study suggests that the bimodality of the S&P 500's distribution may be due to nonlinear forces.

Over the last couple of years, agent-based financial market models have improved our understanding of the functioning of financial markets. For surveys of this line of research see, for instance, LeBaron (2006), Chiarella et al. (2009), Hommes and Wagener (2009) and Lux (2009). Within these models, speculators rely on a nonlinear mix of technical and fundamental analysis to determine their trading behavior. While technical analysis (Murphy, 1999) seeks to derive trading signals out of past asset price movements, fundamental analysis (Graham and Dodd, 1951) predicts that asset prices revert towards their fundamental values.[2] Agent-based financial market models demonstrate that endogenous interactions between destabilizing technical trading rules and stabilizing fundamental trading rules may give rise to realistic asset price dynamics. Early contributions in this direction include Zeeman (1974), Day and Huang (1990), Kirman (1991), Chiarella (1992), de Grauwe et al. (1993), Lux (1995), Brock and Hommes (1998), LeBaron et al. (1999) and Farmer and Joshi (2002) while more recent approaches include Chiarella et al. (2007), Huang et al. (2010), LeBaron (2012), Anufriev and Hommes (2012), Anufriev and Tuinstra (2013), Schmitt and Westerhoff (2014), He and Li (2015) and He and Zheng (2016).

A number of agent-based financial market models may be used to explain the bimodality of the distribution of the S&P 500's distortion. However, the model by Gaunersdorfer and Hommes (2007) seems to us to be the ideal model for understanding the key mechanism that causes this property. Gaunersdorfer and Hommes (2007) propose a standard discounted value asset pricing model in which speculators can invest in a risk-free asset, paying a fixed rate of return, or in a risky asset, paying an uncertain dividend. Moreover, speculators switch between technical and fundamental analysis rules to predict future asset prices with respect to the rules' past profitability and the market's deviation from its fundamental value. To be precise, speculators prefer rules which have produced higher profits in the recent past and yet, in fear of a bursting bubble, they increasingly opt for fundamental analysis as the market's misalignment increases. Gaunersdorfer and Hommes (2007) show that their calibrated model matches important statistical properties of the S&P 500 quite well, including bubbles and crashes, excess volatility, fat-tailed return distributions, uncorrelated returns and volatility clustering.

The deterministic skeleton of the calibrated model by Gaunersdorfer and Hommes (2007) gives rise to a locally stable limit cycle, surrounding a coexisting locally stable fundamental steady state. As it turns out, the bimodality of the distribution of the S&P 500's distortion may be explained by the limit cycle's properties. Close to the fundamental steady state, the dynamics of the model is driven by the trend-extrapolating behavior of chartists. Their trading behavior rapidly pushes the asset price away from its fundamental value. As the market's misalignment increases, fundamental analysis becomes more popular. However, the mean reversion pressure exercised by fundamentalists is rather weak and thus it takes a while for the price to approach its fundamental value. During this adjustment process, both technical and fundamental rules are profitable. However, since the market's misalignment shrinks, more and more speculators return to technical analysis. As a result, the momentum of the adjustment dynamics accelerates and the price overshoots its fundamental value, tracing out a new bubble path. To sum up: fundamental analysis manages to drive asset prices towards fundamental values, but the consequent revival of destabilizing technical rules tends to keep the market distorted. Together, these forces render the distribution of the distortion bimodal. We show that the same mechanism is at work in the calibrated (stochastic) model by

[2] Laboratory experiments surveyed in Hommes (2011) and questionnaire studies summarized in Menkhoff and Taylor (2007) unanimously confirm that financial market participants rely on technical and fundamental analysis.