Index Investing and Sentiment Spillover

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Abstract

We develop a dynamic model of index investing that explains key differences between index and non-index stocks. In our model, investors with extrapolative expectations generate sentiment, and index investing spills the sentiment on an index stock to all other index stocks. Primarily due to this spillover mechanism, consistent with empirical evidence, index stocks exhibit higher and more volatile prices, greater comovement, stronger negative autocorrelation, and higher trading volume than comparable non-index stocks. Our model also accounts for the recently documented "disappearing index effect" and offers novel insights into the welfare costs associated with index investing.

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1 Introduction

The investment management industry has undergone a substantial shift from active management to passive index investing in recent decades. According to the 2024 Investment Company Fact Book, total net assets in U.S. index funds rose from $1.88 trillion in 2010 to $13.3 trillion in 2023, with their market share increasing from 19% to 48%.[1] This trend is often attributed to the poor after-fee performance of active funds relative to their benchmark indices, prompting widespread advice for retail investors to opt for lower-cost index funds. Correspondingly, a growing body of empirical research (discussed below) documents notable cross-sectional differences between index and non-index stocks. Specifically, index stocks tend to exhibit higher and more volatile prices, greater comovement with one another, stronger negative return autocorrelation, and higher trading volumes than comparable non-index stocks. In this paper, we develop a dynamic equilibrium model of index investing that can simultaneously reconcile all these empirical regularities. A key feature of our model is the presence of index investors with extrapolative expectations, a behavior well-documented among retail investors, for whom index investing has become an increasingly popular strategy.

Specifically, we consider an economy with multiple risky stocks that pay uncertain dividends, alongside an index fund that passively tracks a subset of these stocks. Stocks included in the index are referred to as *index stocks*, while the others are *non-index stocks*. Investors in this economy are risk-averse and differ in both their beliefs and investment choices. Belief heterogeneity takes the form of either rational expectations or extrapolative expectations. Investment profiles are similarly segmented: some investors trade individual stocks, while others invest solely in the index fund. For example, stock extrapolators, whose expectations are shaped by the past performance of individual stocks, trade only in individual stocks, not in the index fund. In contrast, index extrapolators, whose expectations are driven by the past performance of the index, trade exclusively in the index fund. Following common usage in the literature, we refer to extrapolators' expectations as *"sentiment"*, with higher (lower) sentiment indicating optimistic (pessimistic) expectation on average. Equilibrium prices for both index and non-index stocks, as well as the index level, are determined endogenously.

[1] See, https://www.icifactbook.org/. Chinco and Sammon (2024) argue that the true extent of passive ownership may be even larger when accounting for internal and closet indexers.

We first characterize the equilibrium and show that the presence of index investors gives rise to a novel *sentiment spillover*: the sentiment of one index stock affects not only its own price but also the prices of other index stocks. When the marginal index investor is extrapolative, an index stock's price becomes positively related to the sentiment of all other index constituents. This spillover emerges because a positive cash flow shock to an index stock raises its price and the overall index level—especially in the presence of stock extrapolators who amplify the shock through sentiment-driven demand. Index extrapolators, reacting to the rising index level, become more optimistic and increase their demand for index fund shares. As the fund reallocates this demand across all index constituents, the prices of all index stocks rise, spilling the impact across the index and amplifying the initial shock.

The presence of both index and non-index stocks in our model enables us to examine cross-sectional differences between them within the same economy. We find that when the marginal index investor is extrapolative, all consistent with empirical evidence, index stocks have higher prices (Harris and Gurel (1986), Shleifer (1986), Greenwood and Sammon (2025)), are more volatile (Sullivan and Xiong (2012), Ben-David, Franzoni, and Moussawi (2018), Coles, Heath, and Ringgenberg (2022)), comove more with other index stocks (Greenwood and Sosner (2007), Wurgler (2010), Boyer (2011), Coles, Heath, and Ringgenberg (2022)), exhibit stronger negative autocorrelations (Ben-David, Franzoni, and Moussawi (2018), Baltussen, van Bekkum, and Da (2019), Höfler, Schlag, and Schmeling (2023)), and have higher trading volume (Vijh (1994), Coles, Heath, and Ringgenberg (2022)), than otherwise identical non-index stocks in equilibrium. We show that these empirically consistent patterns are robust: they emerge not only when index investors are new to the market, but also when existing investors switch from trading individual stocks to index fund. We further elaborate on the mechanisms driving these results below.

The presence of index investors generates an "index effect", characterized by relatively higher prices for index stocks compared to otherwise-identical non-index stocks. This effect primarily stems from increased demand for index stocks when index investors are new to the market, and from reduced demand for non-index stocks when existing investors switch from trading individual stocks to index fund. More notably, we find that an increase in extrapolative indexers leads to a much weaker index effect. This result arises because, unlike rational indexers, extrapolative indexers amplify the volatility of index stocks, and consequently the index itself, through sentiment spillovers and amplification mechanisms described above. As a result, risk-averse investors reduce their demand for index stocks and the index fund, which limits the rise in index stock prices. Empirical evidence shows that the index effect was particularly strong in the 1980s and 1990s but has diminished significantly recently. For example, Greenwood and Sammon (2025) document that the abnormal price increase following a stock's addition to the S&P 500 was 7.4% in the 1990s, but has fallen to less than 1% over the past decade. They propose several potential explanations for this trend, finding strong empirical support for improvement in market liquidity. Our findings provide an additional, complementary explanation consistent with the improved liquidity interpretation: the growing participation of retail investors, who are more likely to have extrapolative expectations, may help explain the disappearing index effect.

We show that an increase in extrapolative index investors leads to stronger comovement among index stocks due to positive sentiment spillovers. Additionally, we find that rising extrapolative index investor participation results in more pronounced price reversals—i.e., stronger negative autocorrelation—for index stocks compared to non-index stocks. The underlying mechanism is as follows: a positive cash flow shock to an index constituent boosts the index level, which raises the expectations of extrapolative investors. These investors then increase their demand for the index fund, applying further upward price pressure. However, as time passes, the initial shock's influence diminishes in extrapolators' beliefs, reducing their demand and causing subsequent price declines—thus generating negative autocorrelation.

Furthermore, we show that an increase in index investors leads to higher trading volume in index stocks. This occurs because a cash flow shock to any index constituent alters index investors' demand for the index fund. To accommodate this demand, the index fund adjusts its holdings by buying or selling proportional amounts of all index stocks, thereby generating trades in all index stocks. Moreover, we demonstrate that trading volume in index stocks is even higher when index investors are extrapolators rather than rational. This effect stems from the fact that both index stock prices and investor sentiment become more volatile under extrapolative expectations. The resulting increase in belief dispersion intensifies disagreement among investors, which in turn leads to more frequent and aggressive trading activity in index stocks.

We also examine how index investing affects investors' welfare and find that the welfare loss from switching to index investing is greater for rational investors when the stock market is more heavily populated by extrapolators relative to rational stock investors. This finding is intuitive. The rational stock investors expect to make larger profits and would be unwilling to switch to index investing when there are more stock extrapolators who, compared to index extrapolators, generate more profit opportunities in individual stocks for them.

Our paper contributes to the extensive literature on subjective expectations in financial markets. More specifically, motivated by growing survey evidence that many investors' stock return expectations are extrapolative, several theories have been developed to study the asset pricing implications of such beliefs (e.g., Cutler, Poterba, and Summers (1991), De Long et al. (1990), Hong and Stein (1999), Barberis et al. (2015, 2018), Jin and Sui (2022), Atmaz (2022), Li and Liu (2023), Atmaz et al. (2024)). Among these, the framework closest to ours is Barberis et al. (2015), who consider a single-stock economy and show that extrapolative investors help explain various stock market regularities while aligning with survey evidence on investor expectations. In contrast, our analysis employs a multi-stock framework and incorporates an index fund along with index investors. These differences allow us to complement the existing literature by generating novel implications on the cross-sectional differences between index and non-index stocks.

Our paper also contributes directly to the growing theoretical literature on index investing. In this literature, several papers, like ours, examine the asset pricing implications of index investing in a dynamic framework (Grégoire (2020), Chabakauri and Rytchkov (2021), Jiang, Vayanos, and Zheng (2022)). Grégoire (2020) shows that index investing increases comovement among index stocks. Chabakauri and Rytchkov (2021) find that lockstep trading induced by indexing raises market volatility and comovement, though reduced risk sharing can mitigate these effects—ultimately lowering volatility and generating an ambiguous impact on comovement. Jiang, Vayanos, and Zheng (2022) demonstrate that index investing disproportionately lowers the financing costs of large firms and increases industry concentration.

Other studies investigate index investing in static settings with asymmetric information (Liu and Wang (2023), Baruch and Zhang (2022), Bond and Garcia (2022), Gârleanu and Pedersen (2022), Buss and Sundaresan (2023)). While these papers primarily focus on how index investing affects information production, price informativeness, and market efficiency, some also explore asset pricing implications, as we do. For example, Baruch and Zhang (2022) show that increased index investing increases stock comovement, while Buss and Sundaresan (2023) find that it results in higher and more volatile asset prices. Bond and Garcia (2022) show that more index investing leads to stronger return reversals but lower trading in individual stocks. Our paper differs from the above works on index investing along several dimensions, including methodology, underlying mechanisms, and predictions. In particular, none of these studies has the sentiment spillover mechanism central to our analysis, nor do they simultaneously reconcile the observed cross-sectional differences between index and non-index stocks as our model does.

Finally, our paper is also related to the literature on benchmarking concerns. Several theories show that active fund managers' tendency to tilt their portfolios towards stocks that compose their benchmark index can generate differential implications for index and non-index stocks. For example, Basak and Pavlova (2013) find that benchmarking concerns can produce an index effect, along with higher volatility and comovement among stocks in the benchmark index. Buffa and Hodor (2023) show that heterogeneity in benchmark incentives can generate spillovers leading to negative return comovement among stocks within the same benchmark. Pavlova and Sikorskaya (2022) find that increased benchmarking intensity raises a stock's price. Our mechanism differs fundamentally from these studies, as it is driven by extrapolative investors and the presence of an index fund, yielding a distinct set of novel implications. Distinguishing whether the empirical regularities are primarily driven by index investing or by benchmarking behavior among active managers ultimately requires careful empirical investigation—a task beyond the scope of this paper. In practice, both forces likely contribute. However, given the ongoing shift from active to passive investing, the relevance and explanatory power of the index investing channel are likely to increase over time.

The remainder of the paper is organized as follows. Section 2 introduces our model, and Section 3 characterizes the equilibrium. Section 4 studies the model's cross-sectional implications, and Section 5 explores the effects of switching to index investing and the associated welfare costs. Section 6 concludes. Appendix A provides all proofs, and Appendix B discusses the parameter values.

2 Model

In this section, we develop our model of index investing where some investors in the economy hold extrapolative expectations. The economy unfolds in continuous time over an infinite horizon, with uncertainty driven by an N-dimensional Brownian motion $\boldsymbol{\omega}_t = [\omega_{1t}, \omega_{2t}, \ldots, \omega_{Nt}]^\intercal$ defined on a probability space $(\Omega, \mathcal{F}, \mathbb{P})$ with an associated filtration $\{\mathcal{F}_t\}$.

2.1 Securities Market

The securities available for trading are a riskless asset, N risky stocks, and an index fund. The riskless asset is in perfectly elastic supply and pays a constant interest rate r. Each risky stock n, $n = 1, \ldots, N$, is in fixed positive supply of Q_n units, with the supply vector denoted by $\boldsymbol{Q} \equiv [Q_1, Q_2, \ldots, Q_N]^\intercal$. Each stock n is a claim to a dividend (cash flow) D_{nt}, with the dividends $\boldsymbol{D}_t \equiv [D_{1t}, D_{2t}, \ldots, D_{Nt}]^\intercal$ following

$$d\boldsymbol{D}_t = \boldsymbol{\mu}_D dt + \boldsymbol{\sigma}_D d\boldsymbol{\omega}_t, \tag{1}$$

where $\boldsymbol{\mu}_D$ is an $N \times 1$ vector of constants capturing the mean of dividend changes, and $\boldsymbol{\sigma}_D$ is an $N \times N$ matrix of constants capturing their volatility. The variance-covariance matrix of dividend changes is denoted by $\boldsymbol{\Sigma}_D \equiv \boldsymbol{\sigma}_D \boldsymbol{\sigma}_D^\intercal$. To highlight the effects of index investing clearly, we assume dividends are uncorrelated across stocks; i.e., $\boldsymbol{\sigma}_D$ is diagonal. The price of each stock n, S_{nt}, is determined endogenously in equilibrium with the stock price vector $\boldsymbol{S}_t \equiv [S_{1t}, S_{2t}, \ldots, S_{Nt}]^\intercal$ is posited to follow

$$d\boldsymbol{S}_t = \boldsymbol{\mu}_{St} dt + \boldsymbol{\sigma}_{St} d\boldsymbol{\omega}_t, \tag{2}$$

where the (possibly stochastic) $N \times 1$ vector $\boldsymbol{\mu}_{St}$ and $N \times N$ matrix $\boldsymbol{\sigma}_{St}$ capturing the mean and volatility of the stock price changes, respectively. The variance-covariance matrix of stock price changes is denoted by $\boldsymbol{\Sigma}_{St} \equiv \boldsymbol{\sigma}_{St} \boldsymbol{\sigma}_{St}^\intercal$.

In this economy, there is a capitalization-weighted index that consists of the first M stocks, $1 \leq M \leq N$. The index level at time $t \geq 0$ is given by

$$I_t = \boldsymbol{q}^\intercal \boldsymbol{S}_t, \tag{3}$$

where the $N \times 1$ vector of constants $\boldsymbol{q}$ is proportional to the index stocks' supply and is given by

$$\boldsymbol{q} = \frac{1}{\sum_{m=1}^{M} Q_m} [Q_1, Q_2, \ldots, Q_M, 0 \ldots, 0]^\intercal. \tag{4}$$

Under this specification, the index is equivalent to holding $q_j = Q_j / \sum_{m=1}^{M} Q_m$ shares in an index stock j, $j = 1, \ldots, M$, and no shares in a non-index stock n, $n = M+1, \ldots, N$.[2]

Investors can trade the index through a passive index fund, e.g., an exchange-traded fund (ETF), whose each share replicates the index without any tracking error, and thus, is a claim to q_j shares in each index stock j. Hence, at time t, each fund share costs I_t and yields a dollar return of $dI_t + D_{It}dt$ over the next instant dt, where $dI_t = \boldsymbol{q}^\intercal d\boldsymbol{S}_t$ is the change in the index level and $D_{It} = \boldsymbol{q}^\intercal \boldsymbol{D}_t$ is the total dividend paid out by the index stocks. Accordingly, the index dividend and its level follow

$$dD_{It} = \mu_{DI} dt + \sigma_{DI} d\omega_{It}, \tag{5}$$

$$dI_t = \mu_{It} dt + \sigma_{It} d\omega_{It}, \tag{6}$$

where the constants $\mu_{DI} \equiv \boldsymbol{q}^\intercal \boldsymbol{\mu}_D$ and $\sigma_{DI} \equiv \sqrt{\boldsymbol{q}^\intercal \boldsymbol{\Sigma}_D \boldsymbol{q}}$ capture the mean and the volatility of the index dividend changes, and the scalars $\mu_{It} \equiv \boldsymbol{q}^\intercal \boldsymbol{\mu}_{St}$ and $\sigma_{It} = \sqrt{\boldsymbol{q}^\intercal \boldsymbol{\Sigma}_{St} \boldsymbol{q}}$ represent the mean and the volatility of the index changes, respectively. Here, $\omega_{It} \equiv (1/\sigma_{DI}) \boldsymbol{q}^\intercal \boldsymbol{\sigma}_D \boldsymbol{\omega}_t$ is a standard one-dimensional Brownian motion with its associated filtration denoted by $\{\mathcal{F}_{It}\}$.[3] We note that $\mathcal{F}_{It} \subseteq \mathcal{F}_t$, as observing only the index level conveys less information than observing the price of each individual index stock.

[2]The normalization by $\sum_{m=1}^{M} Q_m$ in (4) does not play an economic role in our results. We consider this scaling to have a weighted-average construction for $\boldsymbol{q}$ so that the choice of number of stocks M in the index does not affect the magnitude of index returns.

[3]As we demonstrate in the Proof of Proposition 1 in Appendix A, due to consistency, we have $\omega_{It} = (1/\sigma_{DI}) \boldsymbol{q}^\intercal \boldsymbol{\sigma}_D \boldsymbol{\omega}_t = (1/\sigma_{It}) \boldsymbol{q}^\intercal \boldsymbol{\sigma}_{St} \boldsymbol{\omega}_t$ in equilibrium.

2.2 Investors' Beliefs and Investment Profiles

The economy is populated by a continuum of investors who differ in their beliefs and investment profiles. In terms of beliefs, investors hold either *rational* or *extrapolative* expectations. With respect to investment profile, they can either be an individual *stock* or *index* investor.

The extrapolative beliefs in our model are motivated by survey evidence indicating that individual investors typically form return expectations based on recent stock performance—that is, they expect higher (lower) future returns following periods of high (low) past returns. Such extrapolative expectations are well documented both at the aggregate level (e.g., Vissing-Jorgensen (2003), Amromin and Sharpe (2013), Greenwood and Shleifer (2014), Cassella and Gulen (2018)) and at the individual stock level (Da, Huang, and Jin (2021)).[4] In contrast, the evidence for extrapolative behavior among institutional investors is weak or mixed (e.g., Da, Huang, and Jin (2021), Andonov and Rauh (2022), Nagel and Xu (2023), Dahlquist and Ibert (2024)). Given this evidence, extrapolators in our model can be viewed as unsophisticated retail investors who form expectations using simple extrapolative rules. In contrast, rational investors can be interpreted as sophisticated institutional investors or professional traders who are able to estimate return dynamics more accurately, due to their greater expertise and technological resources.

Rational stock investors have a population mass of π_r and can invest in the riskless asset and N individual stocks. They do not invest in the index fund since it would be redundant given their stock investments in our frictionless economy. These investors observe individual stock prices $\boldsymbol{S}_t$ (and dividends $\boldsymbol{D}_t$) and have correct expectations about their means and volatilities. Hence, from their point of view, stock dividends and prices follow (1) and (2), respectively. Similarly, *rational index investors,* denoted by $\mathcal{R}$, have a population mass of $\pi_{\mathcal{R}}$ and can invest in the riskless asset and the index fund, but not in individual stocks. Accordingly, we assume that these investors observe the index level I_t (and its dividend D_{It}) and have correct expectations about the mean and volatility of index level changes. Thus, from their point of view, index dividend and level follow (5) and (6), respectively.

[4]See also Egan, MacKay, and Yang (2022) and Cassella et al. (2025) for non-survey based evidence and Afrouzi et al. (2023) for experimental evidence for extrapolative expectations. Moreover, in our specification, all investors' unconditional expectations are the same and equal to the true one, consistent with Adam, Matveev, and Nagel (2021) who show that survey expectations of stock returns are unconditionally approximately unbiased.

Stock extrapolators, denoted by e, have a population mass of π_e, and akin to rational stock investors, can invest in the riskless asset and N individual stocks but not the index fund. These investors observe individual stock prices $\boldsymbol{S}_t$ (and dividends $\boldsymbol{D}_t$) and agree on their volatilities but misperceive their means. We follow the tractable formulation in Barberis et al. (2015) and model extrapolators' expectation of stock price changes as an exponentially decaying weighted average of past stock price changes:

$$\mathrm{E}_t^e \left[d\boldsymbol{S}_t \right] / dt = \boldsymbol{X}_t \qquad \text{where} \qquad \boldsymbol{X}_t = \int_{-\infty}^{t} \kappa e^{-\kappa(t-s)} d\boldsymbol{S}_{s-dt}. \tag{7}$$

The n^{th} entry of the $N \times 1$ vector $\boldsymbol{X}_t$ gives the stock extrapolators' conditional expectation of the n^{th} stock, X_{nt}. We follow the literature and refer to the process $\boldsymbol{X}_t$ as *"stock sentiment"* and the parameter κ as *"degree of extrapolation."*[5] A higher degree of extrapolation κ implies that stock extrapolators assign more weights to the most recent stock performance relative to distant ones while forming their expectations. Thus, from stock extrapolators' point of view, stock prices follow

$$d\boldsymbol{S}_t = \boldsymbol{X}_t dt + \boldsymbol{\sigma}_{St} d\boldsymbol{\omega}_t^e, \tag{8}$$

where $\boldsymbol{\omega}_t^e$ is an N-dimensional Brownian motion under their subjective probability measure $\mathbb{P}^e$. Accordingly, they perceive the dividend dynamics as $d\boldsymbol{D}_t = \boldsymbol{\mu}_{Dt}^e dt + \boldsymbol{\sigma}_D d\boldsymbol{\omega}_t^e$, where $\boldsymbol{\mu}_{Dt}^e = \boldsymbol{\mu}_D + \boldsymbol{\sigma}_D \boldsymbol{\sigma}_{St}^{-1} \left(\boldsymbol{X}_t - \boldsymbol{\mu}_{St} \right)$ is their subjective mean of dividends changes.

Index extrapolators, denoted by ε, have a population mass of π_ε, and akin to rational indexers, can invest in the riskless asset and the index fund, but not in individual stocks. These investors observe only the index level I_t but not the prices of individual stocks. Differently from rational indexers, they agree on the index volatility σ_{It} but misperceive its mean in a way that their expectation of index changes is

[5] We note that referring to the process $\boldsymbol{X}_t$ as the sentiment is also consistent with the widespread usage of the term in the literature. For instance, Brown and Cliff (2004) show that the past stock returns are important determinants of commonly employed sentiment measures in empirical studies. Moreover, we view the extrapolative belief formation as an investor-specific behavior rather than stock-specific. Therefore, the parameter κ is common to all stocks. That said, our model remains tractable under the alternative formulation of stock-specific degree of extrapolation κ_n, $n = 1, \ldots, N$. Our model can also accommodate a more general affine functional form for extrapolators' expectation, e.g., $\mathrm{E}_t^e \left[d\boldsymbol{S}_t \right] / dt = \overline{\boldsymbol{\lambda}} + \mathrm{diag}\left(\boldsymbol{\lambda} \right) \boldsymbol{X}_t$ for constant vectors $\overline{\boldsymbol{\lambda}}$ and $\boldsymbol{\lambda}$. Given the evidence in Barberis et al. (2015), we focus on the case $\overline{\boldsymbol{\lambda}} = \mathbf{0}$ and $\boldsymbol{\lambda} = \mathbf{1}$.

an exponentially decaying weighted average of past index changes

$$\mathrm{E}_t^{\varepsilon}\left[dI_t\right]/dt = X_{It} \qquad \text{where} \qquad X_{It} = \int_{-\infty}^{t} \kappa e^{-\kappa(t-s)} dI_{s-dt}. \tag{9}$$

Therefore, index extrapolators expect higher (lower) index fund returns following a good (bad) index performance. Again, a higher value of κ implies that these extrapolators assign more weights to the most recent index performance relative to distant ones while forming their expectations. We note that the *"index sentiment"* X_{It} satisfies $X_{It} = \boldsymbol{q}^{\intercal}\boldsymbol{X}_t$. Therefore, even without index extrapolators, $\pi_{\mathcal{E}} = 0$, there is a non-trivial sentiment on the index as long as some stock extrapolators exist in the economy, $\pi_e > 0$. From index extrapolators' point of view, the index evolves according to

$$dI_t = X_{It}dt + \sigma_{It} d\omega_{It}^{\varepsilon}, \tag{10}$$

where $\omega_{It}^{\varepsilon}$ is a one-dimensional Brownian motion under their subjective probability measure $\mathbb{P}^{\varepsilon}$. Accordingly, they perceive the index dividend dynamics as $dD_{It} = \mu_{DI}^{\varepsilon}dt + \sigma_{DI}d\omega_{It}^{\varepsilon}$, where $\mu_{DI}^{\varepsilon} = \mu_{DI} + \sigma_{DI}\sigma_{It}^{-1}\left(X_{It} - \mu_{It}\right)$ is their subjective mean of index dividend changes.

Remark 1 (Further discussion on index investors). In our analysis, we do not model the specific reasons why some investors choose to trade the index fund rather than individual stocks. The literature offers several potential explanations for index investing, including trading costs, information acquisition costs, cognitive and attention constraints, and management fees. We abstract from these frictions to focus on the equilibrium implications of extrapolative index investors in a simplified and transparent setting, without committing to any particular cost-based rationale.[6] That said, a simple way to incorporate costs in our framework would be to introduce a holding cost of ϵdt over the next instant dt for each risky asset investors trade. A sufficiently high ϵ and M would create an incentive to trade the index fund—incurring a cost of ϵdt—rather than trading all M individual stocks, which would entail a total cost of $M\epsilon dt$.

In our model, index investors do not trade individual stocks and therefore have no need to monitor

[6] Other works on index investing considering a frictionless economy like ours include Chabakauri and Rytchkov (2021) and Jiang, Vayanos, and Zheng (2022). For an equilibrium with index participation costs, see Bond and Garcia (2022).

individual stock prices. Therefore, their consumption and portfolio strategies are adapted to a coarser filtration $\{\mathcal{F}_{It}\}$, generated by ω_{It}, which captures the information relevant to the index fund. Alternatively, one could assume that index investors observe all individual stock prices but are constrained to invest only in the index fund. In this case, their strategies would be adapted to the full filtration $\{\mathcal{F}_t\}$ generated by $\boldsymbol{\omega}_t$. We find that both modeling choices yield similar results in our frictionless setting.

2.3 Investors' Preferences and Optimization

Each i-type investor, $i = r, e, \mathcal{R}, \mathcal{E}$, is endowed with identical initial wealth W_0 and a constant absolute risk aversion (CARA) preferences with identical absolute risk aversion coefficient $\gamma > 0$ and time discount rate $\rho > 0$.[7] Each investor optimally chooses her intertemporal consumption c_{it} and an admissible portfolio strategy (adapted to the respective filtration) to maximize her subjective expected utility from a life-time consumption

$$\mathrm{E}^i \left[\int_0^\infty e^{-\rho t} \frac{e^{-\gamma c_{it}}}{-\gamma} dt \right],$$

subject to her dynamic budget constraint

$$dW_{it} = \begin{cases} rW_{it}dt + \boldsymbol{\psi}_{it}^\intercal \left(d\boldsymbol{S}_t + \boldsymbol{D}_t dt - r\boldsymbol{S}_t dt \right) - c_{it}dt & \text{for } i = r, e, \\ rW_{it}dt + \psi_{it} \left(dI_t + D_{It}dt - rI_t dt \right) - c_{it}dt & \text{for } i = \mathcal{R}, \mathcal{E}, \end{cases} \tag{11}$$

where E^i denotes the unconditional expectation under i-type investors' subjective beliefs $\mathbb{P}^i$, the $N \times 1$ vector $\boldsymbol{\psi}_{it}$ denotes the portfolio of the i-type stock investors, $i = r, e$, as the number of shares in individual stocks, and the scalar ψ_{it} denotes the portfolio of the i-type index investors, $i = \mathcal{R}, \mathcal{E}$, as the number of shares in the index fund.

[7]Our model could be extended to incorporate heterogeneous risk aversion among investor types, such as index investors to be more risk-averse than stock investors, as in Chabakauri and Rytchkov (2021).

3 Equilibrium

In this section, we characterize the equilibrium in our index investing economy with extrapolative investors. As a key finding, we demonstrate that index investing generates a novel sentiment spillover effect: the sentiment of an index stock affects not only the price of that stock but also the prices of all other stocks included in the index.

The equilibrium in our economy is defined in a standard way. The economy is said to be in equilibrium if stock prices $\boldsymbol{S}_t$, the index level I_t, and consumption-portfolio strategies of stock investors $(c_{it}, \boldsymbol{\psi}_{it})_{i=r,e}$ and index investors $(c_{it}, \psi_{it})_{i=\mathcal{R},\mathcal{E}}$ are such that all investors optimally choose their strategies given prices and beliefs, and the stock market clears for all t,

$$\pi_r \boldsymbol{\psi}_{rt} + \pi_e \boldsymbol{\psi}_{et} + \left(\pi_{\mathcal{R}} \psi_{\mathcal{R}t} + \pi_{\mathcal{E}} \psi_{\mathcal{E}t}\right) \boldsymbol{q} = \boldsymbol{Q}. \tag{12}$$

We employ the standard stochastic dynamic programming method (e.g., Merton (1971)) to solve for each investor's optimal consumption and portfolio strategies and apply the stock market clearing condition (12) to obtain the equilibrium.[8] Proposition 1 characterizes the equilibrium in our index investing economy with extrapolators by presenting the equilibrium prices of individual stocks, the index level, along with investors' consumption and portfolio strategies.

Proposition 1 (**Equilibrium**). *In the index investing economy with extrapolators, the equilibrium prices of individual stocks are given by*

$$\boldsymbol{S}_t = \boldsymbol{A} + \boldsymbol{B}\boldsymbol{X}_t + \frac{1}{r}\boldsymbol{D}_t, \tag{13}$$

where the $N \times 1$ vector of constants $\boldsymbol{A}$ and the $N \times N$ matrix of constants $\boldsymbol{B}$ solve systems of non-linear equations provided in Appendix A, and the equilibrium stock sentiment evolves according to

$$d\boldsymbol{X}_t = \kappa \boldsymbol{\Lambda} \left(\bar{\boldsymbol{X}} - \boldsymbol{X}_t\right) dt + \frac{\kappa}{r} \boldsymbol{\Lambda} \boldsymbol{\sigma}_D d\boldsymbol{\omega}_t, \tag{14}$$

[8]The bracketed term $\pi_{\mathcal{R}} \psi_{\mathcal{R}t} + \pi_{\mathcal{E}} \psi_{\mathcal{E}t}$ in (12) represents the total number of index fund shares held by index investors at time t. Since each index fund share is a claim to $\boldsymbol{q}$ shares of individual stocks, multiplying this term with $\boldsymbol{q}$ yields the total demand for stocks originating from the index fund.

where $\boldsymbol{\Lambda} = (\boldsymbol{I}_N - \kappa \boldsymbol{B})^{-1}$ *and* $\bar{\boldsymbol{X}} = \boldsymbol{\mu}_D / r$*, with* $\boldsymbol{I}_N$ *denoting the* $N \times N$ *identity matrix.*

The equilibrium index level is given by

$$I_t = A_I + B_I X_{It} + \frac{1}{r} D_{It}, \tag{15}$$

where $A_I = \boldsymbol{q}^\intercal \boldsymbol{A}$ *and* B_I *satisfies* $\boldsymbol{B}^\intercal \boldsymbol{q} = B_I \boldsymbol{q}$*, and the equilibrium index sentiment follows*

$$dX_{It} = \kappa \Lambda_I \left(\bar{X}_I - X_{It} \right) dt + \frac{\kappa}{r} \Lambda_I \sigma_{DI} d\omega_{It}, \tag{16}$$

where $\Lambda_I = (1 - \kappa B_I)^{-1}$ *and* $\bar{X}_I = \mu_{DI} / r$*.*

The equilibrium consumption and portfolio strategies of i-type stock investor, $i = r, e$*, are given by*

$$c_{it} = rW_{it} - \frac{1}{\gamma} \ln(\gamma r) - \frac{1}{\gamma} \left(F_i + \boldsymbol{G}_i^\intercal \boldsymbol{X}_t - \tfrac{1}{2} \boldsymbol{X}_t^\intercal \boldsymbol{H}_i \boldsymbol{X}_t \right) \qquad \text{and} \qquad \boldsymbol{\psi}_{it} = \boldsymbol{K}_i + \boldsymbol{L}_i \boldsymbol{X}_t, \tag{17}$$

and those of i-type index investor, $i = \mathcal{R}, \mathcal{E}$*, by*

$$c_{it} = rW_{it} - \frac{1}{\gamma} \ln(\gamma r) - \frac{1}{\gamma} \left(F_i + G_i X_{It} - \tfrac{1}{2} H_i X_{It}^2 \right) \qquad \text{and} \qquad \psi_{it} = K_i + L_i X_{It}, \tag{18}$$

where the scalars F_i*,* G_i*,* H_i*, the* $N \times 1$ *vector of constants* $\boldsymbol{G}_i$*, and the* $N \times N$ *symmetric matrix of constants* $\boldsymbol{H}_i$ *solve systems of non-linear equations provided in Appendix A, and the scalars* K_i *and* L_i *are given by* (A.27) *and* (A.28)*, the* $N \times 1$ *vector of constant* $\boldsymbol{K}_i$ *and the* $N \times N$ *matrix of constants* $\boldsymbol{L}_i$ *are given by* (A.10) *and* (A.11)*.*

Proposition 1 shows that, in the presence of extrapolative investors, individual stock prices take simple linear forms and are driven not only by their cash flows (dividends) $\boldsymbol{D}_t$, but also by sentiment $\boldsymbol{X}_t$. In the absence of index investors, the coefficient matrix $\boldsymbol{B}$, which captures the sensitivity of prices to sentiment, becomes diagonal. Consequently, each stock's sentiment affects only its own price, without affecting the prices of other stocks. For example, in an economy with $N = 5$ stocks and no index investors, the matrix $\boldsymbol{B}$ takes the form:

$$\boldsymbol{B} = \begin{bmatrix} + & 0 & 0 & 0 & 0 \\ 0 & + & 0 & 0 & 0 \\ 0 & 0 & + & 0 & 0 \\ 0 & 0 & 0 & + & 0 \\ 0 & 0 & 0 & 0 & + \end{bmatrix}. \tag{19}$$

In this case, each stock's price is positively associated with its own sentiment, determined by its own past performance. This result is well-documented in the extrapolative expectations literature (e.g., Barberis, Greenwood, Jin, and Shleifer (2015)). It arises because, after a sequence of positive returns, extrapolative investors anticipate continued price increases and raise their demand for the stock, thereby reinforcing the positive relationship between a stock's past performance and its current price.

With index investors present, stock prices exhibit richer dynamics due to *sentiment spillover*: the sentiment of each index stock affects not only its own price but also the prices of other index stocks. In other words, off-diagonal entries of the coefficient matrix $\boldsymbol{B}$ corresponding to index stocks become non-zero in equilibrium. For example, if the index includes the first three stocks ($M = 3$) and the marginal index investor is extrapolative, the equilibrium coefficient matrix $\boldsymbol{B}$ takes the form:

$$\boldsymbol{B} = \begin{bmatrix} + & + & + & 0 & 0 \\ + & + & + & 0 & 0 \\ + & + & + & 0 & 0 \\ 0 & 0 & 0 & + & 0 \\ 0 & 0 & 0 & 0 & + \end{bmatrix}. \tag{20}$$

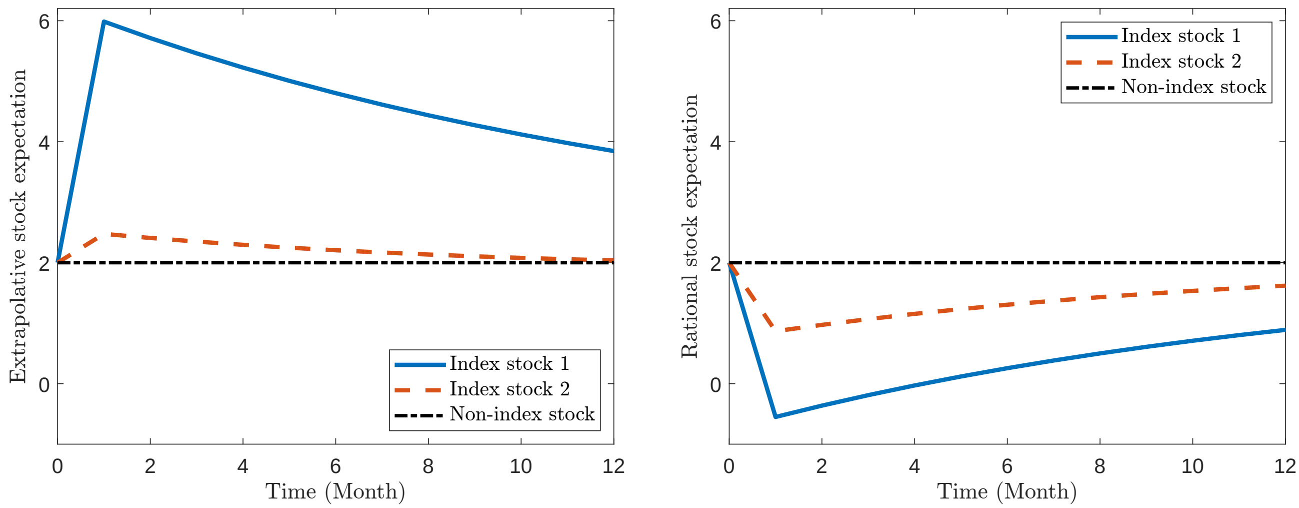
In this case, the price of an index stock is also positively related to the cash flow shocks, and thus, sentiment of all other index stocks. This positive spillover arises because a positive cash flow shock to one index stock raises its sentiment and price, thereby increasing the overall index level. As a result, extrapolative index investors expect further increases in the index and demand more index fund shares.

Since the fund allocates this increased demand proportionally across all index stocks to replicate the index, all constituent stocks experience higher demand, creating a positive relation between the price of an index stock and the sentiment of other index stocks. In contrast, if the marginal index investor is rational, the price of an index stock remains positively related to its own sentiment but negatively related to the sentiment of other index stocks. This negative spillover arises because a rise in one constituent's sentiment lifts the index level, which rational investors correctly interpret as sentiment-driven overvaluation. Anticipating a decline, they reduce their demand for index fund shares, thereby decreasing the prices of the other index stocks. As we show in Section 4, this spillover mechanism plays a crucial role in explaining the strong comovement among index stocks, as well as other empirically documented cross-sectional differences between index and non-index stocks.

Turning to the stock sentiment process $\boldsymbol{X}_t$, we see from (14) that it follows an N-dimensional mean-reverting Ornstein-Uhlenbeck process under the objective measure.[9] Thus, it generates predictable variation in individual stock prices from the perspective of rational investors: high sentiment $\boldsymbol{X}_t$ signals inflated prices. We refer to the key matrix $\boldsymbol{\Lambda}$ in the sentiment dynamics as the *stock amplification term,* since it captures the extent to which stock sentiment—and thus stock prices—respond to cash flow shocks. Notably, when the price-sentiment coefficient matrix $\boldsymbol{B}$ contains non-zero off-diagonal elements due to sentiment spillovers, so does the amplification matrix $\boldsymbol{\Lambda} = (\boldsymbol{I}_N - \kappa\boldsymbol{B})^{-1}$. This implies that, in the presence of index investors, the rational expectation of an index stock's future sentiment depends on the current sentiments of all other index stocks.

To better highlight this sentiment spillover, Figure 1 illustrates how investors' subjective expectations respond over time to a cash flow shock to the first index stock. We observe that extrapolative investors raise their expectations not only for the index stock that experienced the shock, but also—albeit to a lesser extent—for other index stocks, reflecting the sentiment spillover. In contrast, rational investors correctly interpret the resulting overvaluation as sentiment-driven and anticipate future price declines

[9] Consequently, the sentiment process $\boldsymbol{X}_t$ admits a stationary Gaussian distribution when all eigenvalues of its persistence matrix $\kappa\boldsymbol{\Lambda}$ have positive real parts. In this case, the ergodic distribution of $\boldsymbol{X}_t$ is characterized by its long-run mean $\bar{\boldsymbol{X}} = \boldsymbol{\mu}_D/r$ and variance $\mathrm{Var}\left[\boldsymbol{X}_\infty\right] \equiv \lim_{t\to\infty} \mathrm{Var}\left[\boldsymbol{X}_t\right] = \mathrm{vec}^{-1}\left[\left(\kappa\boldsymbol{\Lambda} \oplus \kappa\boldsymbol{\Lambda}\right)^{-1} \mathrm{vec}\left[\boldsymbol{\Sigma}_X\right]\right]$, where $\boldsymbol{\Sigma}_X \equiv \mathrm{Var}_t\left[d\boldsymbol{X}_t\right]/dt = \frac{\kappa^2}{r^2}\boldsymbol{\Lambda}\boldsymbol{\Sigma}_D\boldsymbol{\Lambda}^\intercal$. Here, $\oplus$ denotes the Kronecker sum, vec [.] stacks the columns of a matrix into a vector, and $\mathrm{vec}^{-1}[.]$ reverses this operation. Our numerical analysis confirms that, for a wide range of plausible parameter values—including our baseline calibration—the model admits stationary equilibria in which all eigenvalues of $\kappa\boldsymbol{\Lambda}$ have positive real parts.



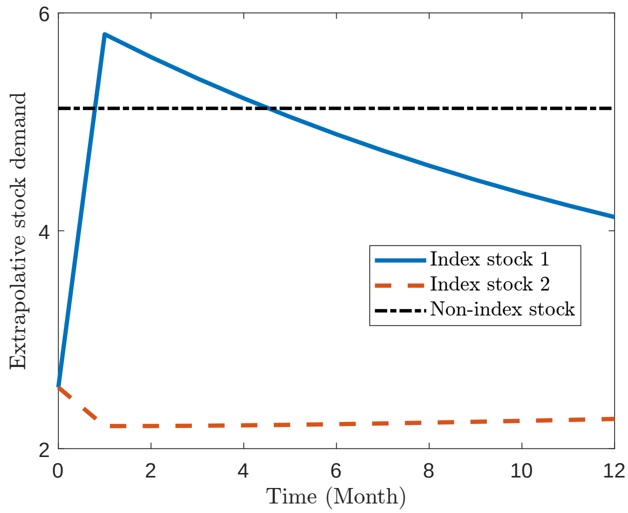
Panel A. Extrapolative response to cash flow shock ω_1

Panel B. Rational response to cash flow shock ω_1

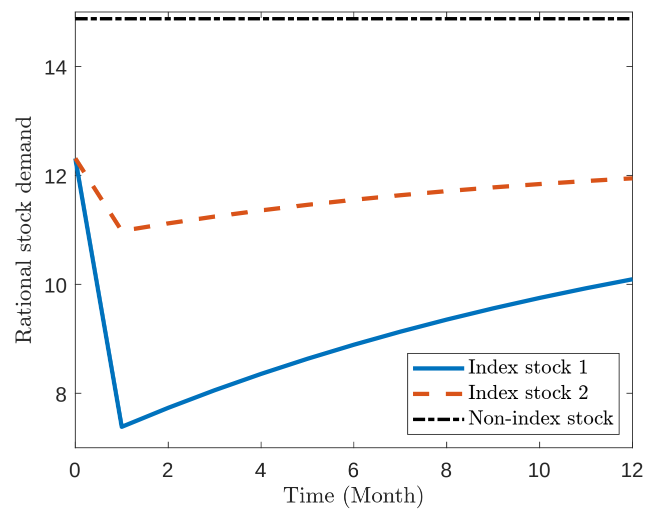
Figure 1. Impulse response of subjective expectations to a cash flow shock. These panels plot the expectations of extrapolators (Panel A) and rational investors (Panel B) in response to cash flow shock to the first index stock at time 1 when the stock sentiment is at its long-run average $\boldsymbol{X}_t = \bar{\boldsymbol{X}}$. The population shares of investors are $(\pi_r, \pi_e, \pi_{\mathcal{R}}, \pi_{\mathcal{E}}) = (0.25, 0.25, 0, 0.5)$. All other parameter values are as in Table B1.

in index stocks, with smaller expected declines for those stocks indirectly affected by the spillover.

Proposition 1 shows that the equilibrium index level I_t also takes a simple linear form and is driven by its cash flow D_{It} and its sentiment X_{It}. A key feature of the equilibrium is that the index level increases with its sentiment (i.e., past performance), implying a positive sentiment coefficient $B_I > 0$. This positive relation arises as long as some extrapolators—either stock or index extrapolators—are present in the economy. For example, when only stock extrapolators are present, positive cash flow shocks to some index stocks raise both their prices and their individual sentiments. Extrapolative stock investors respond by further increasing demand for those stocks, driving their prices—and consequently the index level—even higher, thus generating a positive B_I. Similarly, when only index extrapolators are present, an increase in the index level raises index sentiment. In turn, extrapolative index investors increase their demand for index fund shares, pushing the index level further up—again resulting in a positive B_I. We also see that the index sentiment process (16) follows a one-dimensional Ornstein-Uhlenbeck process driven by a single Brownian motion ω_{It}, which generates the filtration $\{\mathcal{F}_{It}\}$. We refer to the term $\Lambda_I = (1 - \kappa B_I)^{-1}$ as the *index amplification term,* since it plays an analogous role to



Panel A. Extrapolative response to cash flow shock ω_1



Panel B. Rational response to cash flow shock ω_1

Figure 2. Impulse response of stock demand to a cash flow shock. These panels plot the stock demand of extrapolators (Panel A) and rational investors (Panel B) in response to cash flow shock to the first index stock at time 1 when the stock sentiment is at its long-run average $\boldsymbol{X}_t = \bar{\boldsymbol{X}}$. The population shares of investors are $(\pi_r, \pi_e, \pi_{\mathcal{R}}, \pi_{\mathcal{E}}) = (0.25, 0.25, 0, 0.5)$. All other parameter values are as in Table B1.

its stock-level counterpart and determines the extent to which index sentiment—and thereby the index level—is amplified in response to cash flow shocks.

Examining the equilibrium consumption and portfolio strategies in (17)–(18), we observe that stock investors' strategies are driven by the sentiment process $\boldsymbol{X}_t$ and are therefore adapted to the full filtration $\{\mathcal{F}_t\}$. In contrast, index investors' strategies are driven by the index sentiment X_{It} and are adapted to the coarser filtration $\{\mathcal{F}_{It}\}$, with the relation $\mathcal{F}_{It} \subseteq \mathcal{F}_t$ holding for all t. This difference arises because stock investors observe the prices and dividends of individual stocks, while index investors observe only the aggregate index level and its associated dividend. As a result, stock investors base their decisions on a richer information set. We also observe a convex relation between investors' consumption and sentiments. Typically, the matrix $\boldsymbol{H}_i$ is positive definite for stock investors, and the scalar H_i is positive for index investors, implying that investors consume more in extreme sentiment states—both high and low. In such extreme states, all types of investors expect to make large gains from their respective portfolios, leading to higher consumption through the income effect.

Proposition 1 further shows that investors' equilibrium portfolios are linearly related to sentiment.

In particular, index extrapolators' demand for the index fund increases with index sentiment ($L_{\mathcal{E}} > 0$), while rational index investors' demand decreases ($L_{\mathcal{R}} < 0$), confirming that index investors' portfolios reflect their subjective expectations. When the index level rises, index extrapolators become more optimistic about future performance and increase their demand for index fund shares. In contrast, rational index investors interpret the elevated index level as sentiment-driven overvaluation and anticipate mean reversion, thereby reducing their demand for the fund. While the portfolio behavior of index investors is straightforward, stock investors display more interesting—and somewhat surprising—portfolio behavior. To that end, in Figure 2, we illustrate how stock investors adjust their holdings in response to a cash flow shock to the first index stock.

Figure 2 shows that extrapolative investors increase their holdings of the index stock that experienced the shock, consistent with their subjective expectations. However, they reduce their holdings of other index stocks, even though their expectations for these stocks also rise due to sentiment spillovers, as shown in Figure 1. This seemingly counterintuitive behavior is driven by a substitution effect that naturally arises in multi-stock portfolio choice. Specifically, extrapolators' expectations for the shocked index stock increase substantially more, leading them to overinvest in that stock. Consequently, stock extrapolators reduce their holdings of the other index stocks to limit their aggregate risk exposure, given that index stocks are positively correlated due to sentiment spillovers (see also Section 4.3). On the other hand, Panel B shows that rational investors recognize the overvaluation resulting from the shock and accordingly reduce their holdings of index stocks. The portfolio reductions are more pronounced for the index stock that experienced the shock, while the declines are more moderate for stocks indirectly affected by the sentiment spillover—consistent with their subjective expectations.

Recently, there has been growing interest in understanding whether investors act on their subjective beliefs when forming portfolios. Several studies find that investors' portfolio responses to their beliefs are much smaller than what standard portfolio theories predict, which is often referred to as the "attenuation puzzle" (e.g., Amromin and Sharpe (2013), Ameriks et al. (2020), Giglio et al. (2021), Dahlquist and Ibert (2024)). Our findings contribute to understanding this puzzle by showing that sentiment spillovers can make portfolios unresponsive to beliefs for index stocks.

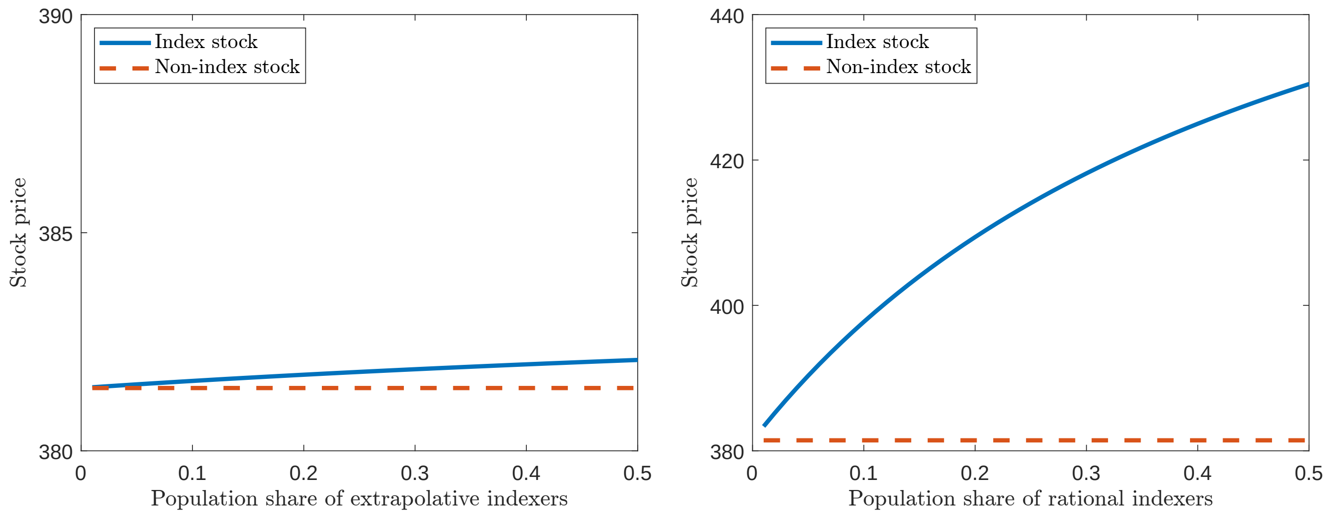
4 Cross-Sectional Effects of Index Investing

Having characterized the equilibrium, we now examine our model's implications for cross-sectional differences between index and non-index stocks. We show that when the marginal index investor is extrapolative—all consistent with empirical evidence—index stocks exhibit higher and more volatile prices, stronger comovement with other index stocks, more pronounced negative return autocorrelations, and greater trading volume compared to otherwise identical non-index stocks. We further demonstrate that the index effect is much smaller when index investors are extrapolators. In the following section, we also show that these empirically consistent patterns are robust: they emerge not only when index investors are new to the market, but also when existing investors switch from trading individual stocks to index fund.

4.1 Stock Price and Index Effect

Beginning with the seminal studies of Harris and Gurel (1986) and Shleifer (1986), a large body of empirical research has documented that stocks tend to experience price increases (decreases) following their inclusion in (removal from) the S&P 500 and other major indices—a phenomenon commonly referred to as the index effect. This effect was particularly pronounced during the 1980s and 1990s but has weakened considerably in recent years. For example, Greenwood and Sammon (2025) report that the abnormal price increase associated with S&P 500 inclusions averaged 7.4% in the 1990s but has declined to below 1% over the past decade. We argue that the recent growth in index investing by retail investors—who are more likely to exhibit extrapolative expectations—may help explain the disappearing index effect. To demonstrate this result, we use the equilibrium prices derived in Proposition 1 and illustrate the distinct price impacts of extrapolative and rational index investors in Figure 3.

Figure 3 illustrates that a higher population share of index investors leads to a stronger index effect by raising the prices of index stocks, while leaving the prices of non-index stocks unchanged. This effect arises because index investor demand for the index fund raises equilibrium prices of the underlying index stocks. However, more interestingly, the magnitude of the index effect is much smaller when the index investors are extrapolators. This result can be understood through the shifts in the supply and



Panel A. Effects of $\pi_{\mathcal{E}}$

Panel B. Effects of $\pi_{\mathcal{R}}$

Figure 3. Stock price and index effect. These panels plot the index and non-index stock prices in equilibrium by varying the population share of extrapolative indexers (Panel A) and rational indexers (Panel B) when the stock sentiment is at its long-run average $\boldsymbol{X}_t = \bar{\boldsymbol{X}}$ and the population share of stock investors are $\pi_r = 0.5$ and $\pi_e = 0.5$. All other parameter values are as in Table B1.

demand curves faced by stock investors. The entry of index investors reduces the residual supply of index stocks available to stock investors, with the size of this shift depending on the indexers' beliefs. When index investors are extrapolators, their sentiment-driven demand induces greater volatility in the index (see also Section 4.2), making the index fund less attractive in equilibrium. As a result, their overall demand for the fund is lower, leading to a smaller upward shift in the residual supply curve. Combined with a downward shift in the aggregate demand curve due to higher volatility, this generates a weaker index effect as illustrated in Panel A. In contrast, rational index investors stabilize the index by dampening the sentiment-driven volatility arising from stock extrapolators, thereby making index stocks more attractive to stock investors. This results in a larger upward shift in the residual supply curve, as well as an *upward* shift in aggregate demand due to lower volatility, ultimately producing a larger index effect in equilibrium as depicted in Panel B.[10]

As discussed earlier, the index effect has substantially diminished over the past decade. Green-

[10] We note that our analysis in this section includes both rational and extrapolative stock investors, which generates rich asset pricing dynamics even without index investors. It is important to highlight that all our results are robust and continue to hold in a simpler economy without stock extrapolators. For instance, in such an economy, the introduction of rational index investors does not affect the volatility of index stocks—implying no shift in the demand curve. However, the upward shift in the supply curve from index fund demand still results in a substantial index effect.

wood and Sammon (2025) propose several potential explanations for this trend, including: (i) changes in the composition of index additions and deletions; (ii) front-running due to increasingly predictable index changes; (iii) migration from other indices; and (iv) improved market liquidity. Among these, their empirical analysis finds the strongest support for the last two explanations. Our findings offer an additional, complementary explanation—also consistent with the improved liquidity interpretation. Specifically, the growing participation of retail investors, who are more likely to exhibit extrapolative expectations, may help account for the disappearing index effect as demonstrated above.[11] Put differently, the mechanism in our model supports the efficient markets argument highlighted by Greenwood and Sammon (2025): when index demand is driven by sentiment-based fluctuations, well-capitalized arbitrageurs—represented by rational investors in our model—respond aggressively by supplying liquidity, thereby limiting the price impact. Conversely, if index demand were not driven by sentiment, arbitrageurs would have no incentive to respond, resulting in a larger index effect.

4.2 Stock Volatility

Another well-documented empirical regularity in index investing literature is that more index investing tends to increase the volatility of index stocks (e.g., Sullivan and Xiong (2012), Ben-David et al. (2018), Coles, Heath, and Ringgenberg (2022)). To examine this phenomenon within our framework, we derive the equilibrium volatility of individual stock price changes in Proposition 2.

Proposition 2 (Equilibrium stock volatility). *In the index investing economy with extrapolators, the equilibrium price change volatility of stock n, $n = 1, \ldots, N$, is given by the square root of the n^{th} row n^{th} column entry of the variance-covariance matrix of stock price changes*

$$\boldsymbol{\Sigma}_S = \frac{1}{r^2}\boldsymbol{\Lambda}\boldsymbol{\Sigma}_D\boldsymbol{\Lambda}^\intercal. \tag{21}$$

[11] For example, during the first half of 2020, retail investors reportedly accounted for approximately 20% of total U.S. equity trading volume—roughly double the level observed in 2010. See, `https://www.wsj.com/articles/individual-investor-boom-reshapes-u-s-stock-market-11598866200`. This surge in retail trading has been widely attributed to the advent of zero-commission trading and the popularity of user-friendly platforms such as Robinhood, which have encouraged both higher trading intensity among existing retail investors and the entry of new participants into the market.

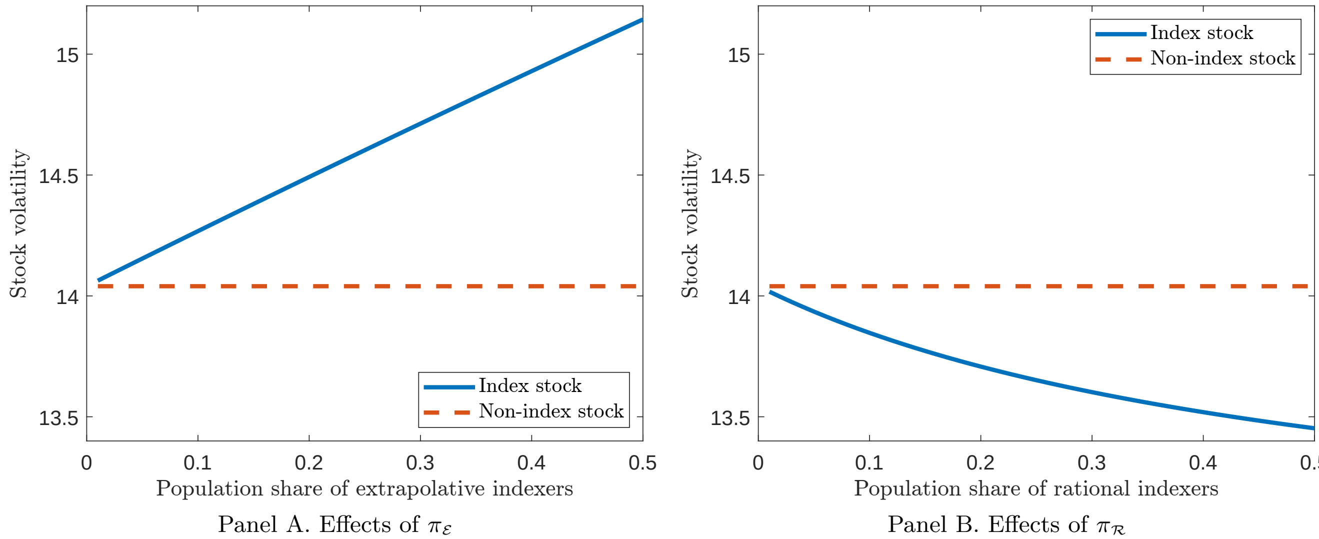


Figure 4. Stock volatility. These panels plot the equilibrium price change volatility of index and non-index stocks by varying the population share of extrapolative indexers (Panel A) and rational indexers (Panel B) when the population share of stock investors are $\pi_r = 0.5$ and $\pi_e = 0.5$. All other parameter values are as in Table B1.

Proposition 2 shows that, in equilibrium, the volatility of individual stock price changes is constant and shaped by the amplification term $\mathbf{\Lambda}$, which emerges in the presence of extrapolative investors. Prior research (e.g., Barberis et al. (2015)) has highlighted how extrapolative expectations amplify price movements: positive cash flow shocks raise prices, which in turn increase extrapolators' expectations of future returns, leading to greater demand and further price increases. A symmetric mechanism operates in the case of negative shocks, amplifying price declines. However, the impact of this amplification mechanism on index versus non-index stocks has not been examined. This distinction is nontrivial, as discussed in Section 3, the presence of index investors creates a sentiment spillover, whereby the price of an index stock reflects not only its own sentiment but also the sentiments of other index constituents. As a result, in the presence of index investors, the volatility of an individual stock depends not only on the extent to which extrapolators amplify that stock's cash flow shocks, but also on how other index stocks' cash flow shocks are amplified. To illustrate how index investing with extrapolators impacts the volatilities of the index and non-index stocks, we plot them in Figure 4.

Figure 4 shows that index stocks exhibit higher price volatilities than non-index stocks when index investors are extrapolative (Panel A). This finding is intuitive given the sentiment spillover and amplification mechanisms discussed in Section 3. Namely, the entry of extrapolative index investors amplifies the response of index stock prices to their own cash flow shocks, as their demand for index funds increases with rising index stock sentiment. Moreover, due to the spillover effect, each index stock's price is also influenced by the sentiments—and hence the cash flow shocks—of other index constituents, contributing an additional source of volatility. In contrast, Panel B shows that an increase in rational index investors leads to lower volatility in index stock prices. Rational index investors effectively counteract the sentiment-driven demand of stock extrapolators, thereby dampening price fluctuations and stabilizing index stock prices.

4.3 Stock Comovement

A large body of empirical evidence documents that index stocks exhibit significantly higher pairwise return correlations than non-index stocks, and that stocks added to an index begin to comove more with other index constituents while comoving less with non-index stocks (e.g., Greenwood and Sosner (2007), Wurgler (2010), Boyer (2011), Coles, Heath, and Ringgenberg (2022)).[12] Our model accounts for these findings through the key sentiment spillover mechanism outlined in Section 3, which generates a nontrivial and empirically consistent correlation structure across stocks. Proposition 3 formalizes this by characterizing the equilibrium correlation in price changes between any two stocks m and n.

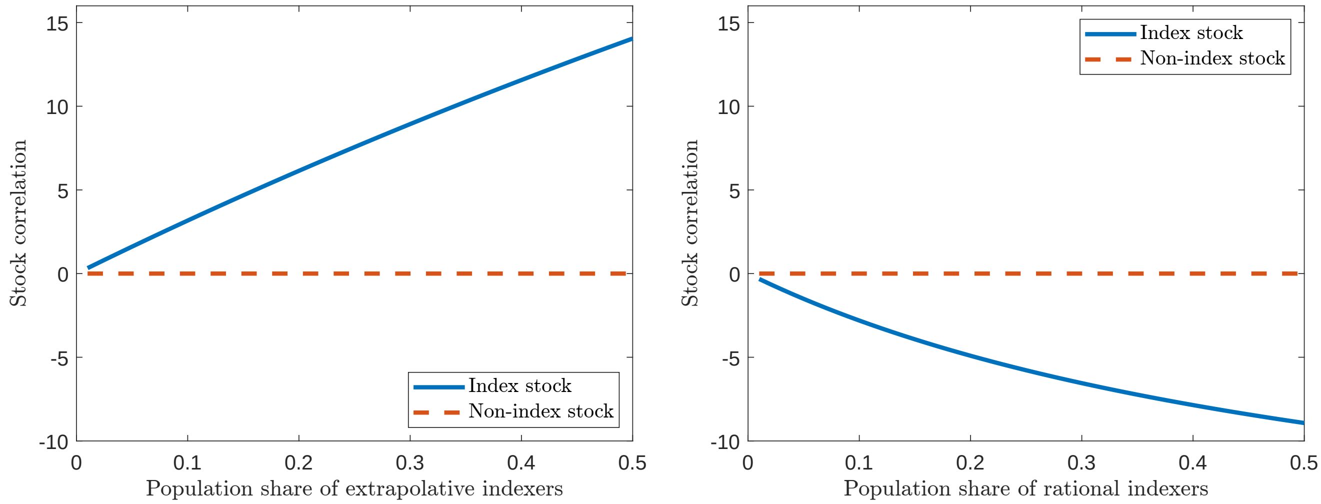
Proposition 3 (Equilibrium stock comovement). *In the index investing economy with extrapolators, the equilibrium price change correlation between stocks m and n for $m, n = 1, \dots, N$ is given by*

$$\rho_{mn} \equiv \mathrm{Corr}_t \left[dS_{mt}, dS_{nt} \right] = \frac{\boldsymbol{e}_m^\intercal \boldsymbol{\Sigma}_S \boldsymbol{e}_n}{\sqrt{\left(\boldsymbol{e}_m^\intercal \boldsymbol{\Sigma}_S \boldsymbol{e}_m\right)\left(\boldsymbol{e}_n^\intercal \boldsymbol{\Sigma}_S \boldsymbol{e}_n\right)}}, \tag{22}$$

where $\boldsymbol{e}_n$ is an $N \times 1$ elementary vector with its n^{th} element being 1 and others being 0.

Proposition 3 shows that the equilibrium price change correlation between any two stocks is constant and depends on the stock variance-covariance matrix $\boldsymbol{\Sigma}_S$, which in turn depends on the amplification

[12]Relatedly, Vijh (1994) and Barberis, Shleifer, and Wurgler (2005) find that a stock's beta with the S&P 500 increases following its inclusion in the index.



Panel A. Effects of $\pi_{\mathcal{E}}$ Panel B. Effects of $\pi_{\mathcal{R}}$

Figure 5. Stock comovement. These panels plot the equilibrium price change correlation (in percentages) among index and non-index stocks by varying the population share of extrapolative indexers (Panel A) and rational indexers (Panel B) when the population share of stock investors are $\pi_r = 0.5$ and $\pi_e = 0.5$. All other parameter values are as in Table B1.

term $\mathbf{\Lambda}$ in the presence of extrapolative investors. To understand the behavior of the stock comovement, we illustrate the pairwise correlations among index stocks and non-index stocks in Figure 5.

Figure 5 highlights a key result: an increase in extrapolative index investors leads to higher and positive pairwise correlations among index stocks, consistent with empirical evidence. In contrast, a rise in rational index investors results in lower, and negative, correlations among index stocks. These patterns are driven by the sentiment spillover mechanism discussed in Section 3. Specifically, a positive cash flow shock to one index stock raises its sentiment and price, thereby increasing the overall index level. Extrapolative index investors interpret this as a signal of continued upward movement and increase their demand for the index fund. Because index funds allocate this demand proportionally across all constituent stocks, each index stock experiences higher demand, leading to positively correlated price movements. Conversely, rational index investors recognize that the index may now be overvalued due to sentiment and reduce their index fund demand. As a result, a positive shock to one index stock can lead to decreased demand—and thus lower prices—for other index stocks, generating negative comovement.

4.4 Stock Autocorrelation

Empirical studies also find that index investing is associated with stronger negative autocorrelation in both individual stock prices and index levels (Ben-David et al. (2018), Baltussen, van Bekkum, and Da (2019), Höfler, Schlag, and Schmeling (2023)). In particular, Baltussen, van Bekkum, and Da (2019) document that return autocorrelations for 20 major market indices have recently become significantly negative, coinciding with the rise of index investing. Similarly, Ben-David et al. (2018) and Höfler, Schlag, and Schmeling (2023) show that, in the cross-section, stocks with a high passive ETF ownership exhibit much stronger return reversals—i.e., more pronounced negative autocorrelation—than stocks with low ETF ownership. To assess whether our model can replicate these empirical patterns, we present the equilibrium autocorrelation of stock price changes in Proposition 4.

Proposition 4 (**Equilibrium stock autocorrelation**). *In the index investing economy with extrapolators, the equilibrium price change autocorrelation of stock n, $n = 1, \ldots, N$, over the periods (t_0, t_1) and (t_2, t_3) for any $t_0 \leq t_1 \leq t_2 \leq t_3$ is given by*

$$\rho_n\left(t_0, t_1, t_2, t_3\right) = \operatorname{Corr}\left[S_{nt_1} - S_{nt_0}, S_{nt_3} - S_{nt_2}\right] = \frac{\operatorname{Cov}\left[S_{nt_1} - S_{nt_0}, S_{nt_3} - S_{nt_2}\right]}{\sqrt{\operatorname{Var}\left[S_{nt_1} - S_{nt_0}\right]\operatorname{Var}\left[S_{nt_3} - S_{nt_2}\right]}}, \tag{23}$$

where $\operatorname{Cov}\left[S_{nt_1} - S_{nt_0}, S_{nt_3} - S_{nt_2}\right]$ *is given by the n^{th}row n^{th}column entry of the covariance matrix*

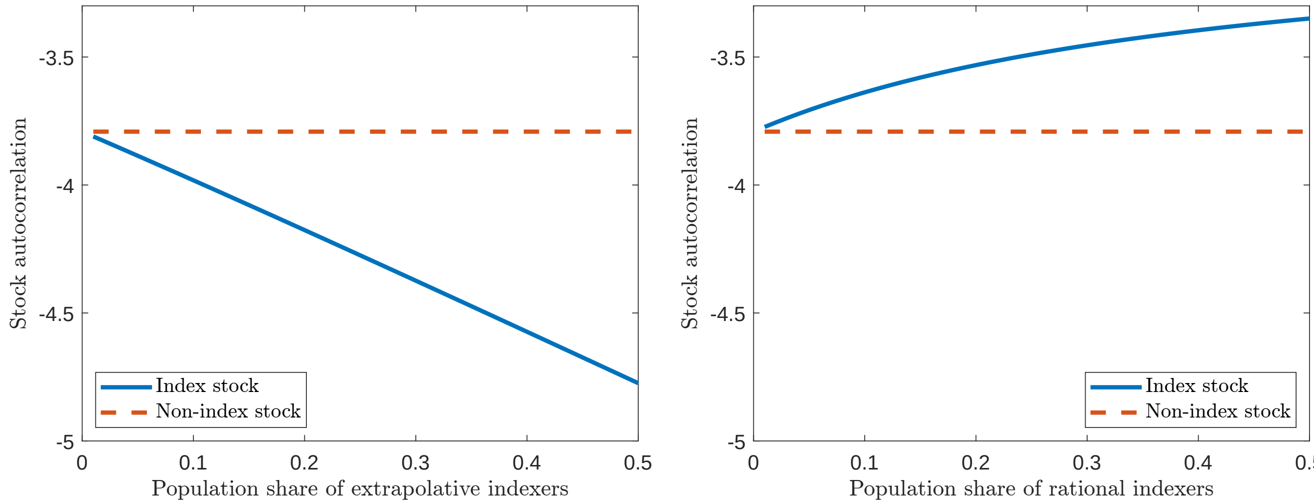
$$\begin{aligned}\operatorname{Cov}[\boldsymbol{S}_{t_1} - \boldsymbol{S}_{t_0}, \boldsymbol{S}_{t_3} - \boldsymbol{S}_{t_2}] = \boldsymbol{B}\Big[\Big(e^{-\kappa\boldsymbol{\Lambda}(t_3-t_1)} - e^{-\kappa\boldsymbol{\Lambda}(t_2-t_1)}\Big) - \Big(e^{-\kappa\boldsymbol{\Lambda}(t_3-t_0)} - e^{-\kappa\boldsymbol{\Lambda}(t_2-t_0)}\Big)\Big]\operatorname{Var}\left[\boldsymbol{X}_\infty\right]\boldsymbol{B}^\intercal \\ + \frac{1}{r^2}\left(e^{-\kappa\boldsymbol{\Lambda}(t_3-t_1)} - e^{-\kappa\boldsymbol{\Lambda}(t_2-t_1)}\right)\boldsymbol{\Lambda}^{-1}\left(\boldsymbol{I}_N - e^{-\kappa\boldsymbol{\Lambda}(t_1-t_0)}\right)\boldsymbol{\Lambda}\boldsymbol{\Sigma}_D\boldsymbol{B}^\intercal,\end{aligned} \tag{24}$$

and $\operatorname{Var}\left[S_{nt_{k+1}} - S_{nt_k}\right]$ *is given by the n^{th}row n^{th}column entry of the variance matrix*

$$\operatorname{Var}\left[\boldsymbol{S}_{t_{k+1}} - \boldsymbol{S}_{t_k}\right] = \frac{1}{r^2}\boldsymbol{\Sigma}_D\tau + 2\boldsymbol{B}\left(\boldsymbol{I}_N - e^{-\kappa\boldsymbol{\Lambda}\tau}\right)\operatorname{Var}\left[\boldsymbol{X}_\infty\right]\boldsymbol{B}^\intercal + \frac{2}{r^2}\boldsymbol{B}\boldsymbol{\Lambda}^{-1}\left(\boldsymbol{I}_N - e^{-\kappa\boldsymbol{\Lambda}\tau}\right)\boldsymbol{\Lambda}\boldsymbol{\Sigma}_D, \tag{25}$$

where $\tau = t_{k+1} - t_k$ and $\operatorname{Var}\left[\boldsymbol{X}_\infty\right]$ *is given by* (A.37).

Proposition 4 shows that the autocorrelation of stock price changes is constant in equilibrium but take a complex form. To better understand the stock serial dependence, Figure 6 illustrates the auto-



Panel A. Effects of $\pi_{\mathcal{E}}$ Panel B. Effects of $\pi_{\mathcal{R}}$

Figure 6. Stock autocorrelation. These panels plot the equilibrium price change autocorrelation (in percentages) between the previous quarter and the next quarter among index and non-index stocks by varying the population share of extrapolative indexers (Panel A) and rational indexers (Panel B) when the population share of stock investors are $\pi_r = 0.5$ and $\pi_e = 0.5$. All other parameter values are as in Table B1.

correlation between stock price changes in the previous quarter and the subsequent quarter.[13]

Figure 6 shows that stock price changes are negatively autocorrelated in the presence of stock extrapolators. Introducing extrapolative index investors further strengthens this price reversal for index stocks relative to non-index stocks, aligning with empirical findings.[14] The underlying mechanism is as follows: a positive cash flow shock to an index constituent increases the index level, which, in turn, raises the expectations of index extrapolators. These investors then increase their demand for the index fund, causing an additional upward price pressure. However, over time, the initial price shock carries decreasing weight in extrapolators' beliefs, leading to waning demand and subsequent price declines—producing negative autocorrelation. In contrast, as shown in Panel B, an increase in rational index investors leads to a weaker negative autocorrelation for index stocks. The reason is that when a cash flow shock raises the price of an index stock, stock extrapolators push the price even higher, inflating the index level. Rational index investors recognize this sentiment-driven overvaluation and

[13]While Proposition 4 presents a more general autocorrelation expression $\rho_n(t_0, t_1, t_2, t_3)$ that is valid for any two intervals (t_0, t_1) and (t_2, t_3), we focus here on quarter-on-quarter autocorrelations for brevity. This choice is motivated by our numerical findings, which indicate that the core message of Figure 6 remains robust across different horizon choices.

[14]Naturally, extrapolative index investors also induce negative autocorrelation in the index level itself, consistent with the evidence in Baltussen, van Bekkum, and Da (2019).

reduce their index fund demand. This moderating effect dampens both the initial price appreciation and the subsequent reversal, resulting in a smaller degree of negative autocorrelation.

4.5 Stock Trading Volume

We also examine stock trading activity in our economy to see whether our model can account for the empirical finding that index stocks tend to exhibit higher trading volumes and turnovers than non-index stocks (e.g., Vijh (1994), Coles, Heath, and Ringgenberg (2022)). To this end, we first denote each i-type stock investor's portfolio changes by $d\boldsymbol{\psi}_{it} = \boldsymbol{\mu}_{\psi it}dt + \boldsymbol{\sigma}_{\psi it}d\boldsymbol{\omega}_t$ where the m^{th} row n^{th} column entry of the diffusion term $\boldsymbol{\sigma}_{\psi it}$ capturing that investor's unpredictable trade in stock m following a cash flow shock ω_{nt}. Similarly, we denote i-type index investor's portfolio change in the index fund by $d\psi_{it} = \mu_{\psi it}dt + \sigma_{\psi it}d\omega_{It}$, with $\sigma_{\psi it}$ capturing her unpredictable trade following an index-level shock ω_{It}. The corresponding trade in individual stocks is given by $\sigma_{\psi it}\boldsymbol{q}$. We then adopt a commonly used measure of stock trading volume in continuous-time settings (e.g., Xiong and Yan (2010), Longstaff and Wang (2012)), which aggregates the population-weighted absolute values of these trades:

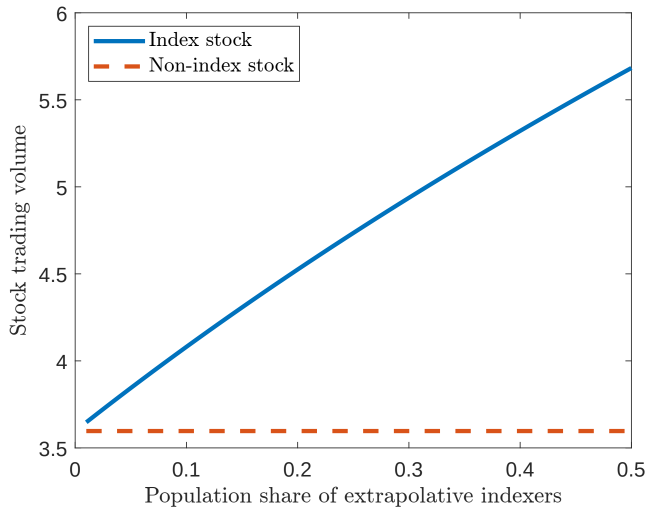
$$\boldsymbol{V}_t \equiv \frac{1}{2}\sum_{i=r,e} \pi_i \left|\boldsymbol{\sigma}_{\psi it}\right| \mathbf{1}_N + \frac{1}{2}\sum_{i=\mathcal{R},\mathcal{E}} \pi_i \left|\sigma_{\psi it}\right| \boldsymbol{q}, \tag{26}$$

where the adjustment 1/2 prevents double-counting of shares traded across investors, with $\mathbf{1}_N$ denoting the $N \times 1$ vector of ones, and $|\boldsymbol{\sigma}_{\psi it}|$ denotes the elementwise absolute value of the diffusion matrix $\boldsymbol{\sigma}_{\psi it}$. Proposition 5 reports the equilibrium trading volume in individual stocks in our model.

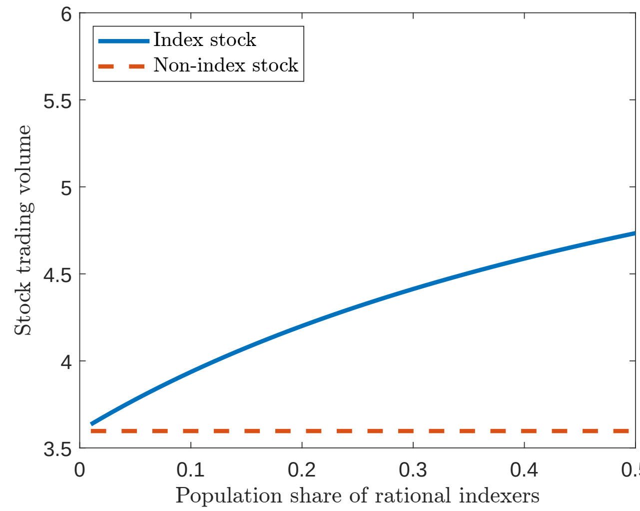
Proposition 5 (**Equilibrium stock trading volume**). *In the index investing economy with extrapolators, the equilibrium trading volume of stock n, $n = 1, \ldots, N$, is given by the n^{th} entry of the vector*

$$\boldsymbol{V}_t = \frac{1}{2}\frac{\kappa}{r}\sum_{i=r,e} \pi_i \left|\boldsymbol{L}_i \boldsymbol{\Lambda} \boldsymbol{\sigma}_D\right| \mathbf{1}_N + \frac{1}{2}\frac{\kappa}{r}\sum_{i=\mathcal{R},\mathcal{E}} \pi_i \left|L_i \Lambda_I \sigma_{DI}\right| \boldsymbol{q}. \tag{27}$$

In our model, when a stock is held by investors with different beliefs, there is a non-trivial trading activity, captured by our trading volume measure in Proposition 5. As (27) shows, the amplification terms $\boldsymbol{\Lambda}$ and Λ_I directly affect the trading volume of each individual stock. In the absence of index



Panel A. Effects of $\pi_{\mathcal{E}}$



Panel B. Effects of $\pi_{\mathcal{R}}$

Figure 7. Stock trading volume. These panels plot the equilibrium trading volume of index and non-index stocks by varying the population share of extrapolative indexers (Panel A) and rational indexers (Panel B) when the population share of stock investors are $\pi_r = 0.5$ and $\pi_e = 0.5$. All other parameter values are as in Table B1.

investors, and thus sentiment spillover, a cash flow shock to an index stock would lead to trades only on that stock. However, under index investing, due to the sentiment spillover, trading in an index stock arises not only from its own cash flow shocks but also from shocks to the cash flows of other stocks within the index (see also Figure 2). For example, following a positive shock to the cash flow of any index constituent, prices of other index stocks also rise—despite no change in their own fundamentals. Rational stock investors, who possess a finer information set, recognize the lack of change in these other stocks' cash flows and are therefore willing to trade against the price movement induced by index investors. To demonstrate this mechanism and its implications, Figure 7 illustrates the equilibrium trading volumes for both index and non-index stocks.

Figure 7 shows that an increase in the share of index investors leads to higher trading volume in index stocks, consistent with empirical findings. This occurs because a cash flow shock to any index constituent alters index investors' demand for the overall index fund. To accommodate this demand, the index fund adjusts its holdings by buying or selling proportional amounts of all index stocks, thereby generating trades in all index stocks. Moreover, we also see that trading volume in index stocks is even higher when index investors are extrapolators. This effect stems from the fact that, as discussed in

Section 4.2, both index stock prices and investor sentiment become more volatile under extrapolative expectations. The resulting increase in belief dispersion intensifies disagreement among investors, which in turn leads to more frequent and aggressive trading activity in index stocks.

In sum, our analysis in this section shows that the observed cross-sectional differences between index and non-index stocks can be reconciled when the marginal index investor holds extrapolative expectations, but not when they are rational. As we discuss in the Introduction, existing theories of index investing can explain some—but not all—of the evidence we highlight in this section. Moreover, several of these patterns can also be explained by alternative mechanisms distinct from index investing. For example, as noted earlier, benchmarking concerns can generate index effects, higher volatility, and positive return comovement among index stocks (Basak and Pavlova (2013)). Return comovement has also been shown to arise in models based on style investing (Barberis and Shleifer (2003)), limited attention and category-based learning (Peng and Xiong (2006)), and time-varying costs of actively managed funds (Vayanos and Woolley (2013)). That said, to the best of our knowledge, ours is the first theory to simultaneously reconcile all the observed cross-sectional differences discussed in this section.

5 Switching to Index Investing

In the preceding section, we demonstrated our main findings by introducing new index investors into the economy. This analysis was sufficient to make our main point that the documented cross-sectional differences between index and non-index stocks can be explained when the marginal index investor is extrapolative. However, that approach implicitly increases the total investor population relative to the baseline economy. In this section, we first show that our main results remain valid even when index investors are not new entrants but existing stock investors who switch to index investing, without altering the total population size. We then examine the welfare implications of such switching and find that the welfare loss from switching to index investing is greater for rational investors when the stock market is more heavily populated by extrapolators relative to rational stock investors.

5.1 Effects of Switching to Index Investing

To study the effects of switching in a concise manner, we present the key economic quantities under different types of switching investors in Table 1. Comparing the first and second columns of Table 1 shows that when a stock extrapolator switches to index investing, index stocks exhibit higher and more volatile prices, stronger comovement with other index stocks, more pronounced negative return autocorrelations, and greater trading volume than otherwise identical non-index stocks. By contrast, as shown in the last column, when a rational stock investor makes the same switch, index stock prices become less volatile, negatively correlated with other index stocks, and display weaker negative autocorrelation than non-index stocks. These findings are consistent with our earlier results in Section 4 and reinforce our main message: the observed cross-sectional differences between index and non-index stocks can be explained when the marginal index investor holds extrapolative expectations. That said, although the total population size remains the same after switching, the relative composition of rational and extrapolative stock investors changes. As a result, the underlying mechanisms differ slightly from those in Section 4. We discuss the mechanisms for each economic quantity in more detail below.

Stock price: We observe that switching has no effect on index stock prices when stock sentiment is at its long-run average, $\boldsymbol{X}_t = \bar{\boldsymbol{X}}$. In this case, both stock investors and their corresponding index investor counterparts have effectively identical demands for each index stock. As a result, switching to index investing does not influence index stock prices.[15] In contrast, switching reduces demand for non-index stocks, since a switching investor ceases trading them. This lowers their equilibrium prices, and the magnitude of this effect depends on the relative population of remaining investors in those stocks. When extrapolators switch, the relative share of rational investors trading non-index stocks rises. These rational investors can better absorb the sentiment-driven demand of remaining extrapolators, leading to lower volatility and higher equilibrium prices for non-index stocks. Conversely, when rational investors switch to index investing, extrapolators dominate the non-index stocks. The remaining rational investors now have less capacity to offset sentiment-driven fluctuations, resulting in higher volatility and lower

[15] In Table 1, the only quantity that depends on the level of sentiment is the stock price. For brevity, we report average stock prices by fixing sentiment at its long-run mean, $\boldsymbol{X}_t = \bar{\boldsymbol{X}}$. However, our main message in Table 1 holds more broadly: index stocks trade at higher prices than non-index stocks, and the price gap narrows when the switchers are extrapolators for other values of sentiment as well.

Table 1. Effects of switching from stock to index investing. This table reports the equilibrium quantities for index and non-index stocks under different population shares $(\pi_r, \pi_e, \pi_{\mathcal{R}}, \pi_{\mathcal{E}})$. The population shares in the economy in the first column is $(0.5, 0.5, 0, 0)$, under extrapolative switchers in the second column is $(0.5, 0.25, 0, 0.25)$, and under rational switchers in the third column is $(0.25, 0.5, 0.25.0)$. The stock price is evaluated when $\boldsymbol{X}_t = \bar{\boldsymbol{X}}$. All other parameter values are as in Table B1.

	Stock	Index Investors		
		None	Extrapolative	Rational
Stock price	Index	381.44	381.44	381.44
	Non-index	381.44	380.90	284.17
	Difference	**0**	**0.54**	**97.27**
Volatility	Index	14.04	12.84	16.17
	Non-index	14.04	12.19	17.14
	Difference	**0**	**0.65**	**-0.97**
Comovement	Index	0	9.80	-12.32
	Non-index	0	0	0
	Difference	**0**	**9.80**	**-12.32**
Autocorrelation	Index	-3.79	-2.83	-5.53
	Non-index	-3.79	-2.20	-6.13
	Difference	**0**	**-0.63**	**0.60**
Trading volume	Index	3.60	3.41	3.97
	Non-index	3.60	2.08	2.93
	Difference	**0**	**1.33**	**1.04**

prices for non-index stocks.[16] More notably, we again find that the magnitude of the index effect is much smaller when the index investors are extrapolators.

Volatility: Switching by extrapolators leads to lower volatility for both index and non-index stocks, with a more pronounced decline for non-index stocks. In contrast, when rational investors switch to index investing, the volatility of both stock types increases—particularly for non-index stocks. These results arise because when extrapolators switch to index investing, they base their expectations on the index, which is inherently less volatile than individual stocks due to the diversification effect. As a result, their expectations become less sensitive to idiosyncratic cash flow shocks, thereby reducing volatility in

[16] As discussed in Section 4.1, these effects can also be interpreted through shifts in supply and demand curves. Switching increases the residual supply of non-index stocks available to remaining stock investors. The aggregate demand curve shifts upward (downward) when extrapolators (rational investors) switch, due to the resulting decrease (increase) in non-index stock volatility.

index stocks. Additionally, with extrapolators exiting the non-index stocks, rational investors become relatively more dominant in those markets. This increased presence allows them to better absorb the remaining extrapolators' sentiment-driven trades, dampening the amplification mechanism and significantly reducing volatility in non-index stocks. By contrast, when rational investors switch to index investing, index stock volatility rises. This is because they can no longer tailor their portfolios to individual index stocks, limiting their ability to offset stock extrapolators' volatile expectations. Meanwhile, for non-index stocks, the reduced presence of rational investors weakens the stabilizing force that counters extrapolator-driven demand. This leads to even greater amplification and volatility in non-index stock prices, as illustrated in the last column of Table 1.

Comovement: We find that switching by extrapolators (rational investors) induces a positive (negative) correlation among index stocks, while the correlation structure of non-index stocks remains unaffected. As discussed in Section 4.3, this result reflects the nature of sentiment spillovers: when the marginal index investor is extrapolative, shocks to one index stock influence the valuation of others in the same direction, generating positive comovement. In contrast, when the marginal index investor is rational, their ability to recognize sentiment-driven over- and under-valuation leads to negative spillovers and weaker comovement across index stocks.

Autocorrelation: When a stock extrapolator switches from trading individual stocks to an index fund, price reversals weaken across all stocks, with more pronounced effects for non-index stocks. In contrast, when rational investors switch, price reversals strengthen, especially for non-index stocks. As discussed earlier, extrapolators who switch to index investing form expectations based on the less volatile index, making them less reactive to individual cash flow shocks. Consequently, shocks have smaller effects on current prices and generate weaker subsequent reversals. These effects are more pronounced for non-index stocks because rational investors—now more dominant in those stocks—can better absorb the remaining stock extrapolators' sentiment-driven demand, further dampening volatility and price reversals. Conversely, when some rational investors switch to index investing, the remaining rational stock investors have less capacity to offset the volatile beliefs of stock extrapolators. This amplifies the impact of shocks on current prices and leads to stronger reversals, particularly for non-index stocks, which the switching rational investors no longer trade.

Trading volume: Index stocks exhibit higher trading volume than non-index stocks, and this difference is more pronounced when the switching investors are extrapolators rather than rational. These results emerge through two channels in our model. First, when a stock investor switches to index investing, they stop trading non-index stocks. All else being equal, this directly reduces trading activity in non-index stocks. Second, switching alters the risk characteristics and the degree of disagreement across all stocks in equilibrium. When extrapolators switch, both index and non-index stocks become less volatile—more so for non-index stocks, as discussed earlier. As a result, extrapolators' beliefs, and hence their trading demand, become less responsive to cash flow shocks, leading to fewer trades. For non-index stocks, both the withdrawal of trading activity (first channel) and the reduced sensitivity to shocks (second channel) reinforce each other, producing a substantial decline in trading volume. In contrast, when rational investors switch to index investing, stock prices and investor sentiments become more volatile. This heightened volatility increases disagreement and leads to more aggressive trading, particularly in non-index stocks where the stabilizing presence of rational investors has diminished. Consequently, while index stocks are only affected by the second channel, non-index stocks are also impacted by the first channel, which dampens their trading volume. This asymmetry results in higher relative trading activity in index stocks.

In sum, our analysis here confirms our main conclusions of Section 4: the observed cross-sectional differences between index and non-index stocks can be explained by the marginal index investor holding extrapolative expectations. While our earlier analysis is better suited to capture the impact of new retail investors entering the market, the current framework—focused on switching behavior—can be interpreted as reflecting the growing trend of investors shifting from active management to passive index investing. Both trends are likely to exert a significant influence on asset prices. The consistency of implications across both cases lends support to the robustness of our central conclusion, irrespective of which channel is more dominant.

5.2 Welfare Loss of Index Investing

In this section, we analyze how switching from individual stock trading to index investing affects investor welfare. Because index investors cannot tailor their portfolios to each index stock individually, they typically achieve lower indirect utility than stock investors in the absence of frictions. To study the welfare loss of becoming an index investor in our frictionless setting, we follow the approach of Chabakauri and Rytchkov (2021) and compute the certainty equivalent loss (CEL).

In our framework, the equilibrium CEL for a given investor type is defined as the dollar amount a stock investor would be willing to forgo to be indifferent between remaining a stock investor and switching to index investing. That is, CEL for rational and extrapolative investors, denoted by η_{rt} and η_{et}, respectively, solve

$$J^{r}\left(W_t - \eta_{rt}, \boldsymbol{X}_t, t\right) = J^{\mathcal{R}}\left(W_t, X_{It}, t\right), \tag{28}$$

$$J^{e}\left(W_t - \eta_{et}, \boldsymbol{X}_t, t\right) = J^{\mathcal{E}}\left(W_t, X_{It}, t\right), \tag{29}$$

where J^i is the i-type investor's indirect utility function defined at time t as

$$J^{i}\left(W_{it}, \boldsymbol{X}_t, t\right) = \max_{(c_i, \boldsymbol{\psi}_i)} \mathrm{E}_t^i\left[\int_t^\infty e^{-\rho u}\frac{e^{-\gamma c_{iu}}}{-\gamma}du\right], \qquad \text{for} \qquad i = r, e,$$

$$J^{i}\left(W_{it}, X_{It}, t\right) = \max_{(c_i, \psi_i)} \mathrm{E}_t^i\left[\int_t^\infty e^{-\rho u}\frac{e^{-\gamma c_{iu}}}{-\gamma}du\right], \qquad \text{for} \qquad i = \mathcal{R}, \mathcal{E},$$

with $X_{It} = \boldsymbol{q}^\intercal \boldsymbol{X}_t$. Proposition 6 presents the equilibrium CEL for rational and extrapolative investors.

Proposition 6 (Equilibrium certainty equivalent loss). *In the index investing economy with extrapolators, the equilibrium certainty equivalent loss for rational and extrapolative investors are given by*

$$\eta_{rt} = \frac{1}{\gamma r}\left[\left(F_{\mathcal{R}} + G_{\mathcal{R}}X_{It} - \tfrac{1}{2}H_{\mathcal{R}}X_{It}^2\right) - \left(F_r + \boldsymbol{G}_r^\intercal \boldsymbol{X}_t - \tfrac{1}{2}\boldsymbol{X}_t^\intercal \boldsymbol{H}_r \boldsymbol{X}_t\right)\right], \tag{30}$$

$$\eta_{et} = \frac{1}{\gamma r}\left[\left(F_{\mathcal{E}} + G_{\mathcal{E}}X_{It} - \tfrac{1}{2}H_{\mathcal{E}}X_{It}^2\right) - \left(F_e + \boldsymbol{G}_e^\intercal \boldsymbol{X}_t - \tfrac{1}{2}\boldsymbol{X}_t^\intercal \boldsymbol{H}_e \boldsymbol{X}_t\right)\right]. \tag{31}$$

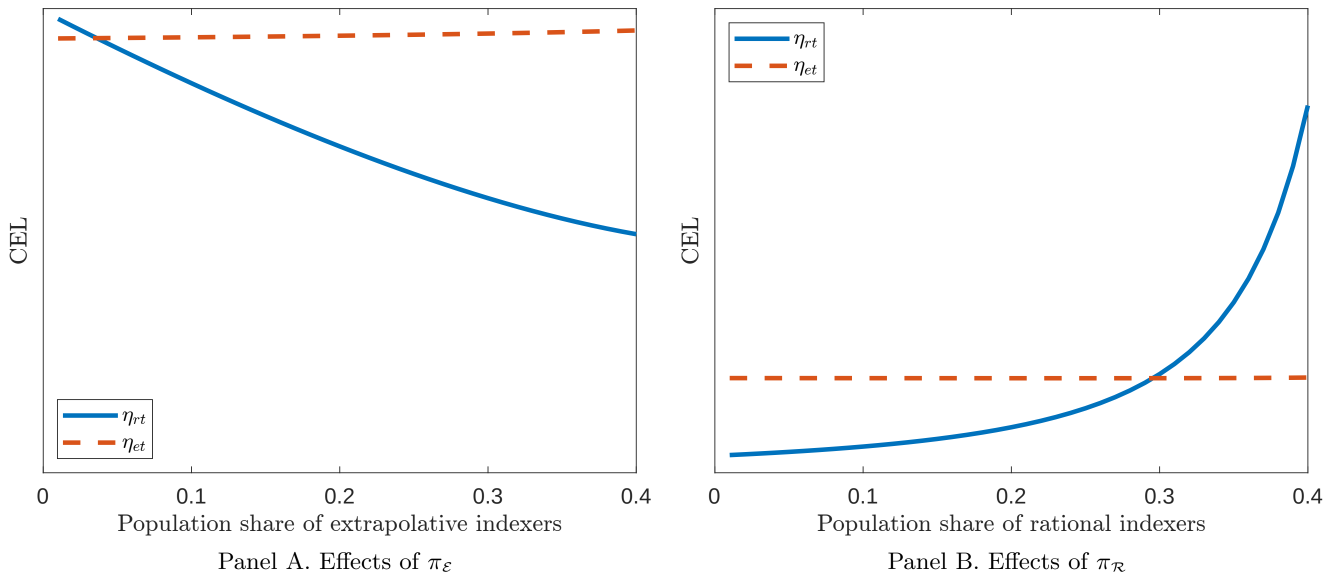


Figure 8. Certainty equivalent loss. These panels plot the equilibrium certainty equivalent loss (CEL) for rational (η_{rt}) and extrapolative (η_{et}) investors against the population share of switching extrapolative indexers $\pi_{\mathcal{E}}$ (Panel A) and rational indexers $\pi_{\mathcal{R}}$ (Panel B) when the stock sentiment is at its long-run average $\boldsymbol{X}_t = \bar{\boldsymbol{X}}$. All other parameter values are as in Table B1.

Proposition 6 shows that the certainty equivalent loss for both rational and extrapolative investors is state-dependent and takes a quadratic form in stock and index sentiments. To assess its average behavior, we evaluate CEL at the long-run average stock sentiment, $\boldsymbol{X}_t = \bar{\boldsymbol{X}}$, and present the results in Figure 8.[17]

Figure 8 shows that the certainty equivalent loss is positive, indicating that—absent any costs and given the choice—both rational and extrapolative investors would strictly prefer to remain stock investors rather than switch to index investing. As highlighted above, index investors cannot tailor their portfolios to each index stock independently, thus they derive lower indirect utility compared to stock investors. Figure 8 further shows that the welfare loss from switching to index investing is greater for rational investors when the stock market is more heavily populated by extrapolators relative to rational stock investors. This result is intuitive: rational investors expect to earn higher profits

[17]In Figure 8, we are interested only in the sign and directional behavior of CEL; accordingly, we omit the y-axis scale to avoid inviting direct comparisons between the CEL of rational and extrapolative investors. As emphasized by Brunnermeier, Simsek, and Xiong (2014), comparing indirect utilities across agents with different beliefs is generally not straightforward and may lack economic meaning. Finally, we note that the qualitative patterns in Figure 8 remain unchanged even when the index includes all stocks in the economy, i.e., $M = N$.

from trading individual stocks when their counterparts are predominantly extrapolators rather than other rational investors. Moreover, stock extrapolators induce greater mispricing opportunities across individual stocks than index extrapolators. Hence, the opportunity cost of switching to index investing is higher for rational investors in such environments.

6 Conclusion

In this paper, we develop a dynamic equilibrium model of index investing in the presence of investors with extrapolative expectations. Our model generates rich implications that support the extensive empirical evidence on the cross-sectional differences between index and non-index stocks regarding their prices, volatilities, comovements, autocorrelations, and trading volume. Our main finding is that the asset pricing impact of index investors depends critically on their beliefs, and the observed cross-sectional differences between index and non-index stocks can be explained when the marginal index investor holds extrapolative expectations.

Beyond its cross-sectional implications, given its richness, our model has several additional equilibrium implications that are omitted in our current analysis to keep our focus. For example, our model can be applied to study the relation between index fund flows and index performance, thereby addressing empirical findings in Goetzmann and Massa (2003), Anadu et al. (2020), and Dannhauser and Pontiff (2024). Moreover, to demonstrate the equilibrium implications of extrapolative index investors in a clear setting, we have also abstracted from any costs and institutional features. Nevertheless, our framework can accommodate features such as per-period index fund management fees, as discussed in Remark 1. It can also be extended to include active fund managers alongside index funds, allowing for an analysis of the joint determination of asset prices and portfolio allocations across active and passive funds. We leave these and other important considerations for future research.

Appendix A: Proofs

Proof of Proposition 1. To determine the equilibrium in the index investing economy with extrapolators, we first solve each investor's optimization problem. We begin with stock investors. The dynamic budget constraint (11) of each i-type stock investors, $i = r, e$, can be rewritten as

$$dW_{it} = rW_{it}dt + \boldsymbol{\psi}_{it}^{\intercal}\boldsymbol{\Pi}_{it}dt + \boldsymbol{\psi}_{it}^{\intercal}\boldsymbol{\sigma}_{St}d\boldsymbol{\omega}_t^i - c_{it}dt. \tag{A.1}$$

where $\boldsymbol{\Pi}_{it}$ is the $N \times 1$ vector of subjective stock risk premia perceived by them and is given by $\boldsymbol{\Pi}_{it} = \boldsymbol{\mu}_{St} + \boldsymbol{D}_t - r\boldsymbol{S}_t$ for $i = r$ and $\boldsymbol{\Pi}_{it} = \boldsymbol{X}_t + \boldsymbol{D}_t - r\boldsymbol{S}_t$ for $i = e$. Moreover, the definition of stock sentiment in (7) implies its dynamics as $d\boldsymbol{X}_t = -\kappa\boldsymbol{X}_t dt + \kappa d\boldsymbol{S}_t$, which is perceived by investors as

$$d\boldsymbol{X}_t = \boldsymbol{\mu}_{\boldsymbol{X}t}^i dt + \kappa\boldsymbol{\sigma}_{St}d\boldsymbol{\omega}_t^i, \tag{A.2}$$

where $\boldsymbol{\mu}_{\boldsymbol{X}t}^i = \kappa\left(\boldsymbol{\mu}_{St} - \boldsymbol{X}_t\right)$ for $i = r$ and $\boldsymbol{\mu}_{\boldsymbol{X}t}^i = 0$ for $i = e$, which follows from the fact that stock extrapolators' subjective Brownian motion is related to the objective one as

$$d\boldsymbol{\omega}_t^e = d\boldsymbol{\omega}_t + \boldsymbol{\sigma}_{St}^{-1}\left(\boldsymbol{\mu}_{St} - \boldsymbol{X}_t\right)dt. \tag{A.3}$$

From the theory of stochastic control, the optimal consumption and portfolio strategies of i-type stock investors', $i = r, e$, satisfy the Hamilton–Jacobi–Bellman (HJB) equation

$$\begin{aligned} 0 = \max_{(c_i,\boldsymbol{\psi}_i)} \frac{e^{-\rho t}e^{-\gamma c_{it}}}{-\gamma} + J_t^i + J_W^i\left[rW_{it} + \boldsymbol{\psi}_{it}^{\intercal}\boldsymbol{\Pi}_{it} - c_{it}\right] + \frac{1}{2}J_{WW}^i\boldsymbol{\psi}_{it}^{\intercal}\boldsymbol{\Sigma}_{St}\boldsymbol{\psi}_{it} \\ + J_{\boldsymbol{X}}^{i\intercal}\boldsymbol{\mu}_{\boldsymbol{X}t}^i + \frac{1}{2}\kappa^2\mathrm{tr}\left[J_{\boldsymbol{X}\boldsymbol{X}}^i\boldsymbol{\Sigma}_{St}\right] + \kappa J_{W\boldsymbol{X}}^{i\intercal}\boldsymbol{\Sigma}_{St}\boldsymbol{\psi}_{it}, \end{aligned} \tag{A.4}$$

where $J^i\left(W_{it}, \boldsymbol{X}_t, t\right) = \max_{(c_i,\boldsymbol{\psi}_i)} \mathrm{E}_t^i\left[\int_t^\infty e^{-\rho u}\frac{e^{-\gamma c_{iu}}}{-\gamma}du\right]$ is i-type stock investor's indirect utility function with its partial derivative with respect to x is denoted by J_x^i and $\mathrm{tr}\left[\boldsymbol{M}\right]$ is the trace of a square matrix $\boldsymbol{M}$, denoting the sum of elements on the main diagonal of $\boldsymbol{M}$.

We proceed by conjecturing a linear equilibrium in which prices of individual stocks take the form

(13) and i-type stock investor's indirect utility taking the form

$$J^i\left(W_{it}, \boldsymbol{X}_t, t\right) = -e^{-\rho t} e^{-\gamma r W_{it}} e^{F_i + \boldsymbol{G}_i^\intercal \boldsymbol{X}_t - \frac{1}{2} \boldsymbol{X}_t^\intercal \boldsymbol{H}_i \boldsymbol{X}_t}, \tag{A.5}$$

for some scalar F_i, $N \times 1$ vector of constants $\boldsymbol{A}$ and $\boldsymbol{G}_i$, and $N \times N$ matrix of constants $\boldsymbol{B}$ and $\boldsymbol{H}_i$. The stock price conjecture implies its dynamics as

$$d\boldsymbol{S}_t = \boldsymbol{\Lambda}\left(\frac{1}{r}\boldsymbol{\mu}_D - \kappa \boldsymbol{B} \boldsymbol{X}_t\right) dt + \frac{1}{r} \boldsymbol{\Lambda} \boldsymbol{\sigma}_D d\boldsymbol{\omega}_t, \tag{A.6}$$

and (14), where the amplification term $\boldsymbol{\Lambda}$ is as in the proposition. From the above dynamics, we immediately have the volatility and variance-covariance matrices of individual stocks as

$$\boldsymbol{\sigma}_S = \frac{1}{r}\boldsymbol{\Lambda}\boldsymbol{\sigma}_D \qquad \text{and} \qquad \boldsymbol{\Sigma}_S = \frac{1}{r^2}\boldsymbol{\Lambda}\boldsymbol{\Sigma}_D\boldsymbol{\Lambda}^\intercal, \tag{A.7}$$

along with the subjective stock risk premia as

$$\boldsymbol{\Pi}_{it} = \begin{cases} \left(\frac{1}{r}\boldsymbol{\Lambda}\boldsymbol{\mu}_D - r\boldsymbol{A}\right) - \left(r\boldsymbol{B} + \kappa\boldsymbol{\Lambda}\boldsymbol{B}\right)\boldsymbol{X}_t & \text{for } i = r, \\ -r\boldsymbol{A} - \left(r\boldsymbol{B} - \boldsymbol{I}_N\right)\boldsymbol{X}_t & \text{for } i = e, \end{cases} \tag{A.8}$$

and the expected change in the sentiment as

$$\boldsymbol{\mu}_{\boldsymbol{X}t}^i = \begin{cases} \kappa\boldsymbol{\Lambda}\left(\frac{1}{r}\boldsymbol{\mu}_D - \boldsymbol{X}_t\right) & \text{for } i = r, \\ 0 & \text{for } i = e. \end{cases} \tag{A.9}$$

Taking the first-order conditions of (A.4) with respect to c_i and $\boldsymbol{\psi}_i$ after substituting the partial derivatives $J_t^i = -\rho J^i$, $J_W^i = -\gamma r J^i$, $J_{WW}^i = \gamma^2 r^2 J^i$, $J_{\boldsymbol{X}}^i = \left(\boldsymbol{G}_i - \boldsymbol{H}_i\boldsymbol{X}_t\right) J^i$, $J_{\boldsymbol{XX}}^i = [-\boldsymbol{H}_i + \left(\boldsymbol{G}_i - \boldsymbol{H}_i\boldsymbol{X}_t\right)\left(\boldsymbol{G}_i - \boldsymbol{H}_i\boldsymbol{X}_t\right)^\intercal] J^i$, and $J_{W\boldsymbol{X}}^i = -\gamma r\left(\boldsymbol{G}_i - \boldsymbol{H}_i\boldsymbol{X}_t\right) J^i$, along with (A.8) and (A.9) gives the optimal consumption and portfolio strategy as in (17) where the portfolio terms are

$$\boldsymbol{K}_i = \begin{cases} \frac{1}{\gamma r}\left[\kappa \boldsymbol{G}_i + \boldsymbol{\Sigma}_S^{-1}\left(\frac{1}{r}\boldsymbol{\Lambda}\boldsymbol{\mu}_D - r\boldsymbol{A}\right)\right] & \text{for } i = r, \\ \frac{1}{\gamma r}\left[\kappa \boldsymbol{G}_i - \boldsymbol{\Sigma}_S^{-1} r\boldsymbol{A}\right] & \text{for } i = e, \end{cases} \tag{A.10}$$

$$\boldsymbol{L}_i = \begin{cases} -\frac{1}{\gamma r}\left[\boldsymbol{\Sigma}_S^{-1}\left(r\boldsymbol{B} + \kappa\boldsymbol{\Lambda}\boldsymbol{B}\right) + \kappa\boldsymbol{H}_i\right] & \text{for } i = r, \\ -\frac{1}{\gamma r}\left[\boldsymbol{\Sigma}_S^{-1}\left(r\boldsymbol{B} - \boldsymbol{I}_N\right) + \kappa\boldsymbol{H}_i\right] & \text{for } i = e, \end{cases} \tag{A.11}$$

Substituting the optimal consumption and portfolio strategy into the HJB equation (A.4) and rearranging gives

$$\begin{aligned} 0 = & -rF_i + r - \rho - r\ln(\gamma r) - \frac{\gamma^2 r^2}{2}\boldsymbol{K}_i^\intercal \boldsymbol{\Sigma}_S \boldsymbol{K}_i + \frac{\kappa^2}{2}\mathrm{tr}\left[\left(\boldsymbol{G}_i\boldsymbol{G}_i^\intercal - \boldsymbol{H}_i\right)\boldsymbol{\Sigma}_S\right] + \frac{\kappa}{r}\boldsymbol{G}_i^\intercal\boldsymbol{\Lambda}\boldsymbol{\mu}_D \mathbf{1}_{i=r} \\ & + \left[-r\boldsymbol{G}_i^\intercal - \gamma^2 r^2 \boldsymbol{K}_i^\intercal \boldsymbol{\Sigma}_S \boldsymbol{L}_i - \kappa^2 \boldsymbol{G}_i^\intercal \boldsymbol{\Sigma}_S \boldsymbol{H}_i - \kappa\left(\frac{1}{r}\boldsymbol{\mu}_D^\intercal \boldsymbol{\Lambda}^\intercal \boldsymbol{H}_i + \boldsymbol{G}_i^\intercal \boldsymbol{\Lambda}\right)\mathbf{1}_{i=r}\right]\boldsymbol{X}_t \\ & - \frac{1}{2}\boldsymbol{X}_t^\intercal\left[-r\boldsymbol{H}_i + \gamma^2 r^2 \boldsymbol{L}_i^\intercal \boldsymbol{\Sigma}_S \boldsymbol{L}_i - \kappa^2 \boldsymbol{H}_i^\intercal \boldsymbol{\Sigma}_S \boldsymbol{H}_i - 2\kappa \boldsymbol{H}_i^\intercal \boldsymbol{\Lambda} \mathbf{1}_{i=r}\right]\boldsymbol{X}_t, \end{aligned} \tag{A.12}$$

where the indicator function $\mathbf{1}_{i=r}$ takes the value 1 if $i = r$ and 0 if $i = e$. Thus, by the method of undetermined coefficients, for $i = r, e$, we must have

$$F_i = \frac{1}{r}\left[r - \rho - r\ln(\gamma r) - \frac{\gamma^2 r^2}{2}\boldsymbol{K}_i^\intercal \boldsymbol{\Sigma}_S \boldsymbol{K}_i + \frac{\kappa^2}{2}\mathrm{tr}\left[\left(\boldsymbol{G}_i\boldsymbol{G}_i^\intercal - \boldsymbol{H}_i\right)\boldsymbol{\Sigma}_S\right] + \frac{\kappa}{r}\boldsymbol{G}_i^\intercal\boldsymbol{\Lambda}\boldsymbol{\mu}_D \mathbf{1}_{i=r}\right], \tag{A.13}$$

and

$$\mathbf{0}_{N\times 1} = -r\boldsymbol{G}_i - \gamma^2 r^2 \boldsymbol{L}_i^\intercal \boldsymbol{\Sigma}_S \boldsymbol{K}_i - \kappa^2 \boldsymbol{H}_i^\intercal \boldsymbol{\Sigma}_S \boldsymbol{G}_i - \kappa\left(\frac{1}{r}\boldsymbol{H}_i^\intercal \boldsymbol{\Lambda}\boldsymbol{\mu}_D + \boldsymbol{\Lambda}^\intercal \boldsymbol{G}_i\right)\mathbf{1}_{i=r}, \tag{A.14}$$

$$\mathbf{0}_{N\times N} = -r\boldsymbol{H}_i + \gamma^2 r^2 \boldsymbol{L}_i^\intercal \boldsymbol{\Sigma}_S \boldsymbol{L}_i - \kappa^2 \boldsymbol{H}_i^\intercal \boldsymbol{\Sigma}_S \boldsymbol{H}_i - 2\kappa \boldsymbol{H}_i^\intercal \boldsymbol{\Lambda} \mathbf{1}_{i=r}, \tag{A.15}$$

Next, we solve the index investors' problem following similar steps to those for stock investors. The dynamic budget constraint (11) of each i-type index investors', $i = \mathcal{R}, \mathcal{E}$, can be rewritten as

$$dW_{it} = rW_{it}dt + \psi_{it}\Pi_{it}dt + \psi_{it}\sigma_{It}d\omega_{It}^i - c_{it}dt. \tag{A.16}$$

where the scalar Π_{it} is the subjective index risk premia perceived by them and is given by $\Pi_{it} = \mu_{It} + D_{It} - rI_t$ for $i = \mathcal{R}$ and $\Pi_{it} = X_{It} + D_{It} - rI_t$ for $i = \mathcal{E}$. Moreover, the definition of index sentiment in (9) implies its dynamics as $dX_{It} = -\kappa X_{It}dt + \kappa dI_t$, which is perceived by investors as

$$dX_{It} = \mu^i_{X_It}dt + \kappa\sigma_{It}d\omega^i_{It}, \tag{A.17}$$

where $\mu^i_{X_It} = \kappa\left(\mu_{It} - X_{It}\right)$ for $i = \mathcal{R}$ and $\mu^i_{X_It} = 0$ for $i = \mathcal{E}$, which follows from the fact that index extrapolators' subjective Brownian motion is related to the objective one as

$$d\omega^{\mathcal{E}}_{It} = d\omega_{It} + \sigma^{-1}_{It}\left(\mu_{It} - X_{It}\right)dt. \tag{A.18}$$

From the theory of stochastic control, the optimal consumption and portfolio strategies of i-type index investors, $i = \mathcal{R}, \mathcal{E}$, satisfy the Hamilton–Jacobi–Bellman (HJB) equation

$$\begin{aligned} 0 = \max_{(c_i,\psi_i)} \frac{e^{-\rho t}e^{-\gamma c_{it}}}{-\gamma} &+ J^i_t + J^i_W\left[rW_{it} + \psi_{it}\Pi_{it} - c_{it}\right] + \frac{1}{2}J^i_{WW}\psi^2_{it}\sigma^2_{It} \\ &+ J^i_{X_I}\mu^i_{X_It} + \frac{1}{2}J^i_{X_IX_I}\kappa^2\sigma^2_{It} + \kappa J^i_{WX_I}\sigma^2_{It}\psi_{it}, \end{aligned} \tag{A.19}$$

where $J^i\left(W_{it}, X_{It}, t\right) = \max_{(c_i,\psi_i)} \mathrm{E}^i_t\left[\int_t^\infty e^{-\rho u}\frac{e^{-\gamma c_{iu}}}{-\gamma}du\right]$ is i-type index investor's indirect utility function.

Given the stock price form (13), the index level becomes

$$I_t = \boldsymbol{q}^\intercal\boldsymbol{A} + \boldsymbol{q}^\intercal\boldsymbol{B}\boldsymbol{X}_t + \frac{1}{r}D_{It}. \tag{A.20}$$

We define $A_I = \boldsymbol{q}^\intercal\boldsymbol{A}$ and posit that there exists a scalar B_I satisfying

$$B_I\boldsymbol{q}^\intercal = \boldsymbol{q}^\intercal\boldsymbol{B}, \tag{A.21}$$

which along with $X_{It} = \boldsymbol{q}^\intercal\boldsymbol{X}_t$ allows us to rewrite (A.20) as in (15). Taking the dynamics of the index

(15) yields

$$dI_t = \Lambda_I \left(\frac{1}{r} \mu_{DI} - \kappa B_I X_{It} \right) dt + \frac{1}{r} \Lambda_I \sigma_{DI} d\omega_{It}, \tag{A.22}$$

$$dX_{It} = \kappa \Lambda_I \left(\frac{1}{r} \mu_{DI} - X_{It} \right) dt + \frac{\kappa}{r} \Lambda_I \sigma_{DI} d\omega_{It}, \tag{A.23}$$

where $\Lambda_I = (1 - \kappa B_I)^{-1}$ is the index amplification term, $\sigma_{DI} = \sqrt{\boldsymbol{q}^\intercal \boldsymbol{\Sigma}_D \boldsymbol{q}}$ is the index dividend volatility, and ω_{It} is the standard Brownian motion under the objective measure defined as

$$d\omega_{It} = \frac{1}{\sigma_{DI}} \boldsymbol{q}^\intercal \boldsymbol{\sigma}_D d\boldsymbol{\omega}_t.$$

From the above dynamics, we immediately have the volatility and variance of the index as $\sigma_I = \Lambda_I \sigma_{DI} / r$ and $\varSigma_I \equiv \sigma_I^2$, the subjective index risk premia as

$$\Pi_{it} = \begin{cases} \left(\frac{1}{r} \Lambda_I \mu_{DI} - r A_I \right) - \left(r B_I + \kappa \Lambda_I B_I \right) X_{It} & \text{for } i = \mathcal{R}, \\ -r A_I - \left(r B_I - 1 \right) X_{It} & \text{for } i = \mathcal{E}, \end{cases} \tag{A.24}$$

and the subjective expected change in the index sentiment as

$$\mu^i_{X_I t} = \begin{cases} \kappa \Lambda_I \left(\frac{1}{r} \mu_{DI} - X_{It} \right) & \text{for } i = \mathcal{R}, \\ 0 & \text{for } i = \mathcal{E}. \end{cases} \tag{A.25}$$

We note that since $I_t = \boldsymbol{q}^\intercal \boldsymbol{S}_t$, for consistency, we also have the index variance $\varSigma_I = \Lambda_I^2 \sigma_{DI}^2 / r^2 = \boldsymbol{q}^\intercal \boldsymbol{\Sigma}_S \boldsymbol{q}$. This can be seen from the fact that $\boldsymbol{q}^\intercal \Lambda_I = \boldsymbol{q}^\intercal \boldsymbol{\Lambda}$, which also implies that $d\omega_{It} = (1/\sigma_I) \boldsymbol{q}^\intercal \boldsymbol{\sigma}_S d\boldsymbol{\omega}_t$.

We take the i-type index investor's indirect utility as

$$J^i \left(W_{it}, X_{It}, t \right) = -e^{-\rho t} e^{-\gamma r W_{it}} e^{F_i + G_i X_{It} - \frac{1}{2} H_i X_{It}^2}, \tag{A.26}$$

for some scalars F_i, G_i, and H_i and obtain the first-order conditions of (A.19) with respect to c_i and ψ_i after substituting the partial derivatives $J^i_t = -\rho J^i$, $J^i_W = -\gamma r J^i$, $J^i_{WW} = \gamma^2 r^2 J^i$, $J^i_{X_I} =$

$(G_i - H_i X_{It})\, J^i$, $J^i_{X_I X_I} = \left[-H_i + (G_i - H_i X_{It})^2\right] J^i$, and $J^i_{W X_I} = -\gamma r\,(G_i - H_i X_{It})\, J^i$, along with (A.24) and (A.25) gives the optimal consumption and portfolio strategy as in (18) where the portfolio terms are

$$K_i = \begin{cases} \frac{1}{\gamma r}\left[\kappa G_i + \varSigma_I^{-1}\left(\frac{1}{r}\Lambda_I \mu_{DI} - r A_I\right)\right] & \text{for } i = \mathcal{R}, \\ \frac{1}{\gamma r}\left[\kappa G_i - \varSigma_I^{-1} r A_I\right] & \text{for } i = \mathcal{E}, \end{cases} \tag{A.27}$$

$$L_i = \begin{cases} -\frac{1}{\gamma r}\left[\varSigma_I^{-1}\left(r B_I + \kappa \Lambda_I B_I\right) + \kappa H_i\right] & \text{for } i = \mathcal{R}, \\ -\frac{1}{\gamma r}\left[\varSigma_I^{-1}\left(r B_I - 1\right) + \kappa H_i\right] & \text{for } i = \mathcal{E}, \end{cases} \tag{A.28}$$

Substituting the optimal consumption and portfolio strategy into the HJB equation (A.19) and rearranging gives

$$\begin{aligned} 0 = & -r F_i + r - \rho - r \ln(\gamma r) - \frac{\gamma^2 r^2}{2} \varSigma_I K_i^2 + \frac{\kappa^2}{2}\left(G_i^2 - H_i\right)\varSigma_I + \frac{\kappa}{r} G_i \Lambda_I \mu_{DI} \mathbf{1}_{i=\mathcal{R}} \\ & + \left[-r G_i - \gamma^2 r^2 L_i \varSigma_I K_i - \kappa^2 H_i \varSigma_I G_i - \kappa\left(\frac{1}{r} H_i \Lambda_I \mu_{DI} + \Lambda_I G_i\right)\mathbf{1}_{i=\mathcal{R}}\right] X_{It} \\ & - \frac{1}{2}\left[-r H_i + \gamma^2 r^2 \varSigma_I L_i^2 - \kappa^2 \varSigma_I H_i^2 - 2\kappa H_i \Lambda_I \mathbf{1}_{i=\mathcal{R}}\right] X_{It}^2, \end{aligned} \tag{A.29}$$

where the indicator function $\mathbf{1}_{i=\mathcal{R}}$ takes the value 1 if $i = \mathcal{R}$ and 0 if $i = \mathcal{E}$. By the method of undetermined coefficients, for $i = \mathcal{R}, \mathcal{E}$, we must have

$$F_i = \frac{1}{r}\left[r - \rho - r \ln(\gamma r) - \frac{\gamma^2 r^2}{2} \varSigma_I K_i^2 + \frac{\kappa^2}{2}\left(G_i^2 - H_i\right)\varSigma_I + \frac{\kappa}{r} G_i \Lambda_I \mu_{DI} \mathbf{1}_{i=\mathcal{R}}\right], \tag{A.30}$$

and

$$0 = -r G_i - \gamma^2 r^2 L_i \varSigma_I K_i - \kappa^2 H_i \varSigma_I G_i - \kappa\left(\frac{1}{r} H_i \Lambda_I \mu_{DI} + \Lambda_I G_i\right)\mathbf{1}_{i=\mathcal{R}}, \tag{A.31}$$

$$0 = -r H_i + \gamma^2 r^2 \varSigma_I L_i^2 - \kappa^2 \varSigma_I H_i^2 - 2\kappa H_i \Lambda_I \mathbf{1}_{i=\mathcal{R}}. \tag{A.32}$$

To determine the constants in prices and indirect value functions, and hence verify our conjecture, we next impose the stock market clearing condition (12). Using investors portfolios in (17)– (18) and the fact $X_{It} = \boldsymbol{q}^\intercal \boldsymbol{X}_t$, we obtain the following system by the method of undetermined coefficients

$$(\pi_r \boldsymbol{K}_r + \pi_e \boldsymbol{K}_e) + (\pi_\mathcal{R} K_\mathcal{R} + \pi_\mathcal{E} K_\mathcal{E})\, \boldsymbol{q} = \boldsymbol{Q}, \tag{A.33}$$

$$(\pi_r \boldsymbol{L}_r + \pi_e \boldsymbol{L}_e) + (\pi_\mathcal{R} L_\mathcal{R} + \pi_\mathcal{E} L_\mathcal{E})\, \boldsymbol{q}\boldsymbol{q}^\intercal = \boldsymbol{0}_{N\times N}. \tag{A.34}$$

We jointly solve for three $N \times N$ matrices $\boldsymbol{B}$, $\boldsymbol{H}_r$, $\boldsymbol{H}_e$ and three scalars B_I, $H_\mathcal{R}$, $H_\mathcal{E}$ using six equations: (A.15) for $i = r, e$, (A.32) for $i = \mathcal{R}, \mathcal{E}$, (A.21), and (A.34). We next determine the three $N \times 1$ vectors $\boldsymbol{A}$, $\boldsymbol{G}_r$, $\boldsymbol{G}_e$ and two scalars $G_\mathcal{R}$ and $G_\mathcal{E}$ using five equations: (A.14) for $i = r, e$, (A.31) for $i = \mathcal{R}, \mathcal{E}$, and (A.33). Substituting these into (A.13) and (A.30) yields the scalars F_i for $i = r, e, \mathcal{R}, \mathcal{E}$. □

Proof of Proposition 2. The price change volatility of stock n is readily given by the square root of the n^{th} row n^{th} column entry of the variance-covariance matrix of stock price changes, which using the stock price dynamics in (A.6), is given by $\boldsymbol{\Sigma}_S = (1/r^2)\boldsymbol{\Lambda}\boldsymbol{\Sigma}_D\boldsymbol{\Lambda}^\intercal$. □

Proof of Proposition 3. The price change correlation between stocks m and n is immediately given by its definition

$$\rho_{mn} = \mathrm{Corr}_t\left[dS_{mt}, dS_{nt}\right] = \frac{\mathrm{Cov}_t\left[\boldsymbol{e}_m^\intercal d\boldsymbol{S}_t, \boldsymbol{e}_n^\intercal d\boldsymbol{S}_t\right]}{\sqrt{\mathrm{Var}_t\left[\boldsymbol{e}_m^\intercal d\boldsymbol{S}_t\right]\mathrm{Var}_t\left[\boldsymbol{e}_n^\intercal d\boldsymbol{S}_t\right]}} = \frac{\boldsymbol{e}_m^\intercal \boldsymbol{\Sigma}_S \boldsymbol{e}_n}{\sqrt{(\boldsymbol{e}_m^\intercal \boldsymbol{\Sigma}_S \boldsymbol{e}_m)\,(\boldsymbol{e}_n^\intercal \boldsymbol{\Sigma}_S \boldsymbol{e}_n)}},$$

where $\boldsymbol{e}_n$ is an $N \times 1$ elementary vector with its n^{th} element being 1 and others being 0. □

Proof of Proposition 4. The price change autocorrelation of stock n, over the periods (t_0, t_1) and (t_2, t_3) for any $t_0 \le t_1 \le t_2 \le t_3$ is by definition given by (23). The numerator in (23) is the n^{th} row n^{th} column entry of the covariance matrix $\mathrm{Cov}\left[\boldsymbol{S}_{t_1} - \boldsymbol{S}_{t_0}, \boldsymbol{S}_{t_3} - \boldsymbol{S}_{t_2}\right]$, which after stock prices in (13) substituted in becomes

$$\mathrm{Cov}[\boldsymbol{S}_{t_1} - \boldsymbol{S}_{t_0}, \boldsymbol{S}_{t_3} - \boldsymbol{S}_{t_2}] = \boldsymbol{B}\,\mathrm{Cov}[\boldsymbol{X}_{t_1} - \boldsymbol{X}_{t_0}, \boldsymbol{X}_{t_3} - \boldsymbol{X}_{t_2}]\boldsymbol{B}^\intercal + \frac{1}{r}\mathrm{Cov}[\boldsymbol{D}_{t_1} - \boldsymbol{D}_{t_0}, \boldsymbol{X}_{t_3} - \boldsymbol{X}_{t_2}]\boldsymbol{B}^\intercal. \tag{A.35}$$

To derive the covariances in (A.35), we employ the fact that $\boldsymbol{X}_t$ is a multi-dimensional Ornstein-Uhlenbeck process, which has a stationary Gaussian distribution when all the eigenvalues of $\kappa\boldsymbol{\Lambda}$ have positive real parts. Under the stationary of $\boldsymbol{X}_t$, we have its steady-state unconditional autocovariance for any $\tau \geq 0$ as

$$\mathrm{Cov}\left[\boldsymbol{X}_t, \boldsymbol{X}_{t+\tau}\right] = e^{-\kappa\boldsymbol{\Lambda}\tau}\mathrm{Var}\left[\boldsymbol{X}_\infty\right], \tag{A.36}$$

where $\mathrm{Var}\left[\boldsymbol{X}_\infty\right]$ is the long-run variance of $\boldsymbol{X}_t$ and is given by

$$\mathrm{Var}\left[\boldsymbol{X}_\infty\right] \equiv \lim_{t\to\infty} \mathrm{Var}\left[\boldsymbol{X}_t\right] = \mathrm{vec}^{-1}\left[(\kappa\boldsymbol{\Lambda} \oplus \kappa\boldsymbol{\Lambda})^{-1}\,\mathrm{vec}\left[\boldsymbol{\Sigma}_X\right]\right], \tag{A.37}$$

with $\boldsymbol{\Sigma}_X \equiv \mathrm{Var}_t\left[d\boldsymbol{X}_t\right]/dt = \frac{\kappa^2}{r^2}\boldsymbol{\Lambda}\boldsymbol{\Sigma}_D\boldsymbol{\Lambda}^\intercal$. Using (A.36), we obtain the first covariance in (A.35) as

$$\mathrm{Cov}\left[\boldsymbol{X}_{t_1} - \boldsymbol{X}_{t_0}, \boldsymbol{X}_{t_3} - \boldsymbol{X}_{t_2}\right] = \left[\left(e^{-\kappa\boldsymbol{\Lambda}(t_3-t_1)} - e^{-\kappa\boldsymbol{\Lambda}(t_2-t_1)}\right) - \left(e^{-\kappa\boldsymbol{\Lambda}(t_3-t_0)} - e^{-\kappa\boldsymbol{\Lambda}(t_2-t_0)}\right)\right]\mathrm{Var}\left[\boldsymbol{X}_\infty\right],$$

and the second covariance in (A.35) as

$$\begin{aligned}
\mathrm{Cov}\left[\boldsymbol{D}_{t_1} - \boldsymbol{D}_{t_0}, \boldsymbol{X}_{t_3} - \boldsymbol{X}_{t_2}\right] &= \boldsymbol{\sigma}_D \mathrm{Cov}\left[\int_{t_0}^{t_1} d\boldsymbol{\omega}_u, \boldsymbol{X}_{t_1}\right]\left(e^{-\kappa\boldsymbol{\Lambda}(t_3-t_1)} - e^{-\kappa\boldsymbol{\Lambda}(t_2-t_1)}\right)^\intercal \\
&= \frac{1}{r}\boldsymbol{\sigma}_D\left[\boldsymbol{\Lambda}^{-1}\left(\boldsymbol{I}_N - e^{-\kappa\boldsymbol{\Lambda}(t_1-t_0)}\right)\boldsymbol{\Lambda}\boldsymbol{\sigma}_D\right]^\intercal\left(e^{-\kappa\boldsymbol{\Lambda}(t_3-t_1)} - e^{-\kappa\boldsymbol{\Lambda}(t_2-t_1)}\right)^\intercal \\
&= \frac{1}{r}\left(e^{-\kappa\boldsymbol{\Lambda}(t_3-t_1)} - e^{-\kappa\boldsymbol{\Lambda}(t_2-t_1)}\right)\boldsymbol{\Lambda}^{-1}\left(\boldsymbol{I}_N - e^{-\kappa\boldsymbol{\Lambda}(t_1-t_0)}\right)\boldsymbol{\Lambda}\boldsymbol{\Sigma}_D.
\end{aligned}$$

The denominator terms in (23) is obtained from the variance matrix $\mathrm{Var}\left[\boldsymbol{S}_{t_{k+1}} - \boldsymbol{S}_{t_k}\right]$, which after (13) substituted in becomes

$$\mathrm{Var}\left[\boldsymbol{S}_{t_{k+1}} - \boldsymbol{S}_{t_k}\right] = \frac{1}{r^2}\mathrm{Var}\left[\boldsymbol{D}_{t_{k+1}} - \boldsymbol{D}_t\right] + \boldsymbol{B}\mathrm{Var}\left[\boldsymbol{X}_{t_{k+1}} - \boldsymbol{X}_t\right]\boldsymbol{B}^\intercal + \frac{2}{r}\boldsymbol{B}\mathrm{Cov}\left[\boldsymbol{X}_{t_{k+1}} - \boldsymbol{X}_t, \boldsymbol{D}_{t_{k+1}} - \boldsymbol{D}_t\right]. \tag{A.38}$$

Letting $\tau = t_{k+1} - t$, we obtain the first variance in (A.38) immediately as $\mathrm{Var}\left[\boldsymbol{D}_{t_{k+1}} - \boldsymbol{D}_t\right] = \boldsymbol{\Sigma}_D\tau$, and the second variance term as

$$\mathrm{Var}\left[\boldsymbol{X}_{t_{k+1}} - \boldsymbol{X}_t\right] = \mathrm{Var}\left[\boldsymbol{X}_{t+\tau}\right] + \mathrm{Var}\left[\boldsymbol{X}_t\right] - 2\mathrm{Cov}\left[\boldsymbol{X}_{t+\tau}, \boldsymbol{X}_t\right] = 2\left(\boldsymbol{I}_N - e^{-\kappa\boldsymbol{\Lambda}\tau}\right)\mathrm{Var}\left[\boldsymbol{X}_\infty\right],$$

after employing (A.36). Finally, the covariance term in (A.38) becomes

$$\mathrm{Cov}\left[\boldsymbol{X}_{t_{k+1}} - \boldsymbol{X}_t, \boldsymbol{D}_{t_{k+1}} - \boldsymbol{D}_t\right] = \frac{1}{r}\boldsymbol{\Lambda}^{-1}\left(\boldsymbol{I}_N - e^{-\kappa\boldsymbol{\Lambda}\tau}\right)\boldsymbol{\Lambda}\boldsymbol{\Sigma}_D,$$

which along with earlier terms substituted in (A.38) yields (25). □

Proof of Proposition 5. To determine the trading volume of individual stocks, we first use investors' portfolio strategies in (17) and (18) and obtain the changes in their portfolios as $d\boldsymbol{\psi}_{it} = \cdots dt + (\kappa/r)\boldsymbol{L}_i\boldsymbol{\Lambda}\boldsymbol{\sigma}_D d\boldsymbol{\omega}_t$, for $i = r, e$, and $d\psi_{it} = \cdots dt + (\kappa/r)L_i\Lambda_I\sigma_{DI}d\omega_{It}$, for $i = \mathcal{R}, \mathcal{E}$. Substituting the diffusion terms into the trading volume measure (26), we obtain the trading volume as in (27). □

Proof of Proposition 6. The certainty equivalent loss for rational and extrapolative investors (30) and (31) are immediately given by using the value functions (A.5) for stock investors and (A.26) for index investors along with the definition of CEL in (28) and (29). □

Table B1. Parameter values. This table reports the parameter values used in our numerical analysis.

Parameter	Variable	Value
Dividend level for stock n	D_{nt}	10
Dividend mean for stock n	μ_{D_n}	0.05
Dividend volatility for stock n	σ_{D_n}	0.25
Supply of stock n	Q_n	5
Number of stocks in the market	N	5
Number of stocks in the index	M	3
Risk-free interest rate	r	0.025
Time discount factor	ρ	0.015
Absolute risk aversion coefficient	γ	0.1
Degree of extrapolation	κ	0.5

Appendix B: Parameter Values

In this Appendix, we discuss the parameter values employed in our analysis, which are summarized in Table B1. We note that the behaviors of the equilibrium quantities depicted in our Tables and Figures are typical and do not vary much with alternative plausible parameter values.

Given that we adopt the framework in Barberis et al. (2015), we simply follow their calibration for parameters that are common to both models. This means, we also choose the dividend level of $D_{nt} = 10$, the mean dividend change of $\mu_{D_n} = 0.05$, the dividend change volatility of $\sigma_{D_n} = 0.25$, the stock supply of $Q_n = 5$ for each stock n, $n = 1, \ldots, N$, the interest rate as $r = 2.5\%$, the time discount factor as $\rho = 1.5\%$, and the absolute risk aversion coefficient as $\gamma = 0.1$.

For the degree of extrapolation, consistent with its empirical estimates in Barberis et al. (2015) and Cassella and Gulen (2018), we set its value to $\kappa = 0.5$. Finally, we simply take the number of stocks in the market as $N = 5$ and the number of stocks in the index as $M = 3$.

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