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Asset allocation with time series momentum and reversal

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To capture the well documented time series momentum and reversal in asset price, we develop a continuous-time asset price model, derive the optimal investment strategy theoretically, and test the strategy empirically. We show that, by combining market fundamentals and timing opportunity with respect to market trend and volatility, the optimal strategy based on time series momentum of moving averages over short-time horizons and reversal significantly outperforms, both in-sample and out-of-sample, the S&P 500 and pure strategies based on either time series momentum or reversal only. The results are robust for different time horizons, short-sale constraints, market states, investor sentiment, and market volatility.

1. Introduction

Short-run momentum and long-run reversal are two of the most prominent financial market anomalies. Though market timing opportunities under return reversal are well documented (Campbell and Viceira, 1999), time series momentum (TSM) that characterizes strong positive predictability of a security's own past returns has been explored recently in Moskowitz et al. (2012). With the mountainous empirical evidence, a fundamental and theoretical question is how to optimally explore time series momentum and reversal simultaneously in financial markets. This paper aims to answer this question theoretically and test the result empirically. We first introduce an asset price model to incorporate momentum and reversal components. By solving a dynamic asset allocation problem, we derive the optimal investment strategy that combines momentum and mean reversion, which includes pure momentum and pure mean-reverting strategies as special cases. By estimating the model to the S&P 500 index, we demonstrate that the optimal strategy outperforms, measured by the utility of the optimal portfolio wealth and Sharpe ratio, not only the strategies based on the pure momentum and pure mean-reversion models but also the S&P 500 index.

Theoretically, to the best of our knowledge, this paper is the first paper to examine the effect of the moving-average time horizon of TSM on the performance of the optimal portfolio. In the empirical literature, TSM is measured by various moving averages over different time horizons with fixed look-back periods. The time horizons play a very important role in the performance of momentum strategies. This has been investigated extensively in the empirical literature (De Bondt and Thaler,

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1985; Jegadeesh and Titman, 1993). In particular, for a large set of futures and forward contracts, Moskowitz et al. (2012) find that TSM based on the moving average of the past 12 months persists for between one and 12 months and then partially reverses over longer time horizons. However, a theoretical understanding of the effect of various time horizons on the performance of momentum strategies is still missing. The asset price model developed in this paper takes the time horizon of TSM into account explicitly and examines the effect of time horizon on the performance. As a result, the historical prices underlying the TSM component affect asset prices. This leads to a non-Markov process characterized by stochastic delay differential equations (SDDEs), which is very different from the Markov asset price process documented in the literature. The SDDEs, recently introduced into financial market modelling, can explicitly characterize important role of the time horizon effect in price behaviour and financial market stability (He and Li, 2012; 2015).

For Markov processes, the stochastic control problem is most frequently solved using the dynamic programming method (Merton, 1971). However, solving the optimal control problem for SDDEs becomes very challenging since it involves infinite-dimensional partial differential equations. One way to solve the problem is to apply a type of Pontryagin maximum principle, which has been developed recently by Chen and Wu (2010) and Øksendal et al. (2011) for the optimal control problem of SDDEs. By exploring these latest advances in the maximum principle, we theoretically derive the optimal strategy for CRRA utility function. In particular, for log-utility, we derive the optimal strategy in closed form, which enables us to examine thoroughly the effect of moving averages over different time horizons.

Empirically, we estimate the model to the S&P 500 index and examine the performance, measured by the utility of portfolio wealth and Sharpe ratio, of the optimal strategy derived. We demonstrate that the performance of TSM strategy can be significantly improved by combining with market fundamentals, while the performance of mean-reverting strategy can be significantly improved by combining with TSM. In contrast to the TSM strategy based on momentum trend only, the optimal strategy takes into account not only the trading signal based on momentum and fundamentals but also the size of position associated with market volatility. Momentum trading in the empirical literature only considers the trading signals of price trend and takes a constant position to trade. Without considering the fundamentals, such pure momentum portfolio is highly leveraged, and hence suffers from high risk, under-performing the optimal strategy. Also, by ignoring the TSM effect, the pure mean-reverting strategy based conservatively on fundamental investments leads to a stable growth in the portfolio wealth, but is not able to explore the price trend, especially during extreme market periods, and hence under-performs the optimal portfolio. We further demonstrate the robustness of the performance of the optimal strategy with respect to different sample periods, out-of-sample predictions, short-sale constraints, market states, investor sentiment, and market volatility. More importantly, based on the estimated model, we examine the effect of different time horizon of the TSM on the performance of the optimal portfolio. Consistent with Moskowitz et al. (2012), we show that the optimal strategy based on the estimated model performs the best when the moving averages of TSM component is based on the past 9 to 12 months. We show that in general the moving averages over short-run, six months to two years, better explain market returns, leading to better performance of the optimal strategy.

This paper is closely related to the literature on reversal and momentum. Reversal is an empirical observation that assets performing well (poorly) over a long period tend subsequently to underperform (outperform). Momentum is the tendency of assets with good (bad) recent performance to continue outperforming (underperforming) in the short term. Reversal and momentum have been documented extensively for a wide variety of assets. On the one hand, Fama and French (1988) and Poterba and Summers (1988), among many others, document reversal for horizons of more than one year, which induces negative autocorrelation in returns. Also mean reversion in equity returns has been shown to induce significant market timing opportunities (Campbell and Viceira, 1999). On the other hand, the literature mostly studies cross-sectional momentum following the influential study of Jegadeesh and Titman (1993). The predicting power of moving averages on the short-run momentum and long-run reversal has been well documented empirically in cross sectional and time series momentum literature. In particular, the moving averages based on the past returns over short-time horizons (say, 3–12 months) predict short-term (3–12 months) returns positively, while the moving averages over long-time horizons (say, 3–5 years) predict long-term (3–5 years) returns negatively (e.g., De Bondt and Thaler, 1985; Jegadeesh and Titman, 1993, and Moskowitz et al., 2012). More recently, for a large set of futures and forward contracts, Moskowitz et al. (2012) find that TSM based on the moving average of a security's own returns over the past 12 months persists for between one and 12 months and then partially reverses over longer time horizons. Through return decomposition, they show that short-term positive auto-covariance is the main driving force for TSM and cross-sectional momentum effects, while the contribution of serial cross-correlations and variation in mean returns is small. This demonstrates that the time horizons of the moving averages and holding periods play important roles in the performance of strategies involving momentum trading. Some behavioral models have been developed to explain the momentum, however, *"the comparison is in some sense unfair since no time horizon is specified in most behavioral models"* (Griffin et al., 2003).[1] Therefore examining the effect of time horizon on the performance of the optimal strategy is important. Asness et al. (2013) highlight that studying value and momentum jointly is more powerful than examining each in isolation.[2] This paper is largely motivated by the empirical literature testing trading signals with

[1] Recently, Chiarella et al. (2006), He and Li (2012; 2015) and Li and Liu (2016) have developed models to explore the role of the time horizon in momentum trading.

[2] They find that separate factors for value and momentum best explain the data for eight different markets and asset classes. Furthermore, they show that momentum loads positively and value loads negatively on liquidity risk; however, an equal-weighted combination of value and momentum is immune to liquidity risk and generates substantial abnormal returns. In the theoretical heterogeneous agent literature, by studying the joint impact of funda-