Exchange-traded Funds and Financial Stability

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Abstract

Exchange-traded Funds (ETFs) are easy to understand, cost-efficient ways of investing in asset markets that have become very popular for both retail and institutional investors. Investing in an index of assets via an ETF can generate quite complex and sometimes counterintuitive investment behaviors on the level of individual assets. These dynamics depend among others on the kind of market index, the types of traders in the market, price trends in individual stocks and the overall market as well as situations of over- or undervaluation of individual stocks and the index. Based on a heterogeneous agent model we find that the presence of ETF chartists counterintuitively lowers the likelihood of price bubbles in individual asset markets while at the same time weakening financial stability as measured by asset price volatility and excess kurtosis.

Keywords

Exchange-traded index funds; ETF; index fund; heterogeneous agent model; bubbles; financial stability; volatility

JEL codes

C63, G01, G10, G11

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1 Introduction

From an investor's point of view, Exchange-traded Funds (ETFs) are easy to understand and cost-efficient investment vehicles that have become very popular for both institutional and retail investors (Gastineau, 2010; Oura et al., 2015; Wiandt and McClatchy, 2002). While the typical ETF tracks the performance of an underlying stock index, ETFs are also available for a wide variety of indices of other asset classes such as bonds as well as commodities and for a broad spectrum of alternative investment strategies. Important advantages of ETFs are low costs and high transparency due to the passive investment approach as well as their high liquidity. It therefore comes as no surprise that ETFs have seen an extraordinary growth since their introduction in the 1990s with assets under management of around 3.4 trillion USD by mid-2016 (Kremer, 2016).

While the associated risks of financial institutions and instruments such as hedge funds, money market funds, and other complex, high-profile segments of the asset management industry have been subject to close scrutiny, the ramifications of "plain-vanilla" products such as ETFs are not yet well understood (Oura et al., 2015). Increasingly questions are asked whether and how their fast growth might affect financial stability and financial market governance (The Economist, 2016; Fichtner et al., 2017; Ivanov and Lenkey, 2014; Ockenfels and Schmalz, 2016b).

At first sight, the increased popularity of investing in indices made possible and affordable by ETFs should increase financial stability as economic agents spread their investment according to the underlying indices over a wide spectrum of assets. However, a closer look makes clear that an appropriate analysis of financial stability also has to take into account the strategies of the market participants. Trades by index orientated investors obviously imply that the individual stocks are also sold and bought in a specific way which reflects the relative weights of the individual stocks in the index giving rise to non-trivial rebalancing effects.

Thus, ETF trading can imply very complex, seemingly counterintuitive trading strategies on the level of the individual stocks depending on

- the strategy of ETF investors, e.g., fundamentalist or chartist,
- the price dynamics of the individual stocks, i.e., increasing or decreasing,
- the prices of the individual stocks relative to their fundamental values, i.e., situation of over- or undervaluation,
- the type of underlying index, e.g., assets being weighted by price or market capitalization.

Take, e.g., a bull market in which stock A rises more slowly than the overall market (index). An index chartist pursuing a trend following strategy would invest in such situation, i.e., she would buy all stocks in the index according to their relative weight. If the stocks in the index are price weighted as, e.g., in the Dow Jones Industrial Average, the relative weight of stock A in the index decreases as its price declines relative to the remaining asset prices in the index.

The necessary rebalancing of the index implies that the index investor buys relatively less of stock A and can even become a net seller, a behavior which is obviously opposite to her trading on the level of the overall index. As a consequence of these complex interactions seemingly destabilizing investment strategies such as trend following can have stabilizing effects on the level of the individual stock while a fundamentalist on the index level might induce instabilities on the level of individual stocks. Thus, depending on specific price developments, rebalancing effects can imply that, e.g., trend following index investors behave like fundamentalists for individual stocks.

While ETFs have grown substantially in assets, diversity, and market significance in recent years, there exists only little analysis whether or how these developments may affect the performance of asset markets. Ben-David et al. (2014) find that ETF ownership of stocks leads to higher volatility and turnover. In contrast, Ivanov and Lenkey (2014) find no empirical evidence for an increase in price volatility in the case of leveraged ETFs. In their broadly based analysis of the asset management industry Oura et al. (2015) identify risk-creating mechanisms even for seemingly simple financial products such as ETFs. They conclude that larger funds do not necessarily contribute to systemic risk. Rather it is the investment focus that appears to be relatively more important. Research on index-based investment strategies is also related to work on the role of institutional asset managers for financial asset prices. Cuoco and Kaniel (2011) find that conditional volatilities of an index stock and aggregate stock market decrease in the presence of benchmarking. Basak and Pavlova (2013) analyze the investment behavior of institutional investors that care about their performance relative to a certain index in a dynamic general equilibrium framework. Their empirical results indicate that this incentive increases stock market volatility and stronger correlation among stocks that are included in the index.

To explicitly allow for different investment strategies and their interactions on the level of the index and individual stocks, we follow Challet et al. (2015) and Drescher and Herz (2012) and use a heterogeneous agent model (HAM) framework (Hommes, 2006) to analyze how the increasing use of ETFs and other index-orientated financial products alters the price dynamics of the underlying assets, possibly increasing risks for financial stability. Our simulation results indicate that it is not so much the presence of ETF funds per se but rather the implemented investment strategy that might be a cause of concern. In particular, we find that ETFs might jeopardize financial stability by increasing asset price volatility and excess kurtosis if they are used by trend following chartists. At the same time, the presence of ETF chartists lowers the likelihood of bubbles which can be explained by smoothing effects.

In Section 2 we present some analytical findings on the effects of index based investment strategies and discuss some counterintuitive price effects that can result from strategies of fundamentalists and chartists, in particular trend following feedback traders, based on index funds. Section 3 studies these effects in greater detail in an HAM based on Monte Carlo simulations. Section 4 concludes the paper.

2 Investment Strategies and Price Dynamics of Individual Assets and Indices

In the following, we analytically investigate the relation between the price dynamics of a stock index and its underlying individual stocks. We conduct some simple simulations to illustrate how investment strategies on the level of an index can imply quite different investment behavior on the level of the individual stocks of the index due to the rebalancing caused by changes in the relative price of the underlying stocks. We define as *index* both a publicly known set of assets that are considered to be representative for a market as well as the price of that index which is defined as the sum of the (weighted) prices of the index's assets. To simplify our analysis, we assume that the price of the index is available to all market participants at any time and at no costs.

For the case of an index in which stocks are price weighted, such as the Dow Jones Industrial Average and the Nikkei 225, the implicit net asset position $I_i^\ell(t)$ of an ETF trader ℓ in stock i at time t is given by

$$\begin{aligned} I_i^\ell(t) &= I^\ell(t) \cdot \pi_i(t) \\ &= I^\ell(t) \cdot \frac{p_i(t)}{p(t)} \end{aligned} \tag{1}$$

where $I^\ell(t)$ denotes trader ℓ's net asset position in the ETF with price $p(t) = \sum_{j=1}^N p_j(t)$. With a market price $p_i(t)$, stock i's relative weight in the index is $\pi_i(t)$.

Investments in an ETF imply trades in individual stocks according to two effects, namely the level of the net asset position $I^\ell(t)$ (*level* or *quantity effect*) and the stocks's relative weight $\pi_i(t)$ (*rebalancing*, *price*, or *composition effect*).[1]

To better understand how trading in ETFs implies specific tradings in the index's underlying stocks, we focus on the level and the rebalancing effect of ETF investments for the underlying individual stocks as given in Equation (1). Given the previous net asset position, its current investment in the index, and the index's rebalancing dynamics, we can determine an ETF trader's investment in the individual stocks.

Proposition 1. The investment in stock i of an ETF trader ℓ with a net asset position I^ℓ in period t is given by

$$\Delta I_i^\ell(t) = \Delta I^\ell(t)\pi_i(t) + I^\ell(t-1)\Delta\pi_i(t) \tag{2}$$

Proof. It holds:

$$\begin{aligned}
\Delta I_i^\ell(t) &= I_i^\ell(t) - I_i^\ell(t-1) \\
&= I^\ell(t)\pi_i(t) - I^\ell(t-1)\pi_i(t-1) \\
&= I^\ell(t)\pi_i(t) - I^\ell(t-1)\pi_i(t) + I^\ell(t-1)\pi_i(t) - I^\ell(t-1)\pi_i(t-1) \\
&= \Delta I^\ell(t)\pi_i(t) + I^\ell(t-1)\Delta\pi_i(t)
\end{aligned}$$

□

To better understand how ETF trading affects the implicit trading of the underlying stocks and to motivate the subsequent Monte Carlo simulation analysis in Section 3, we analyze the quantity and price dimensions of the investment in the individual stocks in greater detail. First, the investment in an individual stock i depends on the investment in the index given the relative weight of the stock in the index, i.e., $\Delta I^\ell(t)\pi_i(t)$ (*level effect*). Secondly, the investment in individual stocks also depends on how the trader reallocates his overall investment in the index due to changes in the relative weight of the individual stocks, i.e., $\Delta\pi_i(t)$ (*rebalancing effect*). The level effect, i.e., the first summand of Equation (2), depends on the trader's strategy and his investment $\Delta I_i^\ell(t)$, whereas the rebalancing effect, the second summand, depends on the change of the relative price of the stock, i.e., on market dynamics that cannot directly be influenced by the trader. Thus, an ETF trader actively controls her investment only on the level of the index, and passively tolerates the implications for investments on the level of the individual assets. As the two effects can work in the same or in opposite directions, the

[1] Obviously, a trader's gain is independent of trading in ETF shares or in the underlying stocks according to Equation (1), see Appendix A.1 for a proof.

net effect of index trading on indivdual stocks is a priori indeterminate and depends on the relative size of the level and the rebalancing effects. The interactions of these two effects can have complex and sometimes counterintuitive effects of ETF investments on the underlying stocks, as we illustrate further below.

Obviously, the effects of ETFs on price and investment dynamics of individual stocks depend substantially on the investment strategies of the ETF traders. In the following, we compare investment decisions under specific price dynamics for different investment strategies.[2] In particular, we specify simple trading strategies for chartists, in particular trend followers, and fundamentalists while differentiating between traders who invest in individual stocks or ETF stock indices giving rise to four distinct types of traders, namely chartists in individual stocks (C) and in ETFs (E-C) as well as fundamentalistic investors in individual stocks (F) and ETFs (E-F).

To keep our analysis simple, we assume in this preliminary analysis that traders can only invest or disinvest a constant amount $\overline{\Delta I}$ per period and that price dynamics are given, i.e., traders are price takers and too small to affect market prices. Therefore, we denote chartists with constant investment with C_Δ and fundamentalists with constant investment with F_Δ. In our subsequent simulation analysis (see Section 3), we allow for investments with varying size and allow traders to affect prices in the framework of an HAM (Hommes, 2006).

Chartists in individual stocks (C_Δ) invest the amount $\overline{\Delta I}$ according to

$$\begin{aligned}\Delta I_i^{C_\Delta}(t) &= \begin{cases} +\overline{\Delta I}, & p_i(t) > p_i(t-1) \wedge t > 1, \\ -\overline{\Delta I}, & p_i(t) < p_i(t-1) \wedge t > 1, \\ 0, & p_i(t) = p_i(t-1) \vee t = 0, \end{cases} \\ &= \overline{\Delta I} sgn(p_i(t) - p_i(t-1))\mathbb{I}_{t>0} \qquad \forall i \in \{1, \ldots, N\}\end{aligned}$$

while ETF chartists (E-C_Δ) invest according to

$$\begin{aligned}\Delta I^{E-C_\Delta}(t) &= \begin{cases} +N\overline{\Delta I}, & p(t) > p(t-1) \wedge t > 1, \\ -N\overline{\Delta I}, & p(t) < p(t-1) \wedge t > 1, \\ 0, & p(t) = p(t-1) \vee t = 0, \end{cases} \\ &= N\overline{\Delta I} sgn(p(t) - p(t-1))\mathbb{I}_{t>0}\end{aligned}$$

[2]In the case of the buy-and-hold trader, the most simple type of trader in our analysis, there is no difference between directly investing in the index's stocks and investing in an ETF, see Appendix A.1.

with N being the number of stocks in the index. Note that the investment of an ETF chartist is diversified across the index according to Equation (1).

Analogously, fundamentalistic traders who invest in individual stocks (F_Δ) follow

$$\begin{aligned}\Delta I_i^{F_\Delta}(t) &= \begin{cases} +\overline{\Delta I}, & p_i(t) < f_i(t+1), \\ -\overline{\Delta I}, & p_i(t) > f_i(t+1), \\ 0, & p_i(t) = f_i(t+1), \end{cases} \\ &= \overline{\Delta I} sgn(f_i(t+1) - p_i(t)) \qquad \forall i \in \{1, \dots, N\},\end{aligned}$$

while fundamentalistic ETF traders ($\mathrm{E}\text{-}\mathrm{F}_\Delta$) invest according to

$$\begin{aligned}\Delta I^{E-F_\Delta}(t) &= \begin{cases} +N\overline{\Delta I}, & p(t) < f(t+1), \\ -N\overline{\Delta I}, & p(t) > f(t+1), \\ 0, & p(t) = f(t+1), \end{cases} \\ &= N\overline{\Delta I} sgn(f(t+1) - p(t))\end{aligned}$$

for given expected fundamental values f_i for all stocks i and respective fundamental value of the index $f = \sum_{i=1}^{N} f_i$. The market environment is non-stochastic, i.e., there is no noise in the fundamentals.

In the subsequent scenario analysis, we assume an index with $N = 30$ stocks with starting price $p_{1-30}(0) = 1$ on time grid $\mathcal{T} = \{0, 1, \dots, T = 250\}$. The price of stock 1 follows $p_1(t+1) = p_1(t)e^{\frac{\mu_1}{250}}$ and the index develops according to $p(t+1) = p(t)e^{\frac{\mu}{250}}$ where $\mu_1 > -1$ and $\mu > -1$ are fixed. The trends μ_1 and μ are chosen so that $p_i(t) > 0$ is fulfilled for all $t \in \mathcal{T}$ and all $i \in \{1, \dots, N\}$. Additionally, we set $0 < f_i \equiv \overline{f_1}$ as constant for all i and so $\overline{f} \equiv N\overline{f_1}$ is constant as well. (Dis)Investment per period is $\pm\overline{\Delta I} = \pm 1$. The parameters under investigation are μ_1, μ, and $\overline{f}$.

Given this simple framework, we identify different scenarios in which ETF investments have interesting, seemingly counterintuitive effects on the level of individual stocks due to the complex interactions of level and rebalancing effects.[3]

Scenario: modestly rising stock in a bull market We assume that the price of stock 1 rises with trend $\mu_1 = 0.1$, while the price of the index grows with trend $\mu = 2$, i.e., π_1, the relative price of stock 1, falls. All stocks are assumed to be overvalued relative to

[3]See Appendix A.3 for two additional scenarios in which ETF trading has counterintuitive effects on individual stocks.

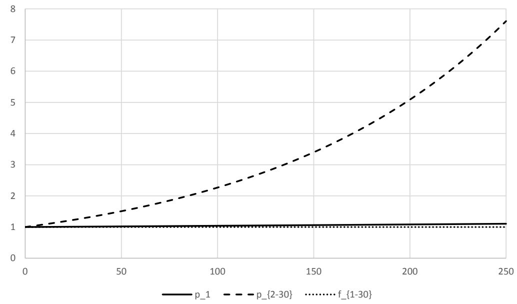


Figure 1: Price paths p_1 of stock 1 and p_{2-30} of stocks 2-30.

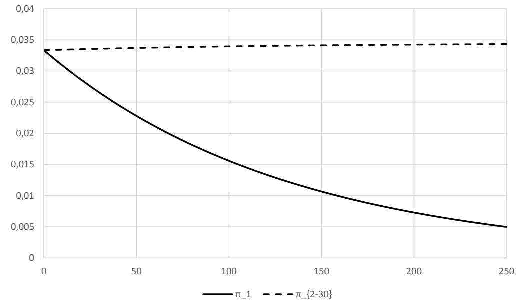


Figure 2: Change of the ratio π_1 and π_{2-30} of stock 1 and stocks 2-30, respectively.

their fundamental values f_i that are set to unity, i.e., $p_i > f_i = 1$ and $p > f = 30$ holds ($t > 0$). Figures 1 and 2 display these price dynamics that underlie the four investment strategies.

Given the price dynamics, how do the different traders allocate their funds? As the prices of all stocks rise, chartists that either invest in individual stocks (C_Δ) or the index (E-C_Δ) buy their respective target asset. As the stocks and the index are overvalued, single stock (F_Δ) and index (E-F_Δ) orientated fundamentalists sell their respective target assets.

Stock 1 as well as the other stocks have increases in price and are above their respective fundamental values (see Figure 1). However, stock 1 differs from the other stocks as its relative price π_1 declines (see Figure 2). Chartists (C_Δ) invest in stock 1 as the absolute price of stock 1 rises, while fundamentalists (F_Δ) disinvest as the stock is overvalued (see Figure 3). These single stock strategies serve as benchmarks to demonstrate how "conventional" fundamentalists and chartists trade given constant investment per period $|\Delta I^{C_\Delta}| \equiv |\Delta I^{F_\Delta}| \equiv \overline{\Delta I}$ being constant.

The strategies of ETF investors can have rather complex effects on the level of individual stocks. Given the assumption that the index is overvalued and its price rises (see Figure 4), ETF chartists invest, while ETF fundamentalists disinvest on average. This implies interesting trade dynamics on the level of stock 1 in the case of the two types of index investors. ETF chartists (E-C_Δ) implicitly invest less and less as the relative price of stock 1, π_1, and thus its relative weight in the index declines (see Figure 2), i.e., the level effect of E-C_Δ investment decreases as less money $\overline{\Delta I}^{E-C_\Delta}\pi_i(t)$ is allocated to stock 1 (see Equation (2)). At the same time the rebalancing effect, the second part of Equation (2), calls for selling stock 1 to account for its reduced weight in net asset

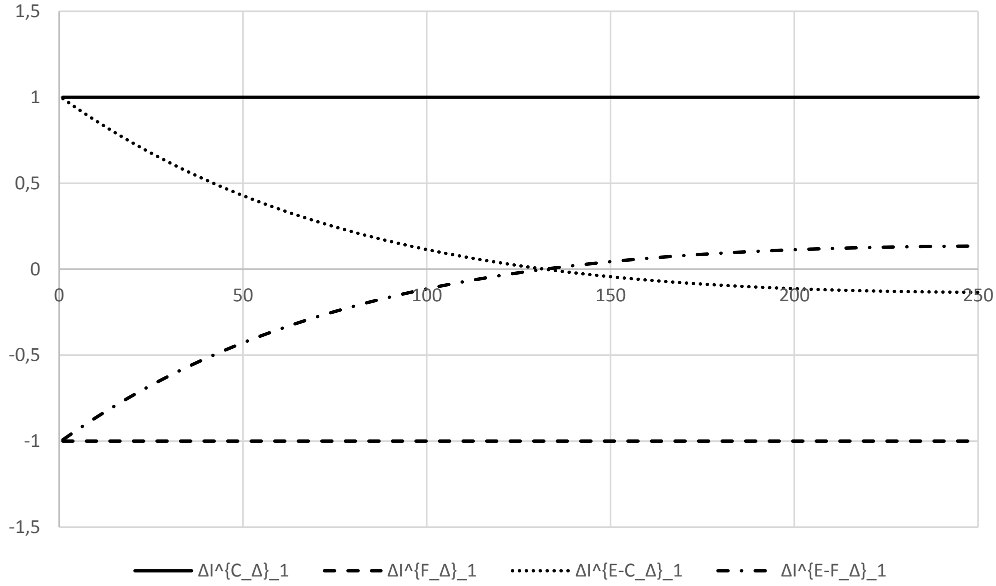


Figure 3: Investment ΔI_1^{ℓ} in stock 1 if the stock price rises more slowly than index price.

position $I^{E-C_{\Delta}}$. Eventually, the rebalancing effect dominates the level effect and the ETF chartists disinvest from stock 1 (see Figure 3). In contrast, ETF fundamentalists (E-F$_{\Delta}$) start off selling the overvalued index and thus disinvest from stock 1 at first. Over time they disinvest less and less of this stock (see Figure 3) as its relative price and thus its relative weight in the index decreases. While they sell ETF shares due to the overvaluation of the index (level effect), they implicitly buy stock 1 to assure the appropriate portfolio allocation (rebalancing effect). As the relative price of stock 1 continues to fall, the positive rebalancing effect eventually dominates the level effect and ETF fundamentalists become de facto net investors in an overvalued stock.

Taken together and somewhat counterintuitively, ETF chartists end up disinvest from a rising stock, while ETF fundamentalists invest in an overvalued stock. From the perspective of financial stability, ETF chartists tend to stabilize, while ETF fundamentalists tend to destabilize this specific stock price development. Ultimately, the complex trade dynamics are driven by the different investment strategies of the two types of traders and the complex interactions between the market price dynamics of individual stocks and the index, the relative market to fundamental price of individual stocks and index, as well as the initial positive of negative net asset position of the investors. Appendix A.2 analyzes in greater detail how these interrelations work to (de)stabilize stock prices. Obviously, these counterintuitive effects only hold for the "outlier" stock 1, while for

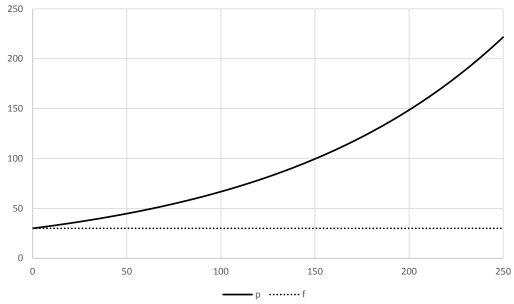


Figure 4: Price path p of the index.

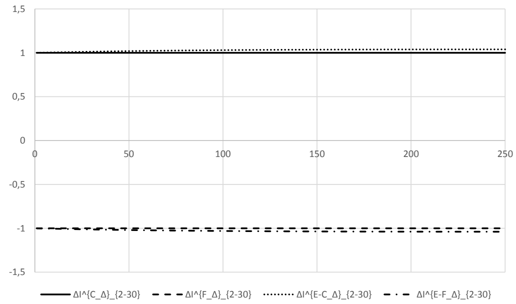


Figure 5: Investment ΔI^{ℓ}_{2-30} in stocks 2-30.

stocks 2-30 the effects of chartists and fundamentalists are as conventionally expected (see Figure 5).[4]

3 Exchange-traded Funds and Market Dynamics in a Heterogeneous Agent Model

Based on the insights developed in Section 2 on the role of ETF traders for financial (in)stability, we analyze in a dynamic HAM how the interactions of different types of (ETF) traders affect asset price dynamics and financial market (in)stability.

3.1 Price Model and Trader Types

We base our analysis on a market maker HAM of the type analyzed by Challet et al. (2015); Baumann et al. (2017b); Drescher and Herz (2012). In this framework, agents decide on selling and buying assets with the market maker clearing the market and adjusting prices according to the timeline depicted in Figure 6. In every time period $t \in \{0, \dots, T-1\}$, agents ℓ determine their net asset positions $I_i^{\ell}(t)$, respectively their investments $\Delta I_i^{\ell}(t)$, based on the market price of their target asset $p_i(t)$, their past net asset positions $I_i^{\ell}(t-1)$, and their expectations of the fundamental value $\mathbb{E}[f_i(t+1)]$.[5]

The market maker aggregates asset demand und adjusts the asset price according to the pricing rule

$$p_i(t+1) = p_i(t) \exp\left(\sum_{\ell} \Delta I_i^{\ell}(t)/M\right)$$

[4]Appendix A.3 contains two more examples, namely *scenario 2: a rising stock in a bear market* and *scenario 3: falling stock in a bull market with the index crossing its fundamental value from below.* Also in these cases, we can see the counterintuitive behavior of ETF traders.

[5]For HAMs in the context of bubble analysis cf. Baumann et al. (2017a); De Long et al. (1990).

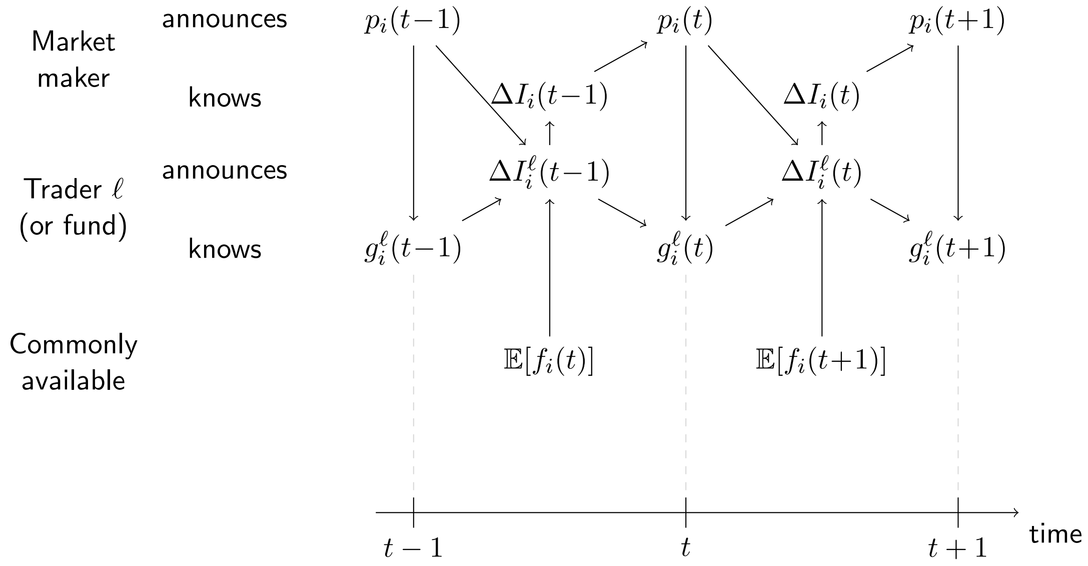


Figure 6: Timeline of actions and distribution of information for stock i.

with $M > 0$ as an overall scaling factor for trading volume and market power. As in the discussion of Section 2, we distinguish between four types of traders depending whether they invest in a single stock or an ETF index and whether they are fundamentalists or chartists. In contrast to the above analysis in which traders could only invest or disinvest a fixed volume of assets, we generalize the investment behavior so that traders can also decide on the volume of their (dis)investment. The single stock traders invest in all assets available on the market separately whereas the ETF traders invest in one index reproducing these assets. At the beginning, the relative weight of single stock and ETF traders is fifty-fifty. This becomes obvious when regarding the specific trading strategies.[6]

Chartists (C) in individual stocks follow a feedback trading rule as introduced by Barmish and Primbs (2011), namely

$$I_i^C(t) = I_0 + K g_i^C(t)$$

with an initial net asset position $I_0 > 0$, feedback parameter $K > 0$, and $g_i^\ell(t) = \sum_{\tau=1}^{t} I_i^\ell(\tau - 1) \cdot \frac{p_i(\tau)-p_i(\tau-1)}{p_i(\tau-1)}$ as the overall gain of trader ℓ from asset i. The overall initial net asset position of such a chartist is therefore $N \cdot I_0$ as he is investing I_0 in all N assets separately. The investment in asset i for $t > 0$ depends on the gain g_i

[6]See, e.g., Timmer (2016) for the mapping of financial institutions and trading stategies.

from the very same asset i, meaning that the single asset trader treats all assets (the investments and gains) separately. Please note that these feedback traders are positive trend followers only as long as they are long sellers. However, their overall investment might also become negative, for example due to a large price decrease.[7]

Fundamentalists (F) in individual stocks follow the investment rule

$$\Delta I_i^F(t) = M \cdot \ln \frac{\mathbb{E}[f_i(t+1)]}{p_i(t)}$$

as also stated by Drescher and Herz (2012). Note that the fundamental value of asset i, f_i, is assumed to be noisy with all traders holding the same expectation $\mathbb{E}[f_i]$. The single asset fundamentalist invests in all N single assets separately.

Analogously, *ETF chartists* (E-C) and *ETF fundamentalists* (E-F) invest according to

$$\Delta I^{E-C}(t) = K \cdot I^{E-C}(t-1) \cdot \frac{p(t) - p(t-1)}{p(t-1)},$$

respectively

$$\Delta I^{E-F}(t) = M \cdot \ln \frac{\mathbb{E}[f(t+1)]}{p(t)},$$

where the fixed initial net asset position of the E-C is $N \cdot I_0$. Investments into ETFs are allocated to the individual stocks according to Equation (1). For simplification issues, we assume that the F and E-F traders are very well informed in the sense that they exactly know $f_i(t+1)$ resp. $f(t+1)$. This simplification does not have substantial influence on the results because in a bubble case the distance between the price and its fundamental value becomes considerably large while the distance between a subjective expectation of the fundamental value and its realization is (in probability) bounded. Thus, this simplification has no influence on indentifying a bubble case as a bubble case resp. a non bubble case as a non bubble case.

[7]Specifically, the chartist's net asset position $I_i^C(t)$ becomes negative if $g_i^C(t) < -\frac{I_0}{K}$ holds for his overall gain from asset i. Rewriting the chartists' investment rule

$$\Delta I_i^C(t) = I_i^C(t) - I_i^C(t-1) = K \cdot I_i^C(t-1) \cdot \frac{p_i(t) - p_i(t-1)}{p_i(t-1)}$$

indicates that in a situation with a price decrease ($p_i(t) < p_i(t-1)$) and a negative net asset position, chartists become short sellers, i.e., they invest despite the negative change in asset price. Taking literally, they could be considered as "anti" trend followers in such situations.

3.2 Simulation Procedures and Parameter Choices

In our Monte Carlo simulation analysis we consider a market with $N = 10$ stocks on a time grid $\mathcal{T} = \{0, 1, \ldots, T\}$ with $T = 250$. Each stock p_i has a fundamental value f_i, $i = 1, \ldots, N$, i.e., we have ten paths of fundamental values in one market scenario. In particular, a market scenario is defined by the specific paths of these ten fundamental values. Each of these fundamental value paths f_i follows a geometric Brownian motion with trend $\mu = 5\%/T$ and volatility $\sigma = 2\%$. The starting points of both fundamental values and stock prices are set to $f_i(0) \equiv p_i(0) \equiv 1$, the scaling parameter is set to $M = 100$. A greater M lessens the influence of traders and keeps the price process closer to a geometric Brownian motion, while moving M closer to zero strenghtens the role of traders and thus makes the price process more independent of the geometric Brownian motion. Furthermore, we set $K = 4$ (Barmish and Primbs, 2011) and $I_0 = 10$ for the chartist. This model set-up is simulated 10,000 times, i.e., for the fundamentals of the ten stocks we generate a total of $10 \cdot 10,000$ different paths of a geometric Brownian motion. The 10,000 scenarios of the set of ten fundamental value paths are the basis for analyzing price dynamics for four different types of trader constellations, leading to actually $4 \cdot 10,000$ market developments. These markets comprise

- chartists and fundamentalists,
- chartists, fundamentalists, and ETF chartists,
- chartists, fundamentalists, and ETF fundamentalists, as well as
- chartists, fundamentalists, ETF chartists, and ETF fundamentalists.

We analyze how the presence of specific types of traders affects the (in)stability of financial markets along three dimensions: the likelihood of bubbles as well as standard deviation (sd) and excess kurtosis (EK) of the asset price series. An asset price bubble is defined to occur if $\exists t : p(t) \geq 10 \cdot f(t)$. Robustness checks find qualitatively similar results for alternative definitions of an asset price bubble. We conducted tests also for $100 \cdot f(t)$ and $1,000 \cdot f(t)$ and got similar results, see Appendix A.4. Note that if the price of an individual asset explodes, then simultaneously also an index bubble occurs, i.e., if $\exists i : p_i \to \infty \Rightarrow p \to \infty$. This correlation, that an exploding asset price leads to an exploding price of the index, is important to understand index price bubbles.

The presence of certain trader types, especially ETF traders, might not only affect the occurrence probability of asset price bubbles but could also influence the volatility of stock prices. We calculate the averaged empirical standard deviation (sd) of the log returns in the non-bubble paths[8] of the single assets, which corresponds to the historical volatility, for the four types of trader constellations. To account for the possibility of fat tails, we also measure excess kurtosis which accounts for the difference between the kurtosis of an arbitrary random variable and the kurtosis of a Gaussian distributed random variable (cf. Peterson et al. (2015)). In our case, the logarithmic returns of the fundamental values are Gaussian distributed. Thus, if the asset prices follow a geometric Brownian motion, their log returns should be mesokurtic with an excess kurtosis of about 0. In constrast, an excess kurtosis of greater zero indicates fat tails, i.e., a leptokurtic distribution of the log returns.

3.3 Empirical Results

We base our empirical analysis on two alternative, albeit related definitions of bubbles in a simulation framework. In a first step, we take the straight forward, natural definition of a bubble, namely that we focus on market prices and consider each specific price path in which a bubble occurs, independently of the underlying trader constellation; in a second step, we focus on the underlying process of the fundamental values and consider as bubble path all paths of fundamental values for which at least in one of the four trader constellations a bubble occurs. This implies that in the case of the second definition, we consider as non-bubble cases only paths of fundamental values in which for none of the four market structures a bubble occured. The bubble cases of the first definition are a subset of those of the latter one.

Based on the definitions of an asset price bubble, the simulation results indicate that independently of the four types of market structure, in the overwhelming number of simulation scenarios no bubble occurred, namely in 9,396 cases out of 10,000. From an aggregated perspective, the likelihood of bubbles is highest (and above 4%) if either only single asset fundamentalists (F) and chartists (C) are active in the market or if they are joined by ETF fundamentalists (E-F) (see Table 1). In contrast, the bubble rate is far below 0.5% whenever ETF chartists (E-C) are present. Somewhat counterintuitively, chartists that invest in the market index seem to stabilize extreme asset price dynamics in the sense that assets become less susceptible to price bubbles (see Table 1).

As alternative measures of financial (in)stability, Table 1 depicts the standard deviation sd_1 and the excess kurtosis EK_1 of the asset prices for the four types of trader constellations in the respective scenarios without an asset price bubble. The averaged standard deviation of the asset prices sd_1 always surpasses the 2% standard deviation of

[8] A non-bubble path may refer to every single price path or the underlying fundamental value paths.

	Trader constellations			
	C + F	C + F + E-C	C + F + E-F	C + F + E-C + E-F
Bubble rate	4.88%	0.29%	4.32%	0.23%
sd_1	2.59%	3.39%	2.59%	3.47%
EK_1	8.68	24.2	8.64	26.4
sd_2	2.58%	3.39%	2.57%	3.47%
EK_2	7.58	24.2	6.39	26.4

Table 1: Monte Carlo simulations: bubble rate and averaged standard deviation (sd_k) and excess kurtosis (EK_k) of non-bubble scenarios.

the fundamental values. Interestingly, price volatility is highest and above 3% whenever ETF chartists trade in the markets—a result which is on the one hand in line with other studies on the destabilizing role of chartists (see, e.g., Drescher and Herz (2012)), yet on the other hand is in contrast to the evidence on the financial instability as measured by the likelihood of bubbles discussed above.

The results for the standard deviation are in line with the average excess kurtosis EK_1. In all configurations, log returns are leptokurtic, i.e., extreme values are more likely than it would be the case under a Gaussian distribution as excess kurtosis is clearly above zero for all types of market structures. Excess kurtorsis is particularly high with values above 24 in market configurations with ETF chartists. This indicates again that the presence of ETF chartists increases price volatility in the sense that extreme price changes are more likely.

To analyze the marginal effects of the different types of traders we apply the second bubble definition and consider each of the 10,000 paths of fundamental values separately. To exclude that the high volatility/excess kurtosis in the market structures including ETF chartists, namely trader constellations C + F + E-C and C + F + E-C + E-F, is due to the considered specific paths of fundamentals values, we also compute standard deviation and excess kurtosis for the non-bubble cases of the second bubble definition, i.e., for fundamental value developments where in no trader constellation a bubble occurred (see sd_2 and EK_2 in Table 1). While for market structures including ETF chartists E-C, there are practically no differences, whereas for the two other constellations without E-C, the excess kurtosis is slightly lower.

To analyze the effects of the different types of traders on the market dynamics in greater detail, we now consider each of the 10,000 paths of fundamental values separately.

This allows us, for example, to check whether the 0.29% bubble cases of the C + F + E-C trader constellation are completely included in the 4.88% bubble cases of the more general C + F structure or if the bubbles occurred for different fundamental value developments. If the 0.29% bubble cases in the C + F + E-C scenario were completely included in the 4.88% cases of the C + F scenario, we would conclude that indeed the ETF chartists are able to prevent bubbles through their presence without causing new bubbles, cf. Table 2.

Thus, for the detailed analysis, we check for each of the 10,000 fundamental value paths whether or not a bubble occurred and if so, under which trader constellation it occurred. The following example should help clarify the selection procedure. We take the first of the 10,000 fundamental value simulations and see that under no trader constellation did a bubble occurred. This situation is filed as no. 0 of our classification scheme (see Table 2). For the second of the 10,000 simulated fundamental values, we might find that a bubble occurred only when chartists, fundamentalists, and ETF fundamentalists were in the market, but not for the other three trader constellations, leading to class no. 4. For the third of the 10,000 simulated fundamental values, a bubble occurred only when chartists and fundamentalists were in the market and for the market structure with chartists, fundamentalists, and ETF fundamentalists (class no. 5). Table 2 depicts all possible $2^4 = 16$ constellations of traders, where 'yes' denotes a bubble occurrence and an empty space denotes no bubble occurrence.

Differentiating the market structures, we find that 9,396 paths of fundamental values are bubble free. In 148 cases, bubbles occurred if and only if the two non-ETF traders acted (class no. 1). In 92 of the 10,000 simulated fundamental value developments, a bubble occurred when chartists (C), fundamentalists (F), and ETF fundamentalists (E-F) were present on the market (class no. 4 in Table 2). For other trader constellations, there did not occur any bubble in the same 92 cases. This encourages the presumption that ETF fundamentalists are bubble boosting in these cases. In 328 cases a bubble occurred for exactly two of the four trader constellations, namely a) chartists (C) and fundamentalists (F) and b) chartists (C), fundamentalists (F), and ETF fundamentalists (E-F) (class no. 5). In the same 328 cases, when ETF chartists (E-C) were present as well, the bubble could be prevented. This supports the conjecture that ETF chartists tend to stabilize markets. All other cases (except for 1, 4, and 5) do not show a significant number of bubbles. Figure 7 illustrates the distribution of the fundamental value developments to the 16 bubble classes as a histogram. When having classified the fundamental value developments into the 16 classes, the slightly higher values of EK_1 compared to EK_2 of Table 1 in the cases without the E-C could be explained from the classes no. 1 and 4. In

No.	Trader constellations C + F	C + F + E-C	C + F + E-F	C + F + E-C + E-F	#
0					9,396
1	yes				148
2		yes			6
3	yes	yes			2
4			yes		92
5	yes		yes		328
6		yes	yes		0
7	yes	yes	yes		5
8				yes	5
9	yes			yes	0
10		yes		yes	11
11	yes	yes		yes	0
12			yes	yes	1
13	yes		yes	yes	1
14		yes	yes	yes	1
15	yes	yes	yes	yes	4

Table 2: Distribution of bubble events according to types of traders present in the market ('yes' indicates a bubble occurrence for the specific trader constellation).

the computation of sd_1 resp. EK_1 for the constellation C + F, the 92 price paths of class no. 4 where a bubble occurred for the constellation C + F + E-F are considered. For sd_2 resp. EK_2, these 92 paths are not considered. As especially EK_2 is smaller than EK_1, the excess kurtosis in these 92 cases seems to be extremely high, which distinctly raises the average excess kurtosis EK_1. The same holds for the 148 price paths of class no. 1 the other way round. The excess kurtosis seems to be very high for the constellation C + F + E-F in these paths, leading to a high EK_1, but for EK_2, these paths are not considered. The 328 price paths in class no. 5 are neither considered for sd_1/EK_1 nor for sd_2/EK_2 in the constellations C + F resp. C + F + E-F.

To better understand traders' behavior underlying the observed price dynamics arising from different fundamental value paths, we discuss in greater detail the investment decisions of ETF fundamentalists and ETF chartists in some interesting market configurations, namely classes no. 4 and 5 of Table 2. In the following, we analyze class no. 4 (bubble occurrence with the presence of E-F and absence of E-C) based on exemplary market simulations whereas an examination of class no. 5 is performed in Appendix A.5

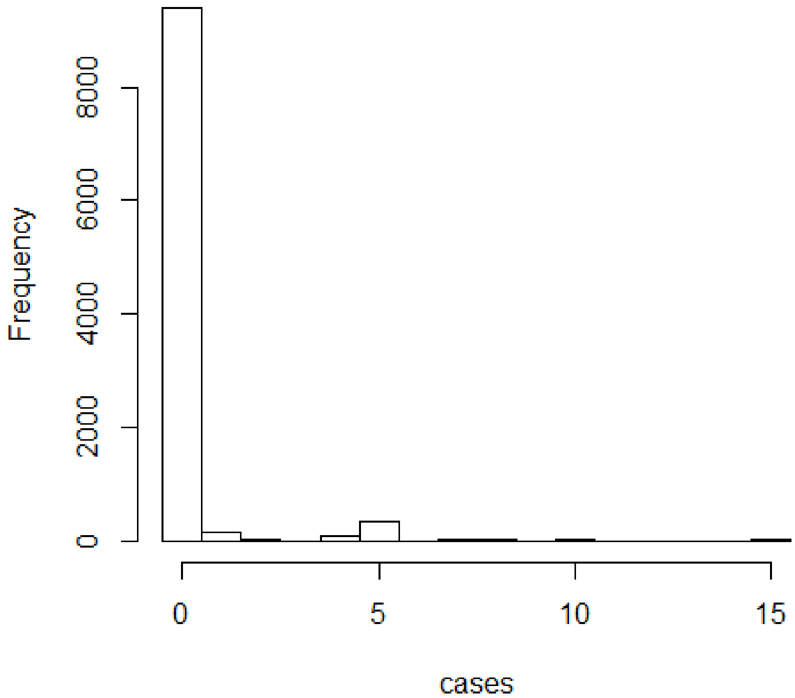
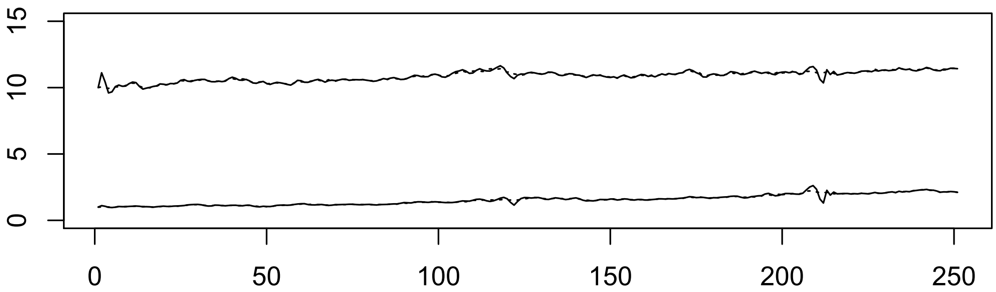


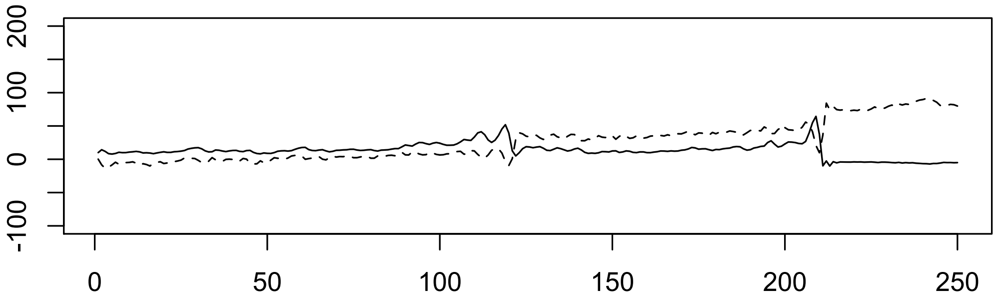
Figure 7: Histogram of different bubble cases observed in the Monte Carlo simulation with 10,000 runs.

analogously.

Figure 8 depicts a typical situation with only a chartist and a fundamentalist trading in the market and no bubble occurring. Fundamentals and prices, measured in monetary units, of both asset i and index develop relatively steadily with more visible changes around periods $t = 120$ and $t = 210$ (see Figure 8a). In particular, at about $t = 210$, the investments of both chartist and fundamentalist change substantially. Due to a higher asset price p_i and thus also a higher index price, the chartist increases his investment, amplifying the price increase (see Figure 8b). As price surpasses the fundamental value, the fundamentalist sells the overvalued asset. In this particular situation, the fundamentalist's selling seems to outweigh the chartist's buying as the asset price drops. The chartist's gain turns negative and he does not only lose money but also influence and impact on the asset market ($I_i^C \approx 0$ at about $t \geq 220$). Subsequently, the fundamentalist keeps the asset price close to its fundamental value via his investment



(a) Prices (solid) and fundamentals (dotted) of index (above) and stock i (below)



(b) Net asset position I_i^ℓ of C (solid) and F (dashed) in asset i

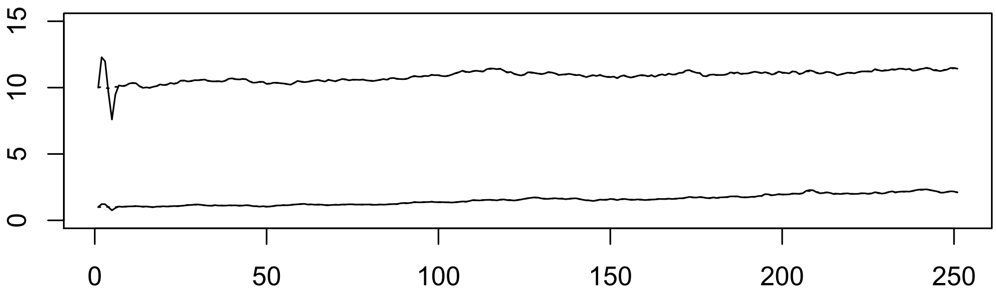
Figure 8: Market structure: single asset chartists and fundamentalists

decisions, a price bubble does not occur.[9]

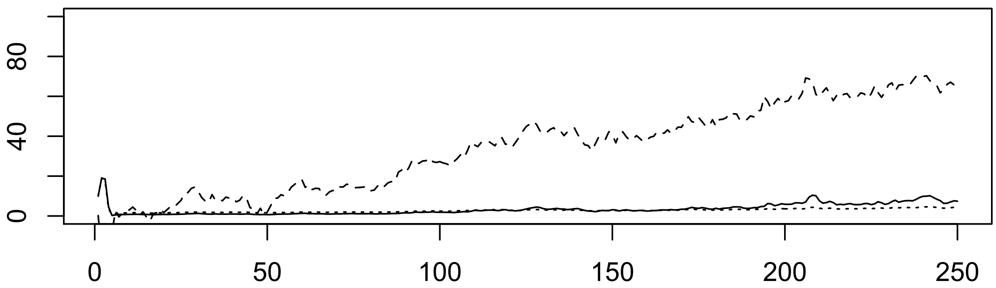
Figure 9 depicts a situation with the same specific paths of the fundamental values as in Figure 8, but with the ETF chartist as additional trader in the market. Again, no bubble occurs. In contrast to the scenario with fundamentalist and chartist only, the chartist does not lose all of his wealth. Due to the implicit investment of the ETF chartist in asset i, its price decreases less and thus the chartist (C) does not stop investing all together. Both the prices of the index and of asset i are very close to their respective fundamental values (see Figure 9a). As the fundamental value of asset i has a positive trend in this example, the fundamentalist invests in asset i.

In Figure 10, we again consider the same paths of fundamental values, however with a chartist and a fundamentalist in single assets and an ETF fundamentalist trading in the market. Even though fundamentals are the same as in the previous two cases, in this constellation a price bubble occurs. In this example, we see that due to an increase of the asset price around $t = 210$, the investment of the chartist strongly increases as well.

[9]The prominent price fluctuations at the beginning of the simulation are caused by the simultaneous entry of all the traders.



(a) Prices (solid) and fundamentals (dotted) of index (above) and stock i (below)



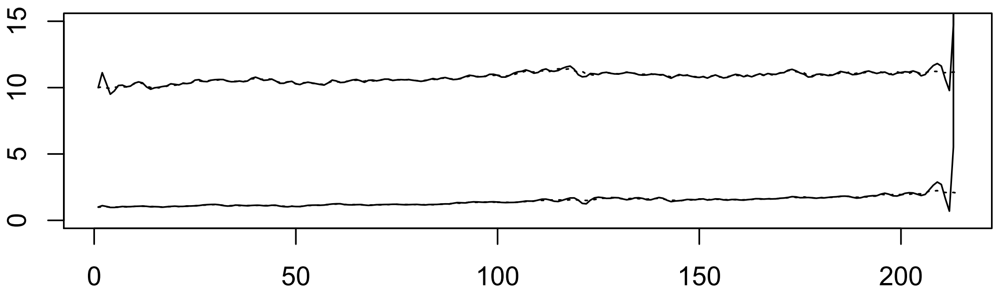
(b) Net asset position I_i^ℓ of C (solid), F (dashed), and E-C (dotted) in asset i

Figure 9: Market structure: single asset chartists, fundamentalists, and ETF chartists

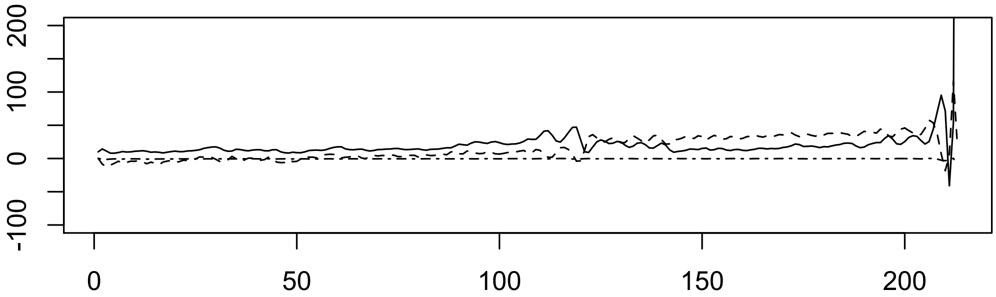
The fundamentalist and also to some degree the ETF fundamentalist trade against by disinvesting as both the asset and the index price exceed their respective fundamental values. The prices of both the asset and the index drop but are still above their fundamental values. The chartist disinvests in the asset as he regards a negative trend in the asset price, but also the fundamentalist and the ETF fundamentalist disinvest as prices of both the asset and the index are yet too high. This causes an even more extreme price decrease leading to a negative net asset position of the chartist which causes the chartist to become a short seller.[10] Short selling in an asset with falling price then generates high gains for the chartist, which he reinvests in the next period. This investment causes the price to rise that much (note that the traders' investment decisions are directly linked to the intensity of the price dynamics), such that the (ETF) fundamentalist cannot compensate this increase (Baumann et al., 2017a).

Finally, Figure 11 depicts a situation with again the same paths of fundamentals but with all types of traders investing in the market. Especially in Figure 11b, we see that at about $t = 210$ the investment of C in the asset increases, also the investment

[10]This unintentional change of trading behavior is shortly discussed at the end of Section 3.1.



(a) Prices (solid) and fundamentals (dotted) of index (above) and stock i (below)



(b) Net asset position I_i^ℓ of C (solid), F (dashed), and E-F (dotdash) in asset i

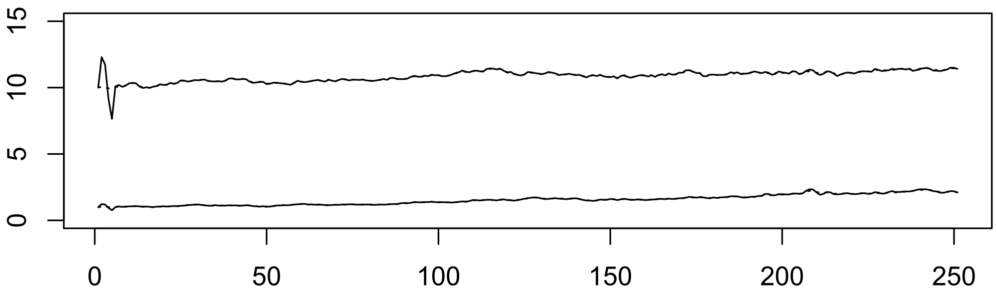
Figure 10: Market structure: single asset chartists and fundamentalists, as well as ETF fundamentalists

of E-C slightly increases. Both F and E-F subsequently disinvest the overvalued asset. Compared to the case without ETF chartist, the single asset chartist loses less. The ETF chartist implicitly stays invested in asset i via the ETF which in this situation seems to prevent a too strong drop in asset price p_i and subsequently a too strong shift in the investment of chartist C thus preventing a bubble to occur.[11]

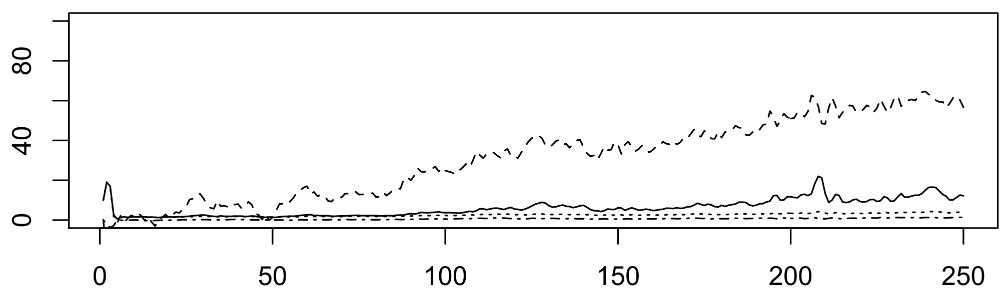
Altogether, these results indicate that ETF chartists tend to make the market more unstable in the sense of a higher price volatility, while at the same time lowering the probability of bubbles. We identified two behavioral characteristics of the participating traders:

- The fundamentalist, respectively ETF fundamentalist, who are supposed to have a stabilizing influence (as they reduce the distance between the price and its fundamental value), at times overcompensate the typical price destabilizing effect of chartists initiating price oscillation themselves. The ETF chartist amplifies the

[11] See Appendix A.5 for a similar example for a situation in which a bubble occurs when chartist C, fundamentalist F, and possibly ETF fundamentalist E-F trade (C, F resp. C, F, E-F), but no bubble occurs with an ETF chartist in the market (C, F, E-C and C, F, E-C, E-F).



(a) Prices (solid) and fundamentals (dotted) of index (above) and stock i (below)



(b) Net asset position I_i^ℓ of C (solid), F (dashed), E-C (dotted) and E-F (dotdash) in asset i

Figure 11: Market structure: single asset chartists and fundamentalists, as well as ETF fundamentalists and chartists

price trend but has a smoothing effect as he dampens strong price fluctuations in single assets when he counteracts the overcompensation of the (ETF) fundamentalist.

- The ETF chartist transfers the volatility of one asset to the index, i.e., to all stocks. When there is only one high volatile asset in the index, the same volatility is reflected in the index, at least to some degree, as the index price is the sum of the individual asset prices. Thus, the ETF chartist often adjusts his investment in the index and therefore also in the other single assets. This raises the volatility of these other assets even though their fundamentals were actually stable causing the other traders to adjust their investment in these assets as well. This effect imposed by the ETF chartist increases the general price volatility, which is in line with Frankfurter Allgemeine Zeitung (2016).

The absence of ETF chartists thus seems to have a double-edged influence, namely asset prices are either kept more stable or are more likely to explode. As intuitively expected, the volatility increases when ETF chartists act on the market but counterintuitively, the bubble rate decreases when ETF chartists are present. This unexpected behavior seems to be in line with the motivating example presented in Section 2. As a caveat we want to remind that our empirical results of Section 3 are based on simulations and not analytically. Thus, it cannot be ruled out that the findings are simulation artifacts though the various simulations and robustness checks make this quite unlikely.

4 Conclusion

Exchange-traded Funds are easy to understand, cost-efficient ways of investing in stock market indices that have become very popular for both retail and institutional investors. The discussion of the wider repercussions of ETFs on the stability of the financial system have just begun and typically focus on the astonishing growth of these financial products and in particular the relative size of ETF index investors in stock markets. In our study we focus on the investment strategies underlying the use of ETFs. We show that it is not so much the size of ETFs that is relevant (cf. Appendix A.1), but rather how these financial instruments are used in portfolio allocation, i.e., which strategy is used when trading with them. Our empirical analysis indicates that ETF chartists significantly change the market behavior in a more or less counterintuitive way. In contrast, ETF fundamentalists do not change market dynamics in a substantial way.

Under the complex interactions caused by index investments on the price dynamics of individual stocks, we find that the usual assessment that fundamentalists tend to stabilize, while chartists tend to destabilize price dynamics does not hold in this context. Rather the absence of ETF chartists increases the likelihood of bubbles. However, measures of price volatility such as the standard deviation and excess kurtosis indicate that ETF followers increase market volatility. Thus ETF chartists seem to have an all-or-nothing effect on stock prices: On the one hand they increase asset price volatility (in normal times), on the other hand they lower the probability of asset price bubbles (thereby increasing the likelihood of normal times).

An important lesson to be drawn from this analysis suggests a refocussing of financial market regulation. New financial products such as ETFs are not (de)stabilizing per se and regulation should not (only) concentrate on their sheer size and speed of spreading. Rather it is the specific use of these products that is of interest and should be the focus of financial market regulators, an idea also suggested from the perspective of market governance by Ockenfels and Schmalz (2016a).

When market stability is considered, usually volatility is used as a measure for stability. As our analysis shows, a high volatility does not necessarily imply a high bubble rate—quite to the contrary. Thus, it is questionable if regarding only volatility as a stability measure is sufficient.

One last thing we learn from our investigation is that products seeming harmless at a first glance like ETFs may have substantial influence on the market. Such new products should therefore be scrutinized closely in particular with respect to alternative market situations and trading strategies.

Acknowledgement

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References

B. R. Barmish and J. A. Primbs. On arbitrage possibilities via linear feedback in an idealized Brownian Motion stock market. In *2011 50th IEEE Conference on Decision and Control and European Control Conference*, pages 2889–2894, Dec. 2011.

S. Basak and A. Pavlova. Asset prices and institutional investors. *American Economic Review*, 103(5):1728–1758, Aug. 2013.

M. H. Baumann, M. Baumann, and A. Erler. Limitations of Stabilizing Effects of Fundamentalists Facing Positive Feedback Traders. XVIII Workshop on Quantitative Finance, Milan, Italy, Jan. 2017a.

M. H. Baumann, M. Baumann, and B. Herz. Stylized Facts in a Phenomena Emulating Heterogeneous Agent Model. (in preparation), 2017b.

I. Ben-David, F. Franzoni, and R. Moussawi. Do etfs increase volatility? Working Paper 20071, National Bureau of Economic Research, Apr. 2014.

D. Challet, J. da Gama Batista, J.-P. Bouchaud, C. Hommes, and D. Massaro. Do investors trade too much? A laboratory experiment. Working Papers hal-01244465, HAL, Dec. 2015.

D. Cuoco and R. Kaniel. Equilibrium prices in the presence of delegated portfolio management. *Journal of Financial Economics*, 101(2):264 – 296, 2011.

J. B. De Long, A. Shleifer, L. H. Summers, and R. J. Waldmann. Positive Feedback Investment Strategies and Destabilizing Rational Speculation. *The Journal of Finance*, 45(2):379–395, 1990.

C. Drescher and B. Herz. Monetary Shocks in Bounded Efficient Financial Markets with Bounded Rational Agents. Wirtschaftswissenschaftliche Diskussionspapiere, Discussion paper 09-12, June 2012.

J. Fichtner, E. M. Heemskerk, and J. Garcia-Bernardo. Hidden power of the big three? passive index funds, re-concentration of corporate ownership, and new financial risk. Technical report, Feb. 2017.

Frankfurter Allgemeine Zeitung. Liberale Verwalter wider den Wettbewerb. *Frankfurter Allgemeine Sonntagszeitung*, 269:31, 2016. 2016-11-17.

G. L. Gastineau. *The Exchange-Traded Funds Manual*. John Wiley & Sons, Inc., 2010.

C. H. Hommes. Heterogeneous Agent Models in Economics and Finance. volume 2 of *Handbook of Computational Economics*, chapter 23, pages 1109 – 1186. Elsevier, 2006.

I. T. Ivanov and S. L. Lenkey. Are Concerns About Leveraged ETFs Overblown? *Federal Reserve Board, Washington, D.C.*, 106, Nov. 2014.

D. Kremer. Die unheimliche Macht der ETF-Fonds. *Frankfurter Allgemeine Sonntagszeitung*, page 31, 2016. 2016-10-02.

A. Ockenfels and M. Schmalz. Die stille Gefahr für den Wettbewerb. *Frankfurter Allgemeine Zeitung*, page 18, 2016a. 2016-07-29.

A. Ockenfels and M. Schmalz. Die neue Macht der Fondsgesellschaften. *FAZ.NET*, 2016b. 2016-07-28.

H. Oura, N. Arregui, J. Beauchamp, R. Bhattacharya, A. Bouveret, C. Cuervo, P. Deb, J. Elliott, H. Ichiue, B. Jones, Y. Kim, J. Maloney, W. Monroe, M. Saldias, N. Valckx, V. Acharya, M.-J. Lee, G. Gelos, and D. He. The Asset Management Industry and Financial Stability. *Global Financial Stability Report: Navigating Monetary Policy Challenges and Managing Risks*, pages 93–135, Apr. 2015.

B. G. Peterson, P. Carl, K. Boudt, R. Bennett, J. Ulrich, E. Zivot, M. Lestel, K. Balkissoon, and D. Wuertz. PerformanceAnalytics: econometric tools for performance and risk analysis, Feb. 2015. R package documentation, https://cran.rproject.org/web/packages/PerformanceAnalytics/PerformanceAnalytics.pdf, last access: 2017-02-28.

R. J. Shiller. Do Stock Prices Move Too Much to be Justified by Subsequent Changes in Dividends? Working Paper 456, National Bureau of Economic Research, Feb. 1980.

The Economist. Passive investment funds create headaches for antitrust authorities. online article, Sep. 2016. http://www.economist.com/news/finance-and-economics/21707191-passive-investment-funds-create-headaches-antitrust-authorities-stealth, last access: 2017-02-28.

Y. Timmer. Cyclical investment behavior across financial institutions. Technical report, Deutsche Bundesbank, Oct. 2016. Discussion Paper.

J. Wiandt and W. McClatchy. *Exchange Traded Funds*. John Wiley & Sons, Inc., 2002.

List of Abbreviations and Symbols

C, C_Δ	chartist/trend follower/feedback trader
d	destabilizing effect
E-C, E-C_Δ	ETF chartist/ETF trend follower/ETF feedback trader
E-F, E-F_Δ	ETF fundamentalist
E-H	ETF buy-and-hold trader
EK	excess kurtosis
ETF	Exchange-traded Fund
F, F_Δ	fundamentalist
H	buy-and-hold trader
HAM	heterogeneous agent model
s	stabilizing effect
sd	standard deviation
?	unknown (de)stabilizing effect
parameters:	
f	fundamental value of the index
f_i	fundamental value of asset i
I	net asset position of the index
I_i	net asset position of asset i
I_0	initial investment of chartists
K	feedback parameter of chartists
N	number of assets in the index
M	scaling factor for trading volume and market power
μ	trend
p	price of the index
p_i	price of asset i
σ	volatility
t	time
T	termination time
$\mathcal{T}$	time grid
operators:	
$\Delta\alpha(t) := \alpha(t) - \alpha(t-1)$	

A Appendix

This is the Appendix to the paper "Exchange-traded Funds and Financial Stability" by Michael Heinrich Baumann, Michaela Baumann, and Bernhard Herz, University of Bayreuth, Germany, February 2017. Here, we provide some basic analytic results, robustness checks, as well as a few more examples, simulations, and insights.

A.1 Further Basic Analytical Results

In this section, before analyzing the buy-and-hold trader as a very straightforward kind of trader, we show that a trader's outcome does not depend on whether he is buying ETF shares or whether the trader is investing directly in the underlying stocks according to Equation (1). Although it can be expected that investing in an index or directly in stocks does not make any difference, in real-world markets it can be observed that indices are more volatile than the underlying assets, i.e., that people are more often shifting their index investments than their direct asset investments (Shiller, 1980). More precisely, we show that if a trader is investing directly in assets with the same weighting as these assets have in the index, then his total gain is the same as he would have invested the same sum in the index. With

$$\Delta g_i^\ell(t) = I_i^\ell(t-1) \cdot \frac{\Delta p_i(t)}{p_i(t-1)}$$

as the period gain of trader ℓ at time t from stock i when investing $I_i^\ell(t-1)$ at time $t-1$ in stock i we propose the following proposition.

Proposition 2. The total profit up to period t

$$g^\ell(t) = \sum_{\tau=1}^{t} \sum_{i=1}^{N} I_i^\ell(\tau-1) \cdot \frac{p_i(\tau) - p_i(\tau-1)}{p_i(\tau-1)}$$

of investing in all stocks $(1, \ldots, N)$ of trader ℓ selecting his portfolio according to Equation (1) only depends on his cumulated investment I^ℓ over all stocks and on the index's return on investment. In particular, for the period gain $\Delta g^\ell(t) = g^\ell(t) - g^\ell(t-1)$ it holds

$$\Delta g^\ell(t) = I^\ell(t-1) \cdot \frac{p(t) - p(t-1)}{p(t-1)}$$

which adds up to a total gain of

$$g^\ell(t) = \sum_{\tau=1}^{t} I^\ell(\tau-1) \cdot \frac{p(\tau)-p(\tau-1)}{p(\tau-1)}.$$

Proof. Exploiting Equation (1) leads to:

$$\begin{aligned}
\Delta g^\ell(t) &= \sum_{i=1}^{N} I^\ell(t-1) \cdot \frac{p_i(t-1)}{p(t-1)} \cdot \frac{p_i(t)-p_i(t-1)}{p_i(t-1)} \\
&= \sum_{i=1}^{N} I^\ell(t-1) \cdot \frac{p_i(t)-p_i(t-1)}{p(t-1)} \\
&= I^\ell(t-1) \cdot \frac{p(t)-p(t-1)}{p(t-1)}
\end{aligned}$$

Adding up over the time periods leads to the specified total gain formula which is independent of the single asset investments. □

Next, we will see that for a buy-and-hold trader there is no difference between directly investing in the index's stocks $1,\ldots,N$ or investing in an ETF, i.e., his investment decisions are the same in both cases. Even if the proposed property seems to be obvious, a priori it is not. Since ETF buy-and-hold traders reallocate there investment due to the rebalancing effect, the behavior of this traders is worth investigation. A buy-and-hold trader (H) as well as an ETF buy-and-hold trader (E-H) buys a specific amount of assets at a certain point of time and keeps these assets irrespective of their price development. Specifically, the net asset position of an ETF buy-and-hold trader is given by

$$\begin{aligned}
I^{E-H}(t) &= I^{E-H}(0) + g^{E-H}(t) \\
&= I^{E-H}(t-1) + I^{E-H}(t-1) \cdot \frac{p(t)-p(t-1)}{p(t-1)} \\
&= I^{E-H}(t-1) \cdot \frac{p(t)}{p(t-1)}
\end{aligned} \tag{3}$$

since $g^{E-H}(t)$ is exactly his shares' increase in value. For a "normal" buy-and-hold trader directly investing in stock i, it holds

$$\begin{aligned}
I_i^H(t) &= I_i^H(0) + g_i^H(t) \\
&= I_i^H(t-1) + I_i^H(t-1) \cdot \frac{p_i(t)-p_i(t-1)}{p_i(t-1)}
\end{aligned}$$

$$= I_i^H(t-1) \cdot \frac{p_i(t)}{p_i(t-1)}$$

where $g_i(t)$ denotes the cumulated gain of stock i up to time t.

Proposition 3. The investment decision for stock i is the same for buy-and-hold traders directly investing in the index's stocks and for buy-and-hold traders investing in the ETF.

Proof. We use mathematical induction for proving Proposition 3 and show

$$I_i^H(t-1) = I_i^{E-H}(t-1) \Rightarrow \Delta I_i^H(t) = \Delta I_i^{E-H}(t).$$

We define $roi(t) := \frac{p(t)-p(t-1)}{p(t-1)}$ and $roi_i(t) := \frac{p_i(t)-p_i(t-1)}{p_i(t-1)}$. Note that for buy-and-hold traders the investment equals the period gain, i.e., the change of total gain $\Delta g_i^H(t)$, as they do not change the invested amount subsequently. With Equation (2) the investment in an individual stock is given by

$$\begin{aligned}
\Delta I_i^{E-H}(t) &= \Delta I^{E-H}(t)\pi_i(t) + I^{E-H}(t-1)\Delta\pi_i(t) \\
&= \left(I^{E-H}(t) - I^{E-H}(t-1)\right)\frac{p_i(t)}{p(t)} + I^{E-H}(t-1)\left(\pi_i(t) - \pi_i(t-1)\right) \\
&\overset{(3)}{=} I^{E-H}(t-1)roi(t) \cdot \frac{p_i(t)}{p(t)} + I^{E-H}(t-1)\left(\frac{p_i(t)}{p(t)} - \frac{p_i(t-1)}{p(t-1)}\right) \\
&= I^{E-H}(t-1)\left(\frac{p(t)}{p(t-1)} \cdot \frac{p_i(t)}{p(t)} - \frac{p_i(t)}{p(t)} + \frac{p_i(t)}{p(t)} - \frac{p_i(t-1)}{p(t-1)}\right) \\
&= I^{E-H}(t-1)\left(\frac{p_i(t)}{p(t-1)} - \frac{p_i(t-1)}{p(t-1)}\right) \\
&= \frac{I_i^{E-H}(t-1)}{\pi_i(t-1)} \cdot \frac{p_i(t)-p_i(t-1)}{p(t-1)} \\
&= I_i^{E-H}(t-1) \cdot \frac{p(t-1)}{p_i(t-1)} \cdot \frac{p_i(t)-p_i(t-1)}{p(t-1)} \\
&= I_i^{E-H}(t-1)roi_i(t) \\
&= \Delta I_i^H(t).
\end{aligned}$$

□

This equation shows that the buy-and-hold trader is of no interest for us in the analyses of this paper as mentioned although the E-H trader consistently reallocates his investment because of $\Delta\pi_i$ in Equation (2). But this reallocation resp. the E-H trader has the same effects on the market as the "normal" buy-and-hold trader has.

A.2 (De)Stabilizing Effects of ETF traders

In this section, we examine and summarize the (de)stabilizing effects of ETF trading for ETF fundamentalists (Table 3) and ETF chartists (Table 4) on one single asset i. Altogether, we identified two influencing characteristics on the development of asset i for the E-F_Δ and two slightly different characteristics for the E-C_Δ derived from Equation (2) and two trader independent characteristics.

The influencing characteristics of the E-F_Δ are his previous net asset position and his decision about investing or disinvesting depending on the ratio of (expected) fundamental value and price.

- In the past, the index has rather been under-/overvalued, leading to a positive net asset position ($I^{E-F_\Delta}(t-1) > 0$) of the E-F_Δ or to a negative one ($I^{E-F_\Delta}(t-1) < 0$).
- The index is now undervalued ($\frac{f(t+1)}{p(t)} > 1$) or overvalued ($\frac{f(t+1)}{p(t)} < 1$).

The influencing characteristics of the E-C_Δ are his previous net asset position and his decision about investing or disinvesting depending on the observed rising or falling price.

- In the past, the index has rather been increasing/decreasing, leading to a positive net asset position ($I^{E-C_\Delta}(t-1) > 0$) of the E-C_Δ or to a negative one ($I^{E-C_\Delta}(t-1) < 0$).
- The price of the index is now increasing ($\frac{p(t)}{p(t-1)} > 1$) or decreasing ($\frac{p(t)}{p(t-1)} < 1$).

Independent of the two ETF trader types, the change of the relative weight of asset i in the index is of importance (also taken from Equation (2)) as well as the price p_i of asset i compared to its fundamental value f_i, which is exactly the basis for calling a certain investment stabilizing or destabilizing:

- The relative share of asset i in the index can be either increasing ($\Delta\pi_i(t) > 0$) or decreasing ($\Delta\pi_i(t) < 0$).
- The i^{th} asset is now undervalued ($\frac{f_i(t+1)}{p_i(t)} > 1$) or overvalued ($\frac{f_i(t+1)}{p_i(t)} < 1$). This parameter is needed for determining the stabilizing or destabilizing effect of the respective trader.

Combining these effects, we determine the sign of the investment decision for the i^{th} asset. We characterize an investment as destabilizing (d) if traders disinvest in an undervalued asset or invest in an overvalued one. An investment is considered as

Effects of E-F_Δ		$\frac{f_i(t+1)}{p_i(t)} > 1$		$\frac{f_i(t+1)}{p_i(t)} < 1$	
		$\Delta\pi_i(t) > 0$	$\Delta\pi_i(t) < 0$	$\Delta\pi_i(t) > 0$	$\Delta\pi_i(t) < 0$
$I^{E-F_\Delta}(t-1) > 0$	$\frac{f(t+1)}{p(t)} > 1$	s	?	d	?
	$\frac{f(t+1)}{p(t)} < 1$	?	d	?	s
$I^{E-F_\Delta}(t-1) < 0$	$\frac{f(t+1)}{p(t)} > 1$	?	s	?	d
	$\frac{f(t+1)}{p(t)} < 1$	d	?	s	?

Table 3: Price dynamics imposed by past net asset position, over-/undervaluated index, over-/undervaluated asset, and increasing/decreasing relative share of the asset in the index leading to (de)stabilizing effects of ETF fundamentalists.

Effects of E-C_Δ		$\frac{f_i(t+1)}{p_i(t)} > 1$		$\frac{f_i(t+1)}{p_i(t)} < 1$	
		$\Delta\pi_i(t) > 0$	$\Delta\pi_i(t) < 0$	$\Delta\pi_i(t) > 0$	$\Delta\pi_i(t) < 0$
$I^{E-C_\Delta}(t-1) > 0$	$\frac{p(t)}{p(t-1)} > 1$	s	?	d	?
	$\frac{p(t)}{p(t-1)} < 1$	?	d	?	s
$I^{E-C_\Delta}(t-1) < 0$	$\frac{p(t)}{p(t-1)} > 1$	?	s	?	d
	$\frac{p(t)}{p(t-1)} < 1$	d	?	s	?

Table 4: Price dynamics imposed by past net asset position, increasing/decreasing index price, over-/undervaluated asset, and increasing/decreasing relative share of the asset in the index leading to (de)stabilizing effects of ETF chartists.

stabilizing (s), if traders invest in an undervalued asset or disinvest in an overvalued one. In the cells marked with a questionmark (?), the direction of the investment cannot be determined in general without knowing the particular values. This is the case when one summand is positive and the other one is negative in Equation (2). Consider, for example, the cell of the first row and the first column of Table 3. According to Equation (2), a positive net asset position together with a rising ratio of asset i (i.e., $I^{E-F_\Delta}(t)\Delta\pi_i(t) > 0$) plus an undervalued index price resulting in a positive investment (i.e., $\Delta I^{E-F_\Delta}(t)\pi_i(t) > 0$ where $\pi_i(t) > 0$ for all t) leads to a positive investment in asset i (i.e., $\Delta I_i^{E-F_\Delta}(t) > 0$). Together with the condition of undervaluation of asset i ($\frac{f_i(t+1)}{p_i(t)} > 1$), the ETF fundamentalist's effect on asset i is stabilizing. In contrast, if asset i is overvalued (first row, third column of Table 3), his effect on asset i is destabilizing.

Note that the 16 cases in the two tables are not the same for E-F$_\Delta$ and E-C$_\Delta$. For ETF fundamentalists, the ratio between fundamental value of tomorrow and price of today is important whereas for ETF chartists the ratio of today's price and yesterday's price is of interest. For better clarity we only consider the relevant market characteristics for the different trader types and also skipped the equality cases ($= 0$ or $= 1$).

A.3 Further Market Scenario Examples

In the following, we show two further example developments for specific market situations (scenarios 2 and 3) with T$_\Delta$, F$_\Delta$, E-T$_\Delta$, and E-F$_\Delta$. The traders as well as the background are the same as in Section 2.

Scenario 2: rising stock in a bear market In the second case, we assume that the absolute price of stock 1 rises with trend $\mu_1 = 0.1$ while the absolute price of the index falls with trend $\mu = -0.1$. As a consequence the relative price of stock 1 increases. Stock 1 is assumed to be overvalued, the index to be undervalued ($t > 0$). The fundamental values of the stocks are again set to $f_i \equiv 1$. Since stock 1 is overvalued and its price increases (see Figure 12), fundamentalists (F$_\Delta$) sell and chartists (C$_\Delta$) buy this stock. Since the index is undervalued and its price falls (see Figure 15), ETF fundamentalists invest on average, while ETF chartists disinvest overall.

Figure 14 depicts the investment of the four types of traders in stock 1. ETF chartists (E-C$_\Delta$) implicitly disinvest more and more of stock 1 as its relative price π_1 and thus its relative weight in the index rises (see Figure 13). The level effect of the ETF chartist (E-C$_\Delta$) causes a disinvestment in stock i which is even amplified through a high ratio of stock 1 in the index. The rebalancing effect through an increase of $\Delta\pi_1$ cannot compensate this. In contrast, ETF fundamentalists (E-F$_\Delta$) invest more in stock 1 as its relative price (weight) increases. While they buy stock 1 as part of buying the ETF due to the undervaluation of the index (level effect), they overproportionally buy stock 1 due to its high ratio in the index, which is even increasing (rebalancing effect). The investment in the other assets (Figure 16) does not show significant changes over time. Again we find the counterintuitive effects that implicitly ETF fundamentalists buy an overvalued stock thereby destabilizing the market, while ETF chartists sell a rising stock with a stabilizing effect on the market.

Scenario 3: falling stock in a bull market with the index crossing its fundamental value from below For the third scenario, we assume a bull market in which

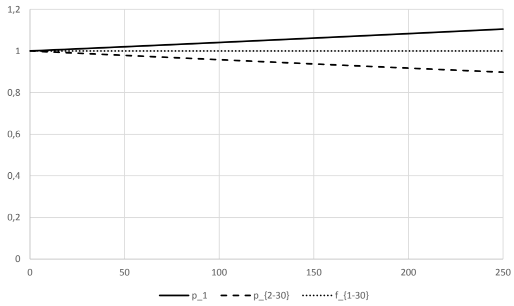


Figure 12: Price paths p_1 of stock 1 and p_{2-30} of stocks 2-30 in scenario 2.

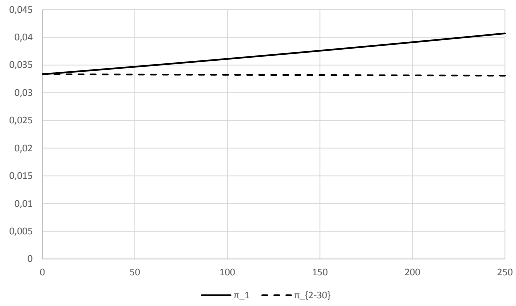


Figure 13: Change of the ratio π_1 and π_{2-30} of stock 1 and stocks 2-30, resp., in scenario 2.

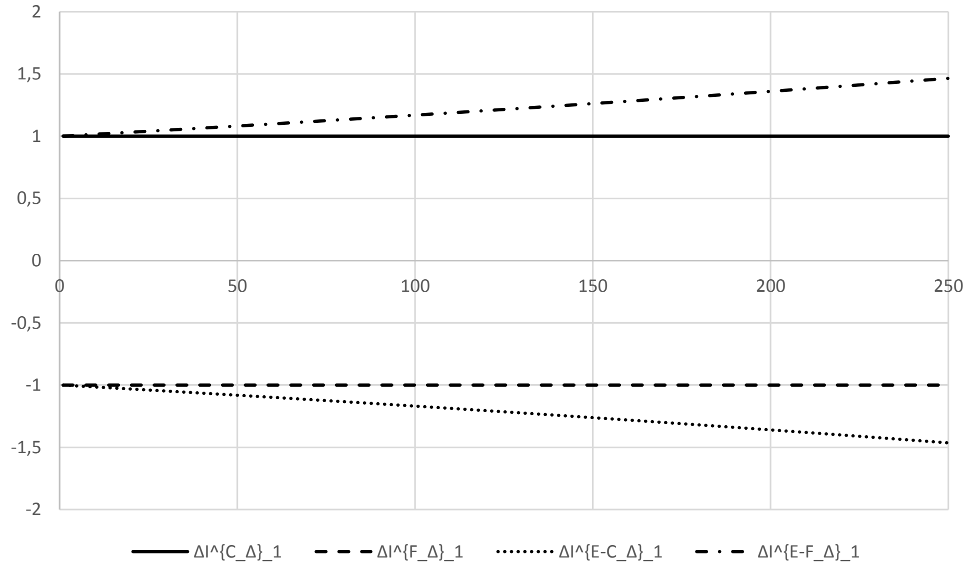


Figure 14: Investment ΔI_1^{ℓ} in stock 1 if this stock is rising when the index falls (scenario 2).

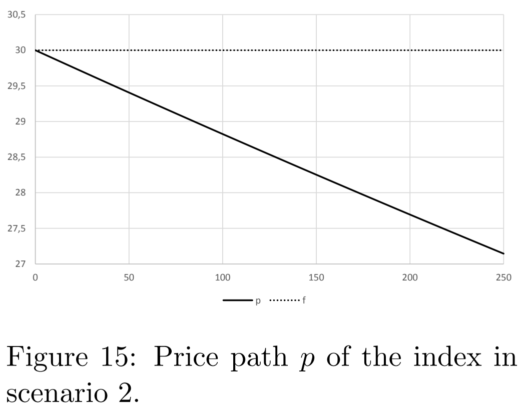


Figure 15: Price path p of the index in scenario 2.

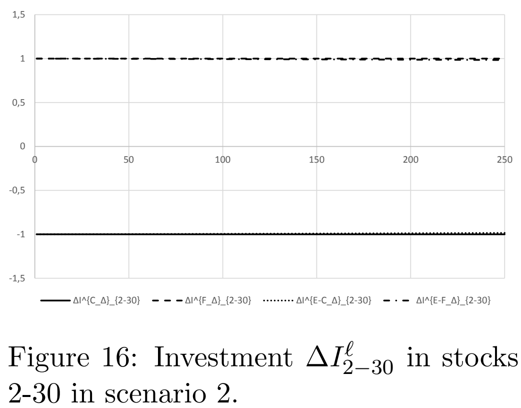


Figure 16: Investment ΔI_{2-30}^{ℓ} in stocks 2-30 in scenario 2.

a specific stock falls. The index's price starts below its fundamental value and is undervalued at first, but later due to trend $\mu = 2$ surpass its fundamental value. Stock 1 is undervalued and its price falls against the general market trend with rate $\mu_1 = -0.5$ (see Figures 17 and 20). For expositional reasons, the fundamental value of the index is set to $f \equiv 30 \cdot 1.3$, i.e., the fundamental values of the individual stocks are set to $f_i \equiv 1.3$.

As has been discussed above, the calculus of ETF and single stock chartists and fundamentalists is straightforward. In the case of index investors, ETF chartists invest, while ETF fundamentalists first buy the undervalued index and later sell the then overvalued index ETF. In case of stock 1 fundamentalists invest as the stock is undervalued while chartists sell (see Figure 19).

Again, we analyze how the investment decisions of ETF investors affect stock 1 and how this compares to the behavior of investors that only target stock 1. ETF chartists (E-C$_\Delta$) invest overall due to the index's rising price. On the level of stock 1 they implicitly invest less and less as its relative price π_1 and thus its relative weight in the index declines (see Figure 18). The level effect of E-C$_\Delta$ investment decreases as less of the newly invested money ΔI^{E-C_Δ} is allocated to stock 1, and due to rebalancing, E-C$_\Delta$ investors sell stock 1 to account for the reduced weight of stock 1 in their overall portfolio I^{E-C_Δ}.

ETF fundamentalists (E-F$_\Delta$) pursue similar investments as long as stock 1 is undervalued (see Figure 19). Once the index's price surpasses its fundamental value they switch to selling the index and implicitly stock 1 due to the overvaluation of the index (see Figure 20). Due to the need to rebalance their portfolio because of the falling relative weight of stock 1, they implicitly buy stock 1 to assure the correct portfolio allocation. As the relative price of stock 1continues to fall the positive rebalancing effect eventually dominates the level effect. In the mean time ETF fundamentalists have been net sellers of an undervalued stock. The ETF fundamentalist's investment behavior in stock 1 suddenly changes although neither the trend nor the fundamental value of stock 1 changes. Concerning stocks 2-30 (Figure 21), we see that both the fundamentalist and the ETF fundamentalist suddenly disinvenst when they get overvalued (Figure 17). This behavior is just as expected.

To sum up, ETF chartists invest for some time in a falling stock, while ETF fundamentalists disinvest from an undervalued stock. Also in this case ETF chartists tend to stabilize, while ETF fundamentalists tend to destabilize stock price developments. This behavior is somewhat counterintuitive.

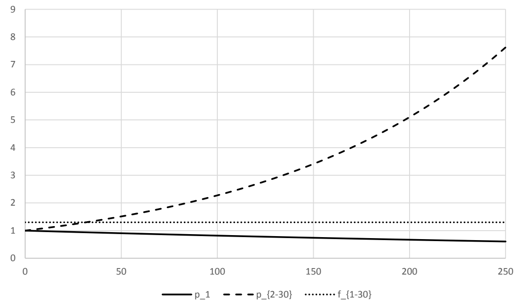


Figure 17: Price paths p_1 of stock 1 and p_{2-30} of stocks 2-30 in scenario 3.

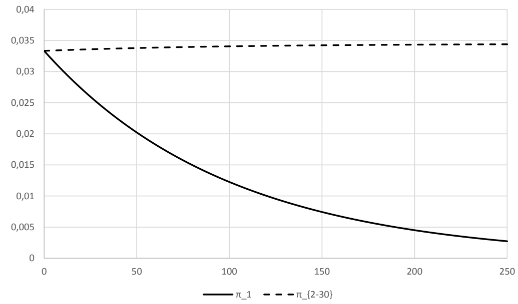


Figure 18: Change of the ratio π_1 and π_{2-30} of stock 1 and stocks 2-30, resp., in scenario 3.

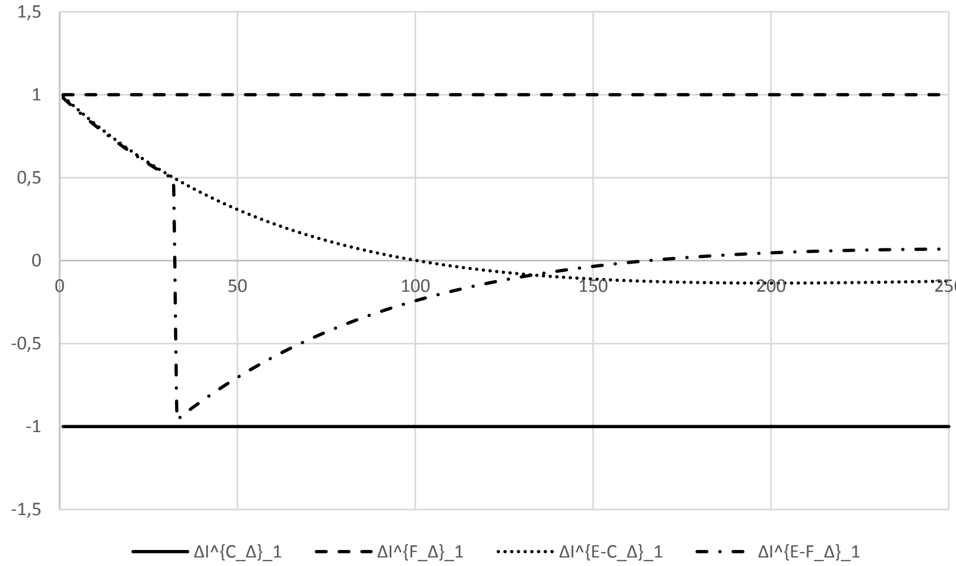


Figure 19: Investment ΔI_1^{ℓ} in stock 1 if this stock is falling when the index rises and crosses its fundamental value from below (scenario 3).

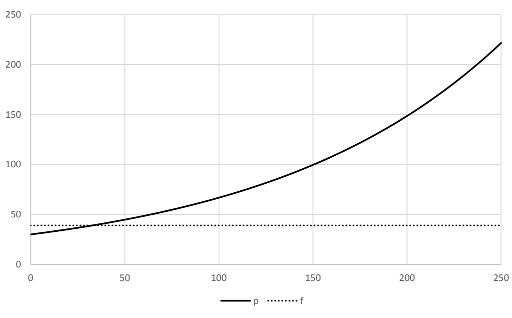


Figure 20: Price path p of the index in scenario 3.

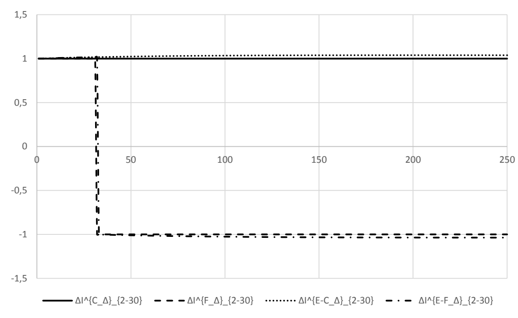


Figure 21: Investment ΔI_{2-30}^{ℓ} in stocks 2-30 in scenario 3.

No.	Trader constellations				#
	C + F	C + F + E-C	C + F + E-F	C + F + E-C + E-F	
0					9,396
1	yes				148
2		yes			6
3	yes	yes			2
4			yes		92
5	yes		yes		328
6		yes	yes		0
7	yes	yes	yes		5
8				yes	5
9	yes			yes	0
10		yes		yes	11
11	yes	yes		yes	0
12			yes	yes	1
13	yes		yes	yes	1
14		yes	yes	yes	1
15	yes	yes	yes	yes	4

Table 5: Results of the Monte Carlo simulation. A bubble is defined via $p(t) \geq 100 \cdot f(t)$.

A.4 Simulation with Modified Parameters for Robustness Check

This Section shows that it does not matter whether a bubble is defined by $p(t) \geq x \cdot f(t)$ with $x = 10$, 100, or 1,000. The histograms and the tables are similar to the ones in Section 3 as well as their interpretation.

In Table 5 and Figure 22 we defined a bubble when the price of the index fulfills $p(t) \geq 100 \cdot f(t)$. With this bubble definition, there is no difference to the case of Section 3.3.

In Table 6 and Figure 23 we defined a bubble when the price of the index fulfills $p(t) \geq 1,000 \cdot f(t)$. With this bubble definition, there is exactly one fundamental value development which is classified in another class than in the case of Section 3.3. This development is shifted from class no. 8 to class no. 0 meaning that the bubble that only occurred in the market constellation with C, F, E-C, and E-F acting, dissolved somewhere between a price of $100 \cdot f(t)$ and $1,000 \cdot f(t)$ or, more likely, the new bubble limit is reached a few time steps further beyond our simulation horizon.

No.	Trader constellations C + F	C + F + E-C	C + F + E-F	C + F + E-C + E-F	#
0					9,397
1	yes				148
2		yes			6
3	yes	yes			2
4			yes		92
5	yes		yes		328
6		yes	yes		0
7	yes	yes	yes		5
8				yes	4
9	yes			yes	0
10		yes		yes	11
11	yes	yes		yes	0
12			yes	yes	1
13	yes		yes	yes	1
14		yes	yes	yes	1
15	yes	yes	yes	yes	4

Table 6: Results of the Monte Carlo simulation. A bubble is defined via $p(t) \geq 1,000 \cdot f(t)$.

A.5 Exemplary Investment Development for Class No. 5 of Table 2

In this section, we provide and exemplary investment development of the Monte Carlo simulation of Section 3 when a bubble occurs if only C and F as well as if only C, F, and E-F are trading, but neither if C, F, and E-C nor if C, F, E-C, and E-F are trading. The analysis and interpretation of these results are analog to that ones in Section 3.3.

Figure 24 shows a situation where C and F are acting on a market with a bubble occurring at about $t = 190$. Figure 25 shows the same fundamental value development but with an additional E-C on the market. In this case, no bubble occurs. In Figure 26 instead of an E-C, we have an E-F on the market together with C and F. The price development looks similar to the that one of Figure 24 with a bubble occurring at about $t = 190$. Instead, having all four trader types acting on the market, i.e., having C, F, E-C, and E-F on the market, the bubble could again be prevented through the presence of the E-C. This is shown in Figure 27. It may be conspicuous that the net asset position of C and F after the prevented bubble is much more volatile than before.

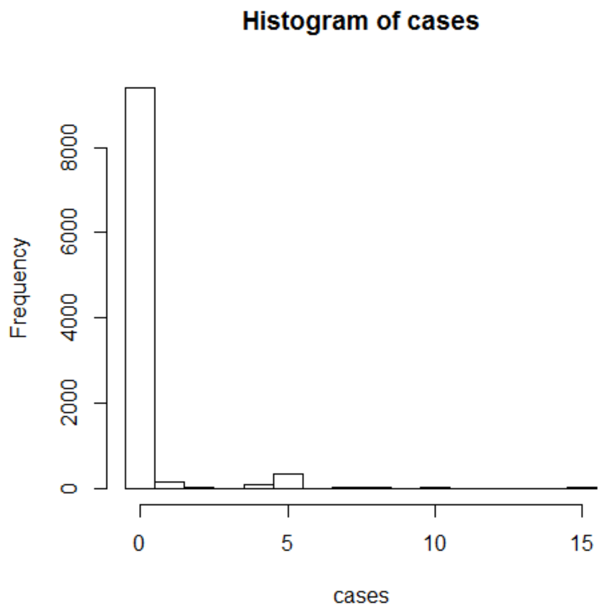


Figure 22: Histogram of different cases observed in the Monte Carlo simulation with 10,000 runs. A bubble is defined via $p(t) \geq 100 \cdot f(t)$.

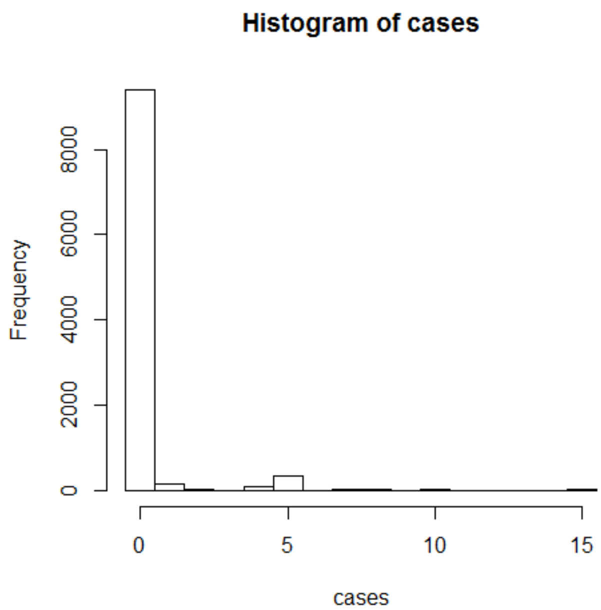
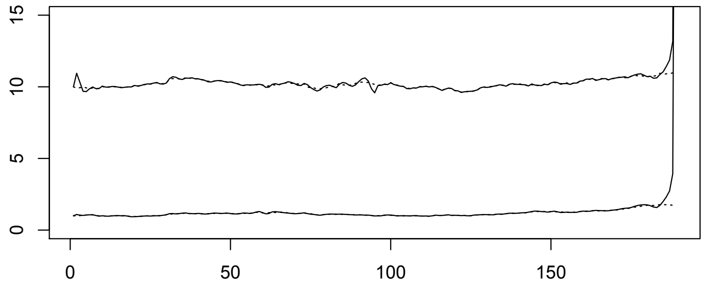
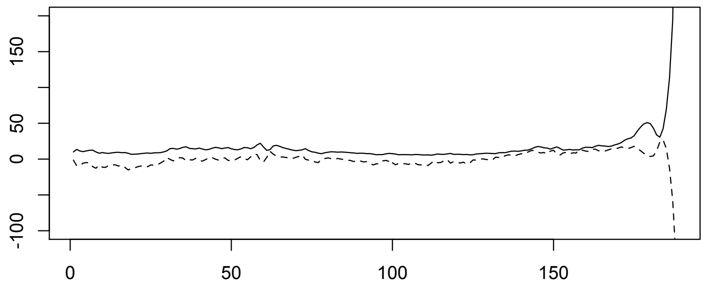


Figure 23: Histogram of different cases observed in the Monte Carlo simulation with 10,000 runs. A bubble is defined via $p(t) \geq 1,000 \cdot f(t)$.

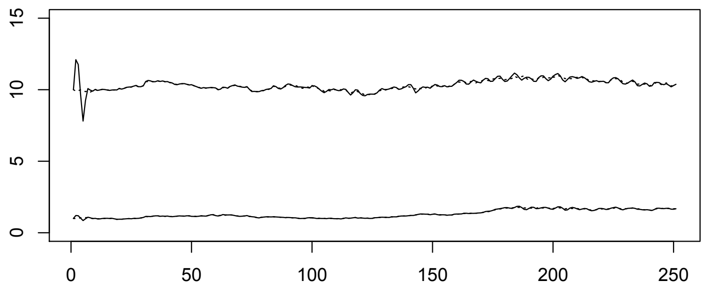


(a) Prices (solid) and fundamentals (dotted) of index (above) and stock i (below)

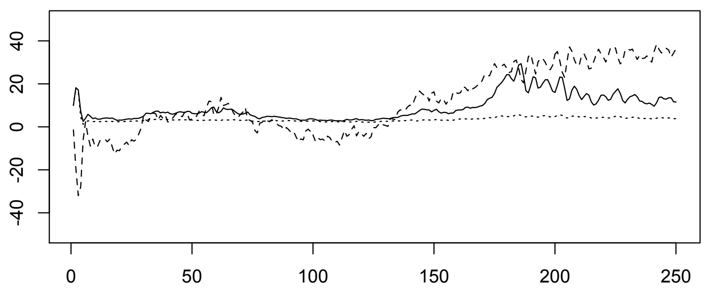


(b) Net asset position I_i^ℓ of C (solid) and F (dashed)

Figure 24: Case C and F

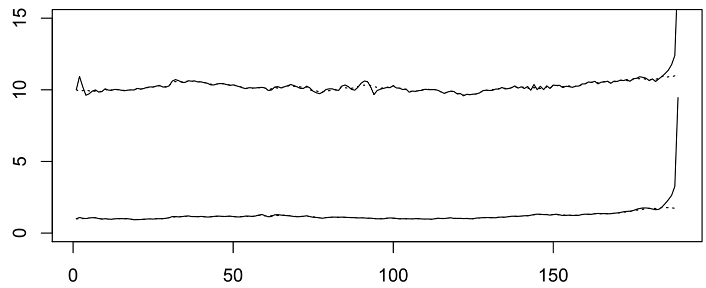


(a) Prices (solid) and fundamentals (dotted) of index (above) and stock i (below)

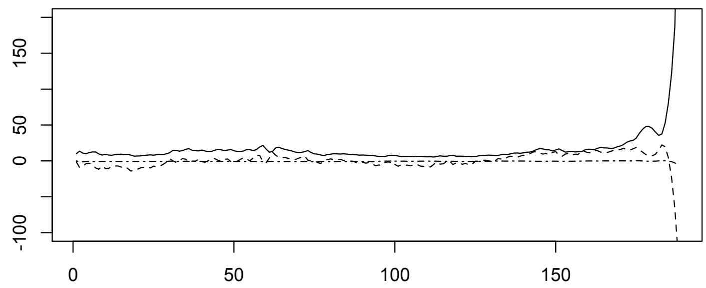


(b) Net asset position I_i^ℓ of C (solid), F (dashed), and E-C (dotted)

Figure 25: Case C, F, and E-C

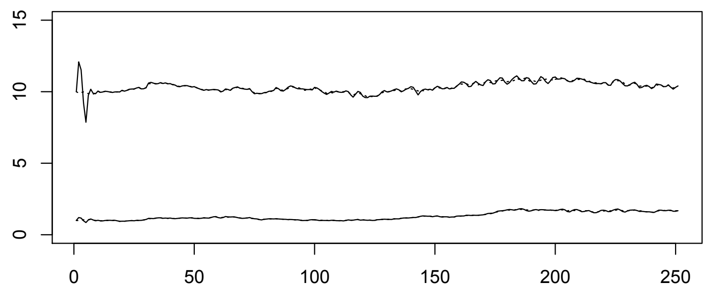


(a) Prices (solid) and fundamentals (dotted) of index (above) and stock i (below)

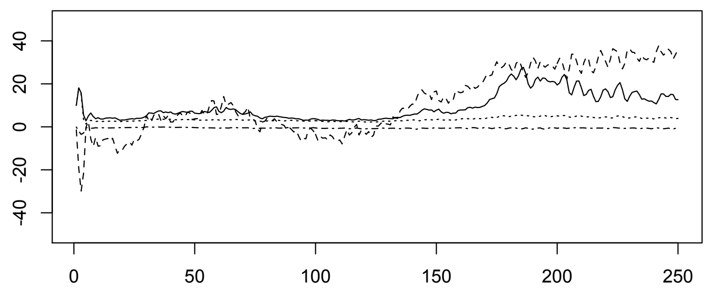


(b) Net asset position I_i^ℓ of C (solid), F (dashed), and E-F (dotdash)

Figure 26: Case C, F, and E-F



(a) Prices (solid) and fundamentals (dotted) of index (above) and stock i (below)



(b) Net asset position I_i^ℓ of C (solid), F (dashed), E-C (dotted), and E-F (dotdash)

Figure 27: Case C, F, E-C, and E-F