More Risk, More Information: How Passive Ownership Can Improve Informational Efficiency*

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Abstract

We develop a novel theoretical framework that highlights a unique economic mechanism through which passive ownership *positively* affects informational efficiency. Passive ownership reduces the sensitivity of the stock price to fundamental variance, encouraging firms to allocate more capital to risky growth opportunities which increases firm-level volatility. This, in turn, induces active investors to acquire more precise information, increasing price informativeness. Higher levels of passive ownership are also associated with higher stock prices, higher stock-return variances, and higher returns. Consistent with our main prediction, we provide new empirical evidence that stocks with large passive ownership tend to have more informative prices.

Keywords: passive investing, informational efficiency, risk taking, asset allocation, asset pricing

JEL: G11, G14, G23

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Passive investors, such as exchange-traded funds or index funds, are nowadays major shareholders of almost all publicly-traded companies; for example, in the U.S., they hold, on average, more than 17% of the shares outstanding. There have been many concerns that, because passive investors do not produce any information and simply buy stocks according to their index weight, this development has a negative impact on the informational content of asset prices and capital-allocation efficiency.

Hence, the key objective of this paper is to understand whether passive ownership limits the ability of financial markets to reflect information and allocate capital efficiently. In fact, we provide new empirical evidence that stocks with large passive ownership tend to have *more* informative stock prices.[1] This pattern holds in the U.S. but also internationally and is complementary to the recent empirical evidence on the link between informational efficiency and institutional ownership (Bai, Philippon, and Savov 2016) as well as firm size (Farboodi, Matray, Veldkamp, and Venkateswaran 2019). Not surprisingly, it poses a challenge to traditional models of information choice.

Using a novel theoretical framework, we identify a new and unique economic mechanism through which passive ownership *positively* affects informational efficiency. Firms with high levels of passive ownership take on more risk which, in turn, induces active investors to acquire more precise private information. As a result, price informativeness is higher for stocks with large passive ownership, consistent with the empirical evidence.

In our economic framework, investors' optimal portfolio and information choices, stock prices, and firms' real-investment decisions are determined jointly in equilibrium—while explicitly accounting for the presence of passive investors. The model has two central features. First, there exist two groups of institutional investors. Passive investors whose demand is information-insensitive and active investors who acquire private information and trade accordingly. Second, firms optimally choose their capital allocation to growth opportunities in order to maximize their stock price; taking into account the ownership structure of their stock. Otherwise, the model is kept as simple as possible to determine the economic mechanisms in the clearest possible way. Indeed, the model is highly tractable and allows us to obtain all our results analytically.

[1] To measure price informativeness, we follow Bai, Philippon, and Savov (2016); that is, focus on the ability of stock prices to predict future cash flows in the cross-section of firms.

Primarily, we use the model to study how variations in the proportion of shares outstanding held by passive investors, capturing *cross-sectional* variations in passive ownership, affect equilibrium outcomes. We first document that passive ownership alters firms' real-investment decisions—through its impact on the marginal cost of allocating capital to risky growth opportunities. Intuitively, because passive investors' demand is variance-insensitive, a larger share of passive owners implies a lower sensitivity of the stock price with respect to (posterior) variance. Consequently, the marginal cost of increasing the allocation to risky growth opportunities declines. As a result, firms with high levels of passive ownership invest more aggressively into growth opportunities, or, equivalently, take on more risk, which drives up the mean and the variance of their fundamentals; compared to identical firms with low levels of passive ownership.

The resulting differences in firms characteristics also change active investors' incentives to produce information and, hence, price informativeness. In particular, the higher fundamental variance of firms with larger proportions of shares held by passive investors induces active investors to acquire private information and, hence, the average private-signal precision increases; relative to otherwise identical firms with low passive ownership. Consequently, consistent with the empirical evidence, price informativeness increases in the share of passive ownership—a result unique to our setting with endogenous real-investment decisions. Indeed, with exogenous firm characteristics, cross-sectional variations in passive ownership do not lead to differences in informational efficiency. Moreover, in our model, firms with large passive ownership endogenously have more informative prices and more growth potential; consistent with the findings in Farboodi, Matray, Veldkamp, and Venkateswaran (2019).

We also characterize the impact of passive ownership on stock prices, stock-return variances, and excess returns. Higher passive ownership pushes up stock prices. This is the result of a combination of two effects: a larger capital allocation to growth opportunities (increasing the fundamental mean) and higher price informativeness (lowering the price discount that active investors command). The unconditional stock-return variance is also positively related to passive ownership because the higher fundamental variance—stemming from the larger allocation of capital to growth opportunities—dominates the opposing effect of higher price informativeness. Excess returns are usually also increasing in the proportion of shares held by passive investors; again driven by the higher fundamental variance.[2]

Our model also allows us to study the implications of a rise in the fraction of *aggregate* capital managed by passive investors.[3] On average, this leads to a decline in price informativeness because the total amount of information produced in the economy goes down—the "naïve" effect usually associated with passive investing. It also strengthens the variations in the cross-section. That is, intuitively, such an increase leads to more pronounced differences in aggregate demand across firms. Naturally, this translates into an amplification of the aforementioned effects: the gap in capital allocations, price informativeness, stock prices, and stock-return variances between stocks with high and low levels of passive ownership widens. Interestingly—for stocks with high levels of passive ownership—the higher signal-precision dominates the decline in information production such that price informativeness *further increases*.

Overall, both our empirical and theoretical findings highlight that the implications of passive investing on informational efficiency are considerable more intricate than simple economic intuition might suggest. In fact, while our empirical results seem initially rather counter-intuitive, they can be rationalized if firms, when making their real-investment decisions, take into account the ownership structure in financial markets.

Methodologically, we provide a tractable corporate-finance addition to an otherwise standard noisy rational-expectations equilibrium model. The key departure from classical models of information choice is that we allow for "supply-side" (i.e., real-investment or leverage) adjustments by firms in response to variations in stock demand. Thus, effectively, the characteristics of the firms (specifically, the mean and variance of their fundamentals) are endogenous in our model which, as demonstrated, can provide strong countervailing forces to those traditionally studied in the literature.

The paper contributes primarily to the literature studying the impact of institutional investors on financial markets; in particular, in settings with noisy rational expectations. Sem-

[2] The exception is the case in which the expected net supply—after accounting for the demand of passive investors—approaches zero. In this case, the excess return converges to zero because the risk that active investors have to bear vanishes.

[3] Intuitively, one can think of the passive investors' average demand for a stock as the stock-specific intensive margin of their trading and of the proportion of aggregate capital managed passively as the extensive margin of their trading.

inal papers in this literature include Basak and Pavlova (2013) and Kacperczyk, Van Nieuwerburgh, and Veldkamp (2016) which sets out the basic framework of this paper. Kacperczyk, Nosal, and Stevens (2018) show that capital can be unevenly gained by more sophisticated investors, while papers such as Breugem and Buss (2018) and Kacperczyk, Nosal, and Sundaresan (2018), Huang, Qiu, and Yang (2019) study the impact of institutional investors on price informativeness. To this point every paper has shown that increasing informed investors in the market increases price informativeness in the aggregate. For Breugem and Buss (2018), the channel comes through benchmarking: an increase in benchmarking results in an increase in prices, reducing the equity premium, and therefore reducing the incentives of active investors to collect information.[4] For Kacperczyk, Nosal, and Sundaresan (2018) an increase in passive investing reduces the relative size of active investors, reducing their market power and shifting their attention towards fewer stocks, lowering aggregate price informativeness. Our paper abstracts from the second point by having atomistic agents, and reverses the first by allowing an endogenous firm response to the price increase, which raises fundamental volatility. Our paper also borrows from Kashyap, Kovrijnykh, Li, and Pavlova (2018) who show that firms within an index take on riskier profiles than firms outside it. We deliver a similar result in a different framework, examining the implications on information collection and aggregation.

The paper is also closely related to the literature on "feedback effects" which studies how financial markets affect firms' real-investment decisions; due to firm managers' learning from market prices.[5] For example, Goldstein and Yang (2019) show that increased market efficiency can actually reduce real efficiency if information disclosure is along dimensions deemed unimportant by the real decision maker. Goldstein and Yang (2017) covers a wide variety of disclosure channels including crowding out of private information, improving real decision maker choices, and welfare effects. Our paper also is interested in how firms might react to financial factors, but while the other papers in this literature focus on how a real decision maker could learn from its market price, we focus on how a firm could take advantage of the informational environment in its stock to take on more risk. We view our work as complementary to this literature.

[4] The result is closely related to information-scale effect, as discussed in detail in van Nieuwerburgh and Veldkamp (2009, 2010).

[5] Confer Bond, Edmans, and Goldstein (2012) for an excellent survey on the literature.

Our work is also related to the recent empirical literature analyzing the impact of institutional investing on price informativeness. Bai, Philippon, and Savov (2016) document an increase in aggregate efficiency and show that the share of institutional investors is positively correlated with price informativeness for stocks in the S&P 500. In subsequent work, Farboodi, Matray, Veldkamp, and Venkateswaran (2019) show that the aggregate increase is driven by a rise in the informativeness of large, growth stocks and use a structural model to decompose changes in price informativeness into changes in information and changes in firm characteristics. Kacperczyk, Sundaresan, and Wang (2018) show that foreign institutional investors positively impact domestic price informativeness. Sammon (2019) documents that passive investing actually leads to a reduction in the post-earnings announcement drift (which can be interpreted as an increase in price efficiency) and an increase in return volatility. While our empirical and theoretical results are largely consistent with these findings, they complement the literature by explicitly studying the impact of passive investors.

Finally, our paper also connects to the empirical market-microstructure literature which has found mixed evidence as to the impact of ETFs on financial markets. For example, Bhattacharya and O'Hara (2018) find that ETFs result in higher aggregate information in markets, but that individual asset prices can face dislocations and can face fragility due to herding. Huang, O'Hara, and Zhong (2018) shows that industry ETFs improved market efficiency among some stocks. Glosten, Nallareddy, and Zou (2016) shows that ETF activity increases short-run efficiency for stocks with weaker informational efficiency while having no such effects for those with stronger efficiency. In contrast to these papers, our focus is more on the ability of stock prices to predict future cash flows and less on liquidity-based features of information.

The rest of the paper is organized as follows. Section 1 provides new empirical evidence regarding the link between passive ownership and informational efficiency. Section 2 introduces our main economic framework and Section 3 characterizes the equilibrium in the economy. In Section 4, we discuss the impact of passive ownership on real-investment decisions, informational efficiency and asset prices. Section 5 concludes.

1 Motivating Empirical Facts

To motivate our theoretical analysis, we now provide new empirical evidence regarding the link between price informativeness and passive ownership. In particular, we document that stocks with large passive ownership tend to have higher price informativeness when compared to stocks with low levels of passive ownership.

1.1 Measuring Price Informativeness

Our measure of price informativeness relies on the cross-sectional predictability of firms' future cash flows by today's market prices and closely follows the well-known measure of price informativeness of Bai, Philippon, and Savov (2016).

Our sample period is from 2000 to 2016—the period in which passive investing became a broad and relevant phenomenon. We merge firm-level international stock-market and accounting data from Datastream with data on global institutional ownership from FactSet (using the last reported value in each calendar year).[6] Consistent with the literature, we exclude firms from the financial industry (one-digit SIC code 6), firms with a market capitalization of less than $1 million, and firms with less than four consecutive years of earnings data.[7] We measure passive ownership as the fraction of shares outstanding held by indexers (index funds and exchange-traded funds) and quasi-indexers; following the classification of Bushee (2001) for U.S. firms and that of Cremers, Ferreira, Matos, and Starks (2016) for non-U.S. firms.

To analyze the link between passive ownership and price informativeness, we first pool all firm-year observations and construct equal-sized "bins" (usually quintiles) based on the share of passive ownership; exploiting the fact that passive ownership varies substantially in the cross-section.[8] Within each bin, we then run a (pooled OLS) regression of future

[6] FactSet reports holdings for a wide range of institutions, including mutual funds, hedge funds, pension funds, bank trusts, and insurance companies. For firms outside the U.S., FactSet collects ownership data directly from national regulatory agencies, stock-exchange announcements, local and offshore mutual funds, mutual-fund-industry directories, and company proxies and financial reports.

[7] A detailed description of the data can be found in Kacperczyk, Sundaresan, and Wang (2018). Overall, the dataset includes information on more than 23,000 publicly-traded firms from 40 different countries; with a total of 186,885 firm-year observations.

[8] For example, in 2017, the proportion of shares outstanding held by passive investors varied between 7.1% to 29.8% for stocks in the S&P500 (Adib 2019).

earnings on today's market prices:[9]

$$E_{i,t+h}/A_{i,t} = a_h + b_h \log\left(M_{i,t}/A_{i,t}\right) + c_h \, E_{i,t}/A_{i,t} + d_h \, X_{i,t} + e_{i,t+h},$$

where future earnings, $E_{i,t+h}/A_{i,t}$, are measured as time-$t+h$ earnings before interest and taxes (EBIT) divided by time-t total assets and today's market price, $\log\left(M_{i,t}/A_{i,t}\right)$, is measured as the natural logarithm of the time-t market capitalization divided by time-t total assets. As controls, we include time-t EBIT divided by time-t total assets, $E_{i,t}/A_{i,t}$, as well as one-digit SIC codes and firm×country×year fixed effects (both captured by $X_{i,t}$).[10] The main coefficient of interest is b_h governing average price informativeness, defined as the sensitivity of future earnings to current market prices. To account for possible dependence across firms and years, we cluster standard errors in these two dimensions.

1.2 Price Informativeness and Passive Ownership

Figure 1 illustrates our main empirical finding: Stocks with large passive ownership tend to have higher price informativeness compared to stocks with low shares of passive owners.

Panel A illustrates the link between price informativeness and passive ownership for U.S. firms at the one-year horizon ($h = 1$). As is apparent, price informativeness is increasing monotonically in the share of passive ownership, which ranges from less than 2% (first quintile – Low) to about 35% (last quintile – High). The finding is very robust. For example, Panels B and C show that the same pattern can be observed when focusing on a three-year forecasting horizon ($h = 3$) and when using the full sample of firms.

One natural concern might be that the share of passive ownership simply proxies for firm size because passive funds often do not replicate the full index but, instead, over-invest into large stocks. As a result, our findings would be largely identical to those of Farboodi, Matray, Veldkamp, and Venkateswaran (2019) who document a strong, positive link between price informativeness and firm size. To address this issue, we sort all firm-year observations first into terciles according to firm size and then, within each size tercile, sort observations

[9] Kacperczyk, Sundaresan, and Wang (2018) and Farboodi, Matray, Veldkamp, and Venkateswaran (2019) follow similar approaches to study the link between price informativeness and foreign institutional ownership as well as between price informativeness and firm size, respectively.

[10] Following Bai, Philippon, and Savov (2016), we measure market capitalization as of the end of March and accounting variables as of the end of the previous fiscal year (typically December); ensuring that market participants have access to the accounting variables that we use as controls.

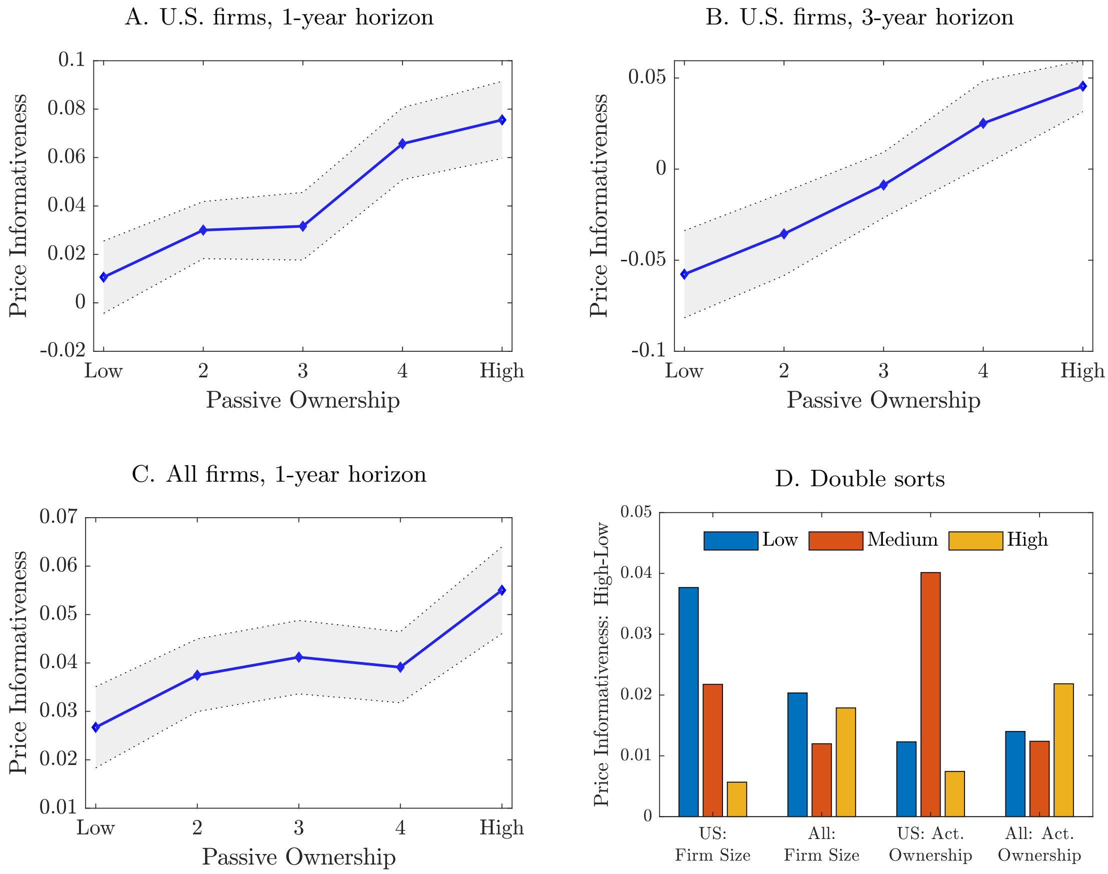

Figure 1: Price Informativeness vs. Passive Ownership. The first three panels of this figure show price informativeness for quintiles of passive ownership. Panel (A) is for U.S. firms at a one-year horizon; Panel (B) is for U.S. firms at a three-year horizon; Panel (C) is for international firms at a one-year horizon. The last panel shows for both terciles of firm size or terciles of active ownership, the difference between the price informativeness of the highest and lowest terciles of passive ownership.

according to the share of passive ownership. Panel D shows that for both U.S. and all firms, the difference in price informativeness between stocks with large passive ownership (third tercile – High) and stocks with low levels of passive ownership (first tercile – Low) is positive—for all levels of firm size.[11]

One might also be concerned that our findings are related to (hidden) variation in the fraction of active ownership. Consequently, we also double-sort firm-year observations into terciles according to active ownership and then, within each active-ownership tercile, sort them into terciles according to the share of passive ownership. As shown in Panel D, even after accounting for variations in active ownership, there exists a strong link between price informativeness and the level of passive ownership—for U.S. and international data.

[11]Note also that the link between passive ownership and firm size is less explicit than one might expect at first. For example, due to differences in index weights, the largest firms in the Russell 2000 have a significant larger share of passive owners than the smallest firms in the Russell 1000—a fact that has been exploited succesfully by Appel, Gormley, and Keim (2016) and subsequent empirical work.

The cause of this cross-sectional pattern in price informativeness is not immediately apparent. Intuitively, passive owners have no incentives to acquire private information because their objective is to simply track the index. In particular, their trades are not driven by information but rather by inflows (or, outflows) which are usually simply invested into all stocks according to their index weights. Hence, our findings poses a challenge to traditional models of information choice.

2 Model

This section introduces our main model, which incorporates a traditional project (capital-structure decision), as in Allen (1983), into a competitive rational expectations equilibrium model of joint portfolio and information choice, as in Verrecchia (1982). We also discuss investors' and firms' optimization problems and formally describe the equilibrium concept.

2.1 Economic Framework

Timing

We consider a static model, which we break up into four subperiods, as illustrated in Figure 2. In period 1, the *real-investment period*, firms make real-investment decisions, that is, decide how much capital to allocate to growth opportunities. In period 2, the *information-choice period*, active investors can spend time and resources to acquire private information. In particular, they choose the precision of their private signals about firm fundamentals; taking into account firms' real-investment decisions in period 1. Higher precision of signals reduces posterior uncertainty (variance) but comes at a higher cost. In period 3, the *portfolio-choice period*, active investors select their optimal portfolios; after observing their private signals (with chosen precision) and public stock prices. Passive investors simply adhere to their (exogenous) investment policy. Prices are set such that markets clear. In period 4, the *consumption period*, payoffs are realized and investors consume the proceeds from their investments.

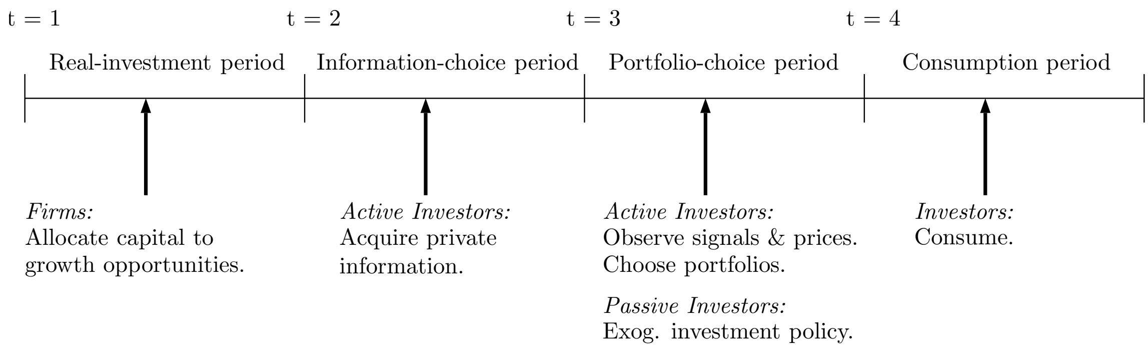

Figure 2: Timing. The figure illustrates the sequence of the events.

Investment Opportunities

There are multiple financial securities that are traded competitively in financial markets: a riskless asset (the "bond") and N risky assets (the "stocks"). The bond has a gross payoff of R_f units of the consumption good in period 4 and is available in perfectly elastic supply. It also serves as the numéraire, with its price normalized to one. The stocks are modeled as claims to random payoffs $X_n, n \in \{1, \ldots, N\}$, which are only observable in period 4. We denote the mean and variance of a stock's payoff—chosen optimally by the firm in period 1—by μ_n and variance σ_n^2, respectively. The supply of each stock is finite and (without loss of generality) normalized to one. Prices in period 3 are denoted by P_n.

Investors

There is a continuum of atomless investors with mass one that we separate into two groups: (1) a fraction $[0, \Gamma]$ of passive investors, $\mathcal{P}$; and (2) a fraction $(\Gamma, 1]$ of active investors, $\mathcal{A}$. Each investor $i \in \{\mathcal{P}, \mathcal{A}\}$ is endowed with the same initial wealth $W_{0,i}$, normalized to 1.

Passive investors, $i \in [0, \Gamma]$, adhere to an exogenous investment policies; for example, determined by the weight of a stock in an index. In particular, passive investor i buys $\theta_{i,n}^{\mathcal{P}}$ shares of stock n. Consequently, their trading is information-insensitive and hence, they naturally have no incentive to acquire private information.[12]

Active investors, $i \in (\Gamma, 1]$, can freely invest in all financial assets and have incentives to acquire information about the stocks. They have CARA-preferences over terminal wealth W_i: $u(W_i) = -(1/\rho) \exp(-\rho W_i)$, with a coefficient of absolute risk-aversion equal to ρ.

[12] Alternatively, one can think of passive investors as being highly benchmarked.

Note that we do not model the compensation of active investors or passive investors explicitly. The compensation of active investors is usually tightly linked to their performance and assets-under-management; both captured by terminal wealth, W_i, in our setting. In contrast, the main objective of passive investment funds is usually a low tracking error; in our framework exogenously specified to be zero.

There also exist noise (liquidity) traders with random—not explicitly modeled—demand for the stocks. This assumption, standard in the literature, prevents prices from fully revealing the information acquired by the active investors and, thus, preserves their incentives to acquire private information in the first place.[13] In particular, noise traders' demand $Z_n, n \in \{1, \ldots, N\}$ is assumed to be normally-distributed $Z_n \sim \mathcal{N}(0, \sigma_Z^2)$ and independently distributed across stocks.[14]

Firms

There exist N firms; each being linked to one of the stocks traded in financial markets. Firms are endowed with one unit of capital $\bar{K} = 1$. They have access to growth opportunities as well as a risk-less project (asset) with payout R_f. We follow Subrahmanyam and Titman (1999) and assume that the payoff of the growth opportunities—for an allocation of capital equal to K_n—is given by:

$$G_n = A_n\, K_n - c\, \frac{K_n^2}{2}, \tag{1}$$

with A_n being normally distributed: $A_n \sim \mathcal{N}(\mu_A, \sigma_A^2)$, with $\mu_A > R_f$ and $\sigma_A > 0$. Thus, growth opportunities "suffer" from decreasing returns to scale. The "productivity" A_n is assumed to be independent across stocks and also independent from noise traders' demands, Z_n.

Each firm decides on the optimal allocation, $K_n \geq 0$, to growth opportunities; in order to maximize the expected stock price.[15] The resultant mean and volatility of a firm's payoff $X_n = G_n + (1 - K_n)R_f$ are given by $\mu_n = R_f + K_n(\mu_A - R_f) - c(K_n^2/2)$ and $\sigma_n = K_n \sigma_A$,

[13] An elegant microfoundation for noise trading can be found in Chinco and Fos (2019).

[14] To rule out any effects arising from differences in the distributions of the noise traders' demands, we set the mean and volatility of noisy demand to be the same for all stocks.

[15] For ease of exposition, we rule out any feedback effects; that is, managers cannot infer information from stock prices while making their real-investment decisions. For recent contributions in the feedback literature, see, e.g., Ozdenoren and Yuan (2008), Edmans, Goldstein, and Jiang (2015) among other papers.

respectively. Intuitively, the more capital a firm assigns to (risky) growth opportunities, the higher the mean and variance of the final payout. Equivalently, one can think of a situation in which the firm chooses its leverage; with $1-K_n$ capturing a firm's borrowing ($1-K_n<0$) or savings ($1-K_n>0$) decision. The firms' choices will become public knowledge in period $t=2$.

Information Structure

Active investors and firm managers are endowed with the same priors.[16] In period $t=2$, active investors can acquire private information about the stock's payoffs, conditional on firms' real-investment choices. For example, they may study financial statements, gather information about consumers' taste, hire outside financial advisers, or subscribe to proprietary databases. Formally, each investor $i \in (\Gamma, 1]$ chooses the precision $q_{i,n}$ of her private signal $Y_{i,n} = X_n + \varepsilon_{i,n}$, $\varepsilon_{i,n} \sim \mathcal{N}(0, 1/q_{i,n})$; to be received in period $t=3$. Higher precision reduces the posterior uncertainty regarding a stock's payoff but increases the information-acquisition costs $\kappa(q_{i,n})$.[17]

We denote the expectation and variance conditional on prior beliefs as $\mathrm{E}[\,\cdot\,]$ and $Var(\,\cdot\,)$. To denote active investor i's expectation and variance conditional on his time-3 information set $\mathcal{F}_i = \big\{\{Y_{i,n}\}, \{P_n\}\big\}$, we use $\mathrm{E}[\,\cdot\,|\,\mathcal{F}_i]$ (or, $\mathrm{E}_3[\,\cdot\,]$) and $Var(\,\cdot\,|\,\mathcal{F}_i)$ (or, $Var_3(\,\cdot\,)$).

2.2 Investors' Optimization Problems and Equilibrium

In the portfolio-choice period ($t=3$), each active investor $i \in (\Gamma, 1]$ chooses the number of shares of the stocks, $\{\theta^{\mathcal{A}}_{i,n}\}$, in order to maximize her expected utility; conditional on the received signals $\{Y_{i,n}\}$ (with chosen precision $\{q_n\}$), the public stock prices $\{P_n\}$ and the firms' real-investment choices $\{K_n\}$:

$$V_{3,i}\big(\{K_n\}, \{q_{i,n}\}, \{P_n\}, \{Y_{i,n}\}\big) = \max_{\{\theta^{\mathcal{A}}_{i,n}\}} \mathrm{E}\left[-\frac{1}{\rho}\exp\big(-\rho\, W_i\big)\,\Big|\,\mathcal{F}_i\right], \tag{2}$$

[16] Passive investors do not make "active" decisions and, hence, their beliefs remain unspecified.

[17] The information-cost function $\kappa(\cdot)$ is assumed to be the same for all stocks (firms) and to be continuous, increasing and strictly convex, with $\kappa(0)=0$. This guarantees the existence of an interior solution and captures the idea that each new improvement in precision is more costly than the previous one.

with terminal wealth, W_i, being given by:[18]

$$W_i = W_{0,i}\, R_f + \sum_{n=1}^{N} \theta^{\mathcal{A}}_{i,n}\, (X_n - PR_f) - \sum_{n=1}^{N} \kappa(q_{i,n}). \tag{3}$$

In the information choice period ($t = 2$), each active investor $i \in (\Gamma, 1]$ chooses the precision of her private signals, $q_{i,n}$, in order to maximize expected utility, taking the firms' real-investment choices, K_n, as given:

$$V_{2,i}(\{K_n\}) = \max_{\{q_{i,n}\}\geq 0} \mathrm{E}\Big[V_{3,i}\big(\{K_n\}, \{q_{i,n}\}, \{P_n\}, \{Y_{i,n}\}\big)\Big], \tag{4}$$

where the expectation is taken over all possible realizations of her private signals $\{Y_{i,n}\}$ and the public prices $\{P_n\}$.

Finally, in the real-investment period ($t = 1$), each firm chooses the capital allocation to growth opportunities, K_n, in order to maximize the expected (discounted) stock price—anticipating the investors' information and portfolio choices in the subsequent periods:

$$S_n = \max_{\{K_n\}\geq 0} \mathrm{E}\big[P_n R_f\big]. \tag{5}$$

Equilibrium Definition

A rational expectations equilibrium is defined by real-investment choices $\{K_n\}$, information choices $\{q_{i,n}\}$ as well as portfolio choices $\{\theta^{\mathcal{A}}_{i,n}\}, i \in (\Gamma, 1]$, and prices $\{P_n\}$, $n \in \{1, \ldots, N\}$ such that:

1. $\{\theta^{\mathcal{A}}_{i,n}\}$ and $\{q_{i,n}\}$ solve active investor i's maximization problems (2) and (4), taking prices as given.
2. K_n solves firm n's maximization problem (5).

[18] This follows from the two budget equations $W_i = \sum_{n=1}^{N} \theta^{\mathcal{A}}_{i,n}\, X_n + \theta^{\mathcal{A}}_{i,0}\, R_f - \sum_{n=1}^{N} \kappa(q_{i,n})$ and $W_{0,i} = \sum_{n=1}^{N} \theta^{\mathcal{A}}_{i,n}\, P_n + \theta^{\mathcal{A}}_{i,0}$ by solving the second equation for $\theta^{\mathcal{A}}_{i,0}$ (number of shares of the bond) and plugging the solution into the first.

3. Expectations are rational; that is, the average precision of private information implied by aggregating investors' precision choices equals the level assumed in optimization problems (2), (4), and (5).

4. Aggregate demand equals aggregate supply.

We restrict our attention to equilibria that are symmetric among active investors in portfolio and information acquisition decisions.

Note that, in equilibrium, stock prices play a "triple" role: They clear the security markets, aggregate as well as disseminate the active investors' private information but also affect firms' investment decisions.

3 Equilibrium Characterization

In this section, we characterize the equilibrium in the economy; working backwards from investors' portfolio and information choices to firms' real-investment decisions.

3.1 Portfolio Choice and Equilibrium Prices

The optimal portfolio choice of an active investor, $i \in (\Gamma, 1]$, is described by the usual CARA-normal demand:

$$\theta^{\mathcal{A}}_{i,n} = h_{i,n} \, \frac{\mathrm{E}\left[X_n \,|\, \mathcal{F}_i\right] - P_n \, R_f}{\rho}, \tag{6}$$

where $h_{i,n} \equiv Var\left(X_n \,|\, \mathcal{F}_i\right)^{-1}$ denotes the precision of investor i's posterior beliefs regarding payoff X_n. The key difference relative to the demand of passive investors, $\theta^{\mathcal{P}}_{i,n}, i \in [0, \Gamma]$, is that an active investor's demand is information-sensitive.

Aggregating the demand of the active and passive investors and imposing market clearing delivers equilibrium stock prices:

Theorem 1. *Conditional on a firm's real-investment choice, K_n (i.e., μ_n and σ_n^2) and active investors' information choices, $q_{i,n}$, $\forall i \in (\Gamma, 1]$, there exists a unique linear rational* *expectations equilibrium:*

$$P_n R_f = \frac{1}{\bar{h}_n}\left(\frac{\mu_n}{\sigma_n^2} - \rho\,\bar{\theta}_n^{\mathcal{A}}\right) + \frac{1}{\bar{h}_n}\left(\bar{h}_n - \frac{1}{\sigma_n^2}\right) X_n + \frac{1}{\bar{h}_n}\left(\frac{\rho}{1-\Gamma} + \frac{(1-\Gamma)\,\bar{q}_n}{\rho\,\sigma_Z^2}\right) Z_n, \qquad (7)$$

$$\textit{where} \quad h_{0,n} \equiv \frac{1}{\sigma_n^2} + \frac{(1-\Gamma)^2\,\bar{q}_n^2}{\rho^2\,\sigma_Z^2}, \quad \bar{q}_n \equiv \frac{1}{1-\Gamma}\int_\Gamma^1 q_{i,n}\,di, \quad \bar{h}_n \equiv h_{0,n} + \bar{q}_n, \qquad (8)$$

$$\bar{\theta}_n^{\mathcal{P}} \equiv \frac{1}{\Gamma}\int_0^\Gamma \theta_{i,n}^{\mathcal{P}}\,di, \quad \textit{and} \quad \bar{\theta}_n^{\mathcal{A}} \equiv \frac{1-\Gamma\bar{\theta}_n^{\mathcal{P}}}{1-\Gamma}. \qquad (9)$$

The characterization of the equilibrium price in (7) is standard for this type of economy, and the variables defined in (8) and (9) allow for intuitive interpretations. $h_{0,n}$ characterizes the precision of public information and is equal to the sum of the precision of prior beliefs, $1/\sigma_n^2$, and the precision of the public price signal, $((1-\Gamma)^2\,\bar{q}_n^2)/(\rho^2\,\sigma_Z^2)$. $\bar{q}_n$ measures the average precision of the private information of the active investors. Consequently, $\bar{h}_n$ governs the average aggregate precision of the active investors, that is, the sum of private and public precision.[19] Finally, $\bar{\theta}_n^{\mathcal{P}}$ captures the average demand of the passive investors and $\bar{\theta}_n^{\mathcal{A}}$ governs the expected average holdings of active investors.[20]

All else equal, the price of stocks experiencing a higher average demand by passive investors is higher. Intuitively, an increase in the average demand of passive investors, $\bar{\theta}_n^{\mathcal{P}}$, implies a reduction in the expected average holdings of active investors, $\bar{\theta}_n^{\mathcal{A}}$. Thus, each active investor has to absorb a smaller number of shares in equilibrium and, hence, commands a lower price discount which pushes up the price.[21] The impact of an increase in the fraction of passive investors, Γ, depends crucially on passive investors' demand for a stock. In particular, if their average demand, $\bar{\theta}_n^{\mathcal{P}}$, exceeds a stock's supply (equal to 1), an increase in the share of passive investors lowers the number of shares to be held by active investors $\bar{\theta}_n^{\mathcal{A}}$ (cf. (9)). Thus, they have to bear less risk; pushing up the price. Vice versa, if the passive investors' average demand is lower than aggregate supply, active investors have to absorb more shares as the fraction of passive investors rises; implying a larger price discount and a lower price.

[19]Because we restrict our attention to symmetric equilibria, the posterior precision of each individual active investor, $h_{i,n}, i \in (\Gamma, 1]$, coincides with $\bar{h}_n$ in equilibrium.

[20]Intuitively, in the absence of passive investors ($\Gamma = 0$), the expected average holdings of active investors simply equal aggregate supply.

[21]Formally, the price discount is given by $-(\rho/\bar{h}_n) \times \bar{\theta}_n^{\mathcal{A}}$. Hence, as expected, the magnitude of the price discount is also driven by active investors' risk-aversion, ρ, and posterior variance, $1/\bar{h}_n$.

Passive investing also affects the sensitivity of the stock price with respect to realizations of the fundamental, X_n, and of the noise traders' demand, Z_n. Hence, it has a direct impact on informational efficiency, as discussed in the following corollary:

Corollary 1. *Conditional on active investors' information choices, $q_{i,n}$, $\forall i \in (\Gamma, 1]$, and a firm's real-investment choice, K_n (i.e., μ_n and σ_n^2), the precision of the public price signal*

$$\mathcal{I}_n \equiv h_{0,n} - \frac{1}{\sigma_n^2} = \frac{(1-\Gamma)^2\, \bar{q}_n^2}{\rho^2\, \sigma_Z^2}$$

is declining in the fraction of passive investors Γ but unrelated to the average demand of passive investors; formally, $d\mathcal{I}_n/d\Gamma < 0$ and $d\mathcal{I}_n/d\bar{\theta}_n^{\mathcal{A}} = 0$.

Holding constant active investors' information choices, price informativeness declines as the number of passive investors increases.[22] Intuitively, as the share of passive investors rises, the total amount of private information, $(1-\Gamma)\bar{q}_n$, and, hence, the informational content of prices, declines. This captures the "naïve" decline in informational efficiency often associated with passive investing. In contrast, variations in the average demand of passive investors have no impact on price informativeness because they do not affect the total amount of information in the economy and the resultant shift in demand is perfectly predictable (i.e., can easily be "filtered out" by the investors).

3.2 Information Choices

While Theorem 1 and Corollary 1 take the information environment as given, information choices are actually an endogenous outcome of the model. In period $t = 2$, active investors choose the precision of their private signals $\{q_{i,n}\}$; anticipating their optimal portfolio choice and price informativeness in the trading period ($t = 3$).

An active investor's optimal information choice, given arbitrary signal-precision choices by the other active investors, is characterized by:

Theorem 2. *Conditional on a firm's real-investment choice, K_n (i.e., μ_n and σ_n^2) and the average private signal precision, $\bar{q}_n$, investor i's optimal signal precision $q_{i,n}$ is the unique*

[22] This is consistent with results in the literature; see, among others, Breugem and Buss (2018) and Kacperczyk, Nosal, and Sundaresan (2018).

solution of:

$$2\,\kappa'\left(q_{i,n}\right)=\frac{1}{\rho}\left(\frac{1}{\sigma_n^2}+\frac{\left(1-\Gamma\right)^2\,\bar{q}_n^2}{\rho^2\,\sigma_Z^2}+q_{i,n}\right)^{-1}=\frac{1}{\rho}\,\frac{1}{h_{0,n}+q_{i,n}}. \tag{10}$$

Hence, an investor's information choice, $q_{i,n}$, increases as the fraction of passive investors or the payoff variance rises but is unaffected by variations in passive investors' average demand; formally, $dq_{i,n}/d\Gamma>0$, $dq_{i,n}/d\sigma_n^2>0$, and $dq_{i,n}/d\bar{\theta}_n^{\mathcal{P}}=0$.

At the optimum, the marginal cost of more precise private information, $2\kappa'\left(q_{i,n}\right)$, equals the marginal benefit which is governed by the inverse of the investor's posterior precision $h_{i,n}=h_{0,n}+q_{i,n}$ and risk-tolerance $1/\rho$. Hence, any decline in the precision of public information, $h_{0,n}$, increases an active investor's incentives to acquire private information.[23]

In particular, as passive investing becomes more prevalent (i.e., Γ rises) and, hence, price informativeness and the precision of public information decline, $h_{0,n}$, the marginal benefits of private information shift up. This is illustrated in Panel A of Figure 3. Thus, active investors acquire more precise information; as highlighted by the intersection with marginal costs. Similarly, an increase in fundamental variance, σ_n^2, lowers the precision of public information, $h_{0,n}$, so that the marginal benefits of private information and private-signal precision shift up (Panel B); leading to higher optimal signal precision. In contrast, passive investors' average demand, $\bar{\theta}_n^{\mathcal{P}}$, does not affect the precision of public information, and, thus, holding constant a firm's real-investment decision, has no implications for active investors' information choice.

In equilibrium, active investors' information choices must be mutual best response functions; in particular, in a symmetric equilibrium they must coincide with average precision: $q_{i,n}=\bar{q}_n, \forall i\in(\Gamma,1]$. Thus, the average private signal precision, $\bar{q}_n$, is determined by:

Theorem 3. *Conditional on a firm's real-investment choice, K_n (i.e., μ_n and σ_n^2), the average private signal precision, $\bar{q}_n$, is the unique solution to:*

$$2\,\kappa'\left(\bar{q}_n\right)=\frac{1}{\rho}\left(\frac{1}{\sigma_n^2}+\frac{\left(1-\Gamma\right)^2\,\bar{q}_n^2}{\rho^2\,\sigma_Z^2}+\bar{q}_n\right)^{-1}. \tag{11}$$

[23] In particular, due to strategic substitutability (see, e.g., Grossman and Stiglitz, 1980), an investor's optimal signal precision, $q_{i,n}$, is declining in average signal precision, $\bar{q}_n$.

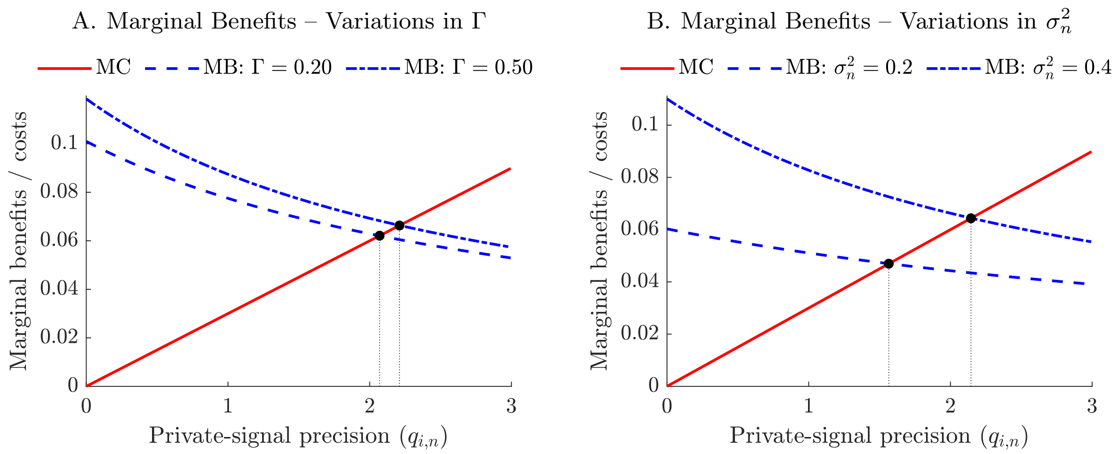

Figure 3: Information choices. The figure depicts the marginal costs and benefits of private information as a function of the signal precision, $q_{i,n}$. Panel A illustrates how the marginal benefits vary with the fraction of passive investors in the economy, Γ. Panel B illustrates how the marginal benefits vary with the fundamental volatilities, σ_n^2.

Hence, conditional on a firm's real-investment choice, the average private-signal precision $\bar{q}_n$ *is increasing in the fraction of passive investors and the payoff variance but is independent of passive investors' average demand; formally,* $d\bar{q}_n/d\Gamma > 0$*,* $d\bar{q}_n/d\sigma_n^2 > 0$*, and* $d\bar{q}_n/d\bar{\theta}_n^{\mathcal{P}} = 0$*.*

Intuitively, as a result of the stronger incentives of active investor to acquire private information, an increase in the share of passive investors, Γ, or in the fundamental variance, σ_n^2, leads to an increase in the average private-signal precision. In contrast, variations in the passive investors' average demand have no impact on equilibrium signal precision because they do not affect investors' incentives to acquire information.

The overall impact on price informativeness can be summarized as follows:

Corollary 2. *Conditional on a firm's real-investment choice,* K_n *(i.e.,* μ_n *and* σ_n^2*), price informativeness declines in the fraction of passive investors, increases in fundamental variance, and is unrelated to passive investors' average demand; formally,* $d\mathcal{I}_n/d\Gamma < 0$*,* $d\mathcal{I}_n/d\sigma_n^2 > 0$*, and* $d\mathcal{I}_n/d\bar{\theta}_n^{\mathcal{P}} = 0$*.*

Conditional on real-investment choices, price informativeness declines as the fraction of passive investors, Γ, increases. That is, the decline in information aggregation (cf. Corollary 1) dominates the positive impact of more precise private signals (cf. Theorem 3). In contrast, an increase in fundamental variance leads to an improvement in price informativeness because it leads to higher signal precision but has no impact on information aggregation. Finally, conditional on real-investment choices, the passive investors' average demand does not affect informational efficiency; consistent with the propositions above.

3.3 Real-Investment Choices

The key new feature of our framework is that we allow for endogenous real-investment decisions. Hence, the fundamental variance, σ_n^2, taken as given by Theorems 2 and 3, is an endogenous outcome of the model; in sharp contrast to the literature.

In particular, in period $t = 1$, each firm chooses the optimal allocation of capital to growth opportunities, K_n, in order to maximize the expected stock price (5):

$$S_n = R_f + K_n\,(\mu_A - R_f) - c\,\frac{K_n^2}{2} - \rho\,\bar{\theta}_n^{\mathcal{A}}\,\frac{1}{\bar{h}_n}. \tag{12}$$

The optimal capital allocation is thus characterized by:

Theorem 4. *There exists an optimal allocation to growth opportunities, $K_n > 0$, which fulfills:*

$$\mu_A - R_f - c\,K_n = \underbrace{\rho\,\bar{\theta}_n^{\mathcal{A}}}_{\equiv C_1} \times \underbrace{2\,K_n\,\sigma_A^2\,\frac{1}{\bar{h}_n^2}\left(-\frac{d\bar{h}_n}{d\sigma_n^2}\right)}_{\equiv C_2}, \tag{13}$$

with

$$-\frac{d\bar{h}_n}{d\sigma_n^2} = \frac{1}{\sigma_n^4}\,\frac{2\,\bar{q}_n\,\rho\,\kappa''(\bar{q}_n)\,\bar{h}_n^2}{\bar{q}_n + 2\mathcal{I}_n + 2\bar{q}_n\,\rho\,\kappa''(\bar{q}_n)\,\bar{h}_n^2} \geq 0.$$

At the optimum, the marginal benefit of allocating more capital to growth opportunities equals the marginal cost. Intuitively, the marginal benefit is given by the increase in the mean payoff, $\mu_A - R_f - cK_n$. The marginal cost derives from the higher price discount that risk-averse investors command in response to an increase in posterior variance $1/\bar{h}_n$ (resulting from the respective higher fundamental variance $\sigma_n^2 = K_n^2\sigma_A^2$). It can be decomposed into two components. First, C_1, the sensitivity of the stock price (12) with respect to posterior variance: $dS_n/d(1/\bar{h}_n)$. Second, C_2, the sensitivity of posterior variance with respect to capital allocations: $d(1/\bar{h}_n)/dK_n$.

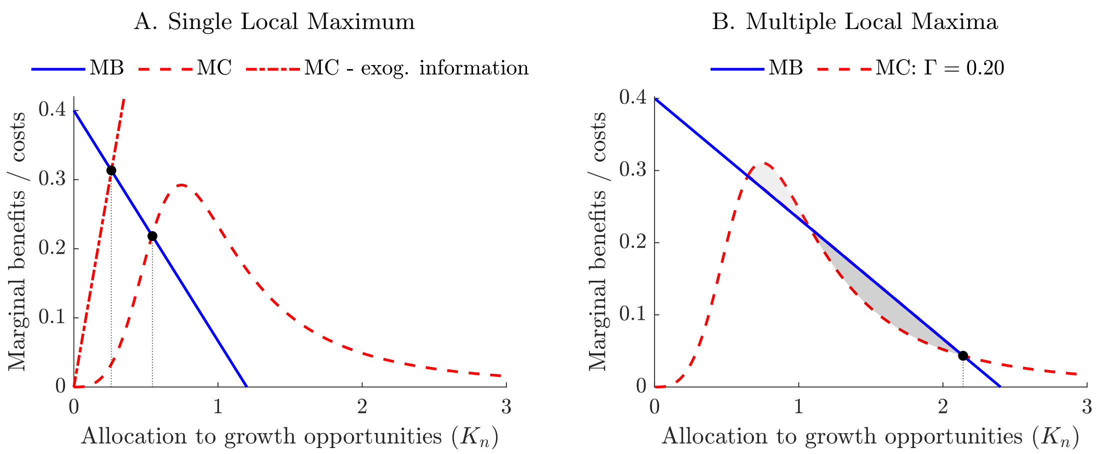

Figure 4: Real-investment choices. The figure depicts the marginal costs and benefits of allocating capital to growth opportunities as a function of the capital allocation, K_n. Panel A illustrates the case of a single local (and, hence, glocal) maximum whereas Panel B illustrates the case of multiple local maxima.

The first component, C_1, does not vary with the allocation of capital to growth opportunities. In contrast, the second component, C_2, and, thus, marginal costs, are—in the absence of information choice—monotonically increasing in the capital allocation; as is illustrated in Panel A of Figure 4.

In contrast, in our setting, marginal costs are prescribed by an inverse U-shape; due to a second effect that is unique to our framework with endogenous information choice. In particular, as the allocation to growth opportunities and, hence, fundamental variance, σ_n^2, rises, the marginal benefits of acquiring more precise private information increase. Consequently, active investors acquire more precise private information (cf. Theorem 3) which (partially) offsets the increase in fundamental variance and, hence, reduces the sensitivity of the posterior variance with respect to capital allocations; compared to the case of exogenous information. Indeed, as illustrated in Panel A, marginal costs increase much slower than with exogenous information and, because the impact of information acquisition strengthens as the capital allocation increases, even start to decline at some point.[24] Consequently, when taking into account active investors' optimal information choice, the allocation to growth opportunities is considerably higher (as highlighted by the intersection with marginal benefits).

Note that, due to this shape of the marginal-cost function, there can be multiple (specifically, three) intersections between marginal benefits and marginal costs. In particular, as

[24]In the limit $K_n \to \infty$ (i.e., $\sigma_n^2 \to \infty$), the marginal cost actually converges to zero because the active investors' information choice perfectly offsets the increase in fundamental variance.

shown in Panel B, there might be two local maxima when marginal benefits "cross" marginal costs from above and one local minimum when marginal benefits "cross" marginal costs from below (at the intermediate value of K_n). In the illustration in Panel B, the second local maximum constitutes the global maximum because the integral of the region in which marginal benefits are higher than marginal costs (dark-grey shaded area) dominates the region in which marginal costs are higher than marginal benefits (light-grey shaded area). In other cases, it might be the other way around.[25]

4 The Impact of Passive Ownership

In this section, we study the equilibrium implications of passive ownership; for firms' real-investment decisions, informational efficiency, and asset prices.

Varying passive investors' average demand, $\bar{\theta}_n^{\mathcal{P}}$, will be our key variable of comparative statics analysis; capturing *cross-sectional* variations in the proportion of shares outstanding held by passive investors. For example, passive ownership is naturally higher for "big" stocks within an index but might also vary due to stocks' membership in different sub-indices, like sector or factor indices.[26] In addition, we illustrate how variations in the fraction of passive investors in the economy, Γ, governing the share of *aggregate* assets managed by passive investors, affect equilibrium outcomes.[27]

4.1 Real Investment

In the first step, we study how passive investing affects firms' real-investment decisions. The following proposition summarizes our main findings:

Theorem 5. *As passive investors' average demand increases, the marginal cost of allocating capital to growth opportunities shifts down. Hence, firms with a larger proportion of passive investors allocate more capital to growth opportunities; formally,* $dK_n/d\bar{\theta}_n^{\mathcal{P}} > 0$.

[25]Note that if the mass under the two integrals perfectly coincides, there exist multiple (two) equilibria. However, the set of parameter values for which this occurs has zero probability. One could rule this out by relying on a simple selection criterion.

[26]For instance, for S&P500 stocks, passive-investor ownership ranged from 7.1% to 29.8% in 2017; with a cross-sectional average of about 14.5% (see, e.g., Adib 2019).

[27]Intuitively, while changes in the average demand of passive investors, $\bar{\theta}_n^{\mathcal{P}}$, govern the *intensive* margin of passive investing, changes in the share of passive investors in the economy, Γ, capture the *extensive* margin.

The passive investors' average demand, $\bar{\theta}_n^{\mathcal{P}}$, only affects the first component of the marginal cost of allocating capital to growth opportunities, $C_1 = \rho\,\bar{\theta}_n^{\mathcal{A}}$, which governs the sensitivity of the stock price with respect to posterior variance (cf. (13)). In particular, a higher average demand by passive investors lowers the average number of shares to be held by active investors, $\bar{\theta}_n^{\mathcal{A}}$, such that each active investor has to bear less risk. As a result, they command a smaller price discount per unit of risk (i.e., the price is less sensitive to posterior variance) and, thus, marginal costs decline; as illustrated in Panel A of Figure 5. This, in turn, pushes up a firm's capital allocation to growth opportunities (as highlighted by the intersection with marginal benefits). Specifically, a firm's optimal capital allocation, K_n, is monotonically increasing in passive investors' average demand, $\bar{\theta}_n^{\mathcal{P}}$—independent of the overall degree of passive investing in the economy, Γ (see Panel B). This result is consistent with the intuition behind Kashyap, Kovrijnykh, Li, and Pavlova (2018).

An increase in the fraction of passive investors in the economy affects both components of marginal costs: the sensitivity of the stock price with respect to posterior variance, C_1, and the sensitivity of posterior variance with respect to capital allocation, C_2. First, it amplifies the impact of passive investors' average demand on the price sensitivity, C_1. For example, if the average passive demand, $\bar{\theta}_n^{\mathcal{P}}$, exceeds aggregate supply (equal to 1), an increase in the share of passive investors further lowers the average number shares to be born by active investors, $\bar{\theta}_n^{\mathcal{A}}$. Thus, marginal costs shift down (cf. Panel A). In contrast, for stocks with a low demand by passive investors ($\bar{\theta}_n^{\mathcal{P}} < 1$), active investors' average holdings increase and so do marginal costs. Consequently, as the share of passive investors goes up, allocations to growth opportunities further increase (decline) for stocks with high (low) proportions of passive ownership; as illustrated in Panel B. Second, an increase in the fraction of passive investors—in general—pushes up posterior variances; due to its adverse effect on information aggregation (cf. Corollary 2). This, in turn, leads to an increase in marginal costs for all levels of passive ownership (by means of an increase in C_2). Quantitatively, this effect is rather small but apparent in that capital allocations decline for $\bar{\theta}_n^{\mathcal{P}}$ slightly above 1.0.

Overall, this also implies that there are more pronounced differences in the optimal capital allocation in the cross-section of firms:

Lemma 1. *The difference in firms' optimal capital allocation to growth opportunities is increasing in the fraction of passive investors; formally,* $d^2 K_n/(d\bar{\theta}_n^{\mathcal{P}}\, d\Gamma) > 0$.

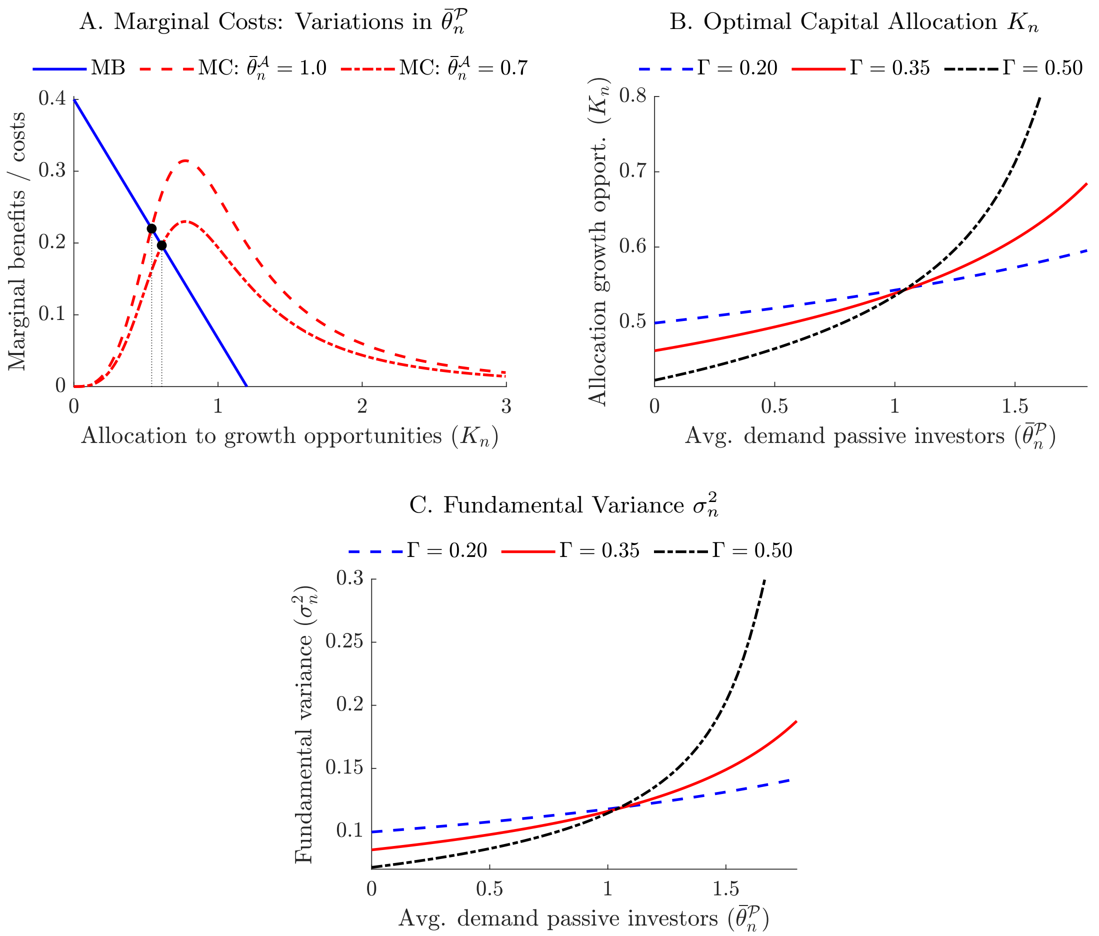

Figure 5: Real-Investment Decisions. The figure depicts the impact of passive investing on firms' real-investment decisions. Panel A shows how the marginal cost of allocating capital to growth opportunities varies with the average holdings of active investors, $\bar{\theta}_n^{\mathcal{A}}$. Panels B and C depict how a firm's allocation to growth opportunities and its fundamental variance varies with the average demand of passive investors $\bar{\theta}_n^{\mathcal{P}}$—for different degrees of passive investing in the economy.

These differences in firms' allocation to growth opportunities also have a direct impact on the mean and variance of firms' fundamentals X_n:

Lemma 2. *As passive investors' average demand increases, the mean and variance of the payoff increase; formally,* $d\mu_n/d\bar{\theta}_n^{\mathcal{P}} > 0$ *and* $d\sigma_n^2/\bar{\theta}_n^{\mathcal{P}} > 0$. *Also, the difference in the payoff's mean and variance is increasing in the fraction of passive investors; formally,* $d^2\mu_n/(d\bar{\theta}_n^{\mathcal{P}}\, d\Gamma) > 0$ *and* $d^2\sigma_n^2/(d\bar{\theta}_n^{\mathcal{P}}\, d\Gamma) > 0$.

Intuitively, due to the higher mean and variance of the growth opportunity, G_n (relative to those of the risk-free alternative), the larger capital allocation by firms with more passive investors naturally translates into a higher fundamental mean and variance. For the variance, σ_n^2, this is illustrated in Panel C of Figure 5. Moreover, as the fraction of passive investors Γ increases and, hence, the variations in firms' capital allocation become more pronounced, so do the variations in firms' fundamentals (as illustrated for σ_n^2 in Panel C).

4.2 Informational Efficiency

We can now turn to the main focus of our analysis: the impact of passive investing on informational efficiency. The following theorem summarizes our key results:

Theorem 6. *As passive investors' average demand increases, the average precision of active investors' private information and price informativeness increase; formally,* $d\bar{q}_n/d\bar{\theta}_n^{\mathcal{P}} > 0$ *and* $d\mathcal{I}_n/d\bar{\theta}_n^{\mathcal{P}} > 0$.

Notably, price informativeness *increases* in the proportion of shares held by passive investors. To understand the economic mechanism behind this result, recall that an increase in passive investors' average demand, $\bar{\theta}_n^{\mathcal{P}}$, implies a larger capital allocation to growth opportunities and, hence, a higher fundamental variance σ_n^2. This lowers the precision of public information, $h_{0,n}$, and, hence, increases the marginal benefit of private information. Consequently, active investors acquire more precise private information which, in turn, pushes up price informativeness (cf. Corollary 2). This is illustrated in Panels A and B of Figure 6.

These graphs also illustrate that a rise in the fraction of passive investors amplifies the impact of passive investors' average demand:

Lemma 3. *The difference in the average precision of active investors' private information as well as in price informativeness is increasing in the fraction of passive investors; formally,* $d^2\bar{q}_n/(d\bar{\theta}_n^{\mathcal{P}}\, d\Gamma) > 0$ *and* $d^2\mathcal{I}_n/(d\bar{\theta}_n^{\mathcal{P}}\, d\Gamma) > 0$.

In particular, recall that while for low levels of passive investors' average demand, the allocation of capital to growth opportunities and, hence, fundamental variance declines when the share of passive investors goes up, both capital allocations and fundamental variance increase for high levels. Consequently, as the fraction of passive investors increases, the marginal benefit of private information and, hence, the optimal private-signal precision decline (increase) for low (high) levels of passive investors' average demand; as is illustrated in Panel A.

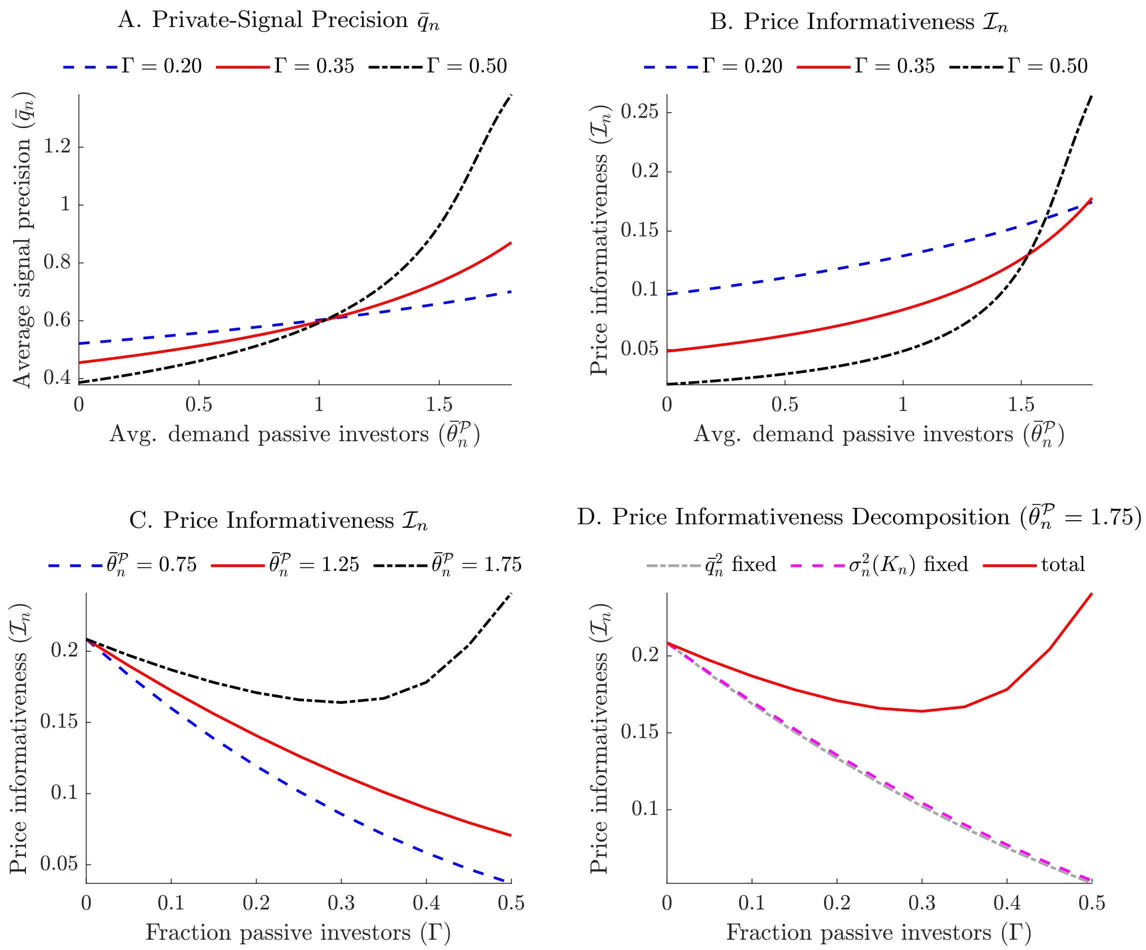

Figure 6: Informational Efficiency The figure depicts the impact of passive investing on informational efficiency. Panels A and B show how the average private-signal precision and price informativeness vary with the average demand of passive investors $\bar{\theta}_n^{\mathcal{P}}$—for different degrees of passive investing in the economy. Panel C illustrates the impact of a rise in the fraction of passive investors on price informativeness—for different degrees passive ownership. Panel D decomposes the effects for the case $\bar{\theta}_n^{\mathcal{P}} = 1.75$.

These changes in active investors' private-signal precisions directly lead to corresponding changes in price informativeness and, hence, the difference in price informativeness between stocks with small and large passive ownership widens as the share of passive investors increases. This can be seen in Panel B but also, more explicitly, in Panel C which shows the dynamics of price informativeness for various levels of passive ownership. Keep in mind that—keeping firms' real-investment decision fixed—an increase in the share of passive investing adversely affects informational efficiency for all stocks (cf. Corollary 2); due to the decline in information aggregation. Hence, on average, price informativeness declines (see Panels B and C). However, for stocks with a large demand by passive investors ($\bar{\theta}_n^{\mathcal{P}} \gg 1$), the increase in private-signal precision dominates and price informativeness actually *increases* in the fraction of passive investors, Γ (Panel B). This is illustrated in Panel D which decomposes, for $\bar{\theta}_n^{\mathcal{P}} = 1.75$, the price-informativeness reaction into its two components: i) a decline in information aggregation (keeping $\sigma_n^2(K_n)$ fixed) and ii) an increase in private-signal precision, as illustrated in Panel A (leading to the total change).

4.3 Asset Prices

Passive investing also affects equilibrium asset prices and returns. The following theorem describes the main implications for stock prices:

Theorem 7. *As passive investors' average demand, $\bar{\theta}_n^{\mathcal{P}}$, increases, the (unconditional) expected stock price $S_n \equiv E[P_n R_f]$ increases; formally, $dS_n/d\bar{\theta}_n^{\mathcal{P}} > 0$. The difference in expected stock prices is increasing in the fraction of passive investors, Γ; formally, $d^2 S_n/(d\bar{\theta}_n^{\mathcal{P}}\, d\Gamma) > 0$.*

Panel A of Figure 7 illustrates the increase in the stock price as passive investors' average demand strengthens. In addition, in Panel B, we decompose the stock-price reaction into its three components: i) an increase in aggregate demand (keeping K_n and $\mathcal{I}_n$ fixed), ii) an increase in the allocation of capital to growth opportunities (keeping $\mathcal{I}_n$ fixed), and iii) an increase in price informativeness (leading to the total change).

As discussed in the previous two subsections, each of the three components strengthens as the fraction of passive investors, Γ, increase. Thus, as shown in Panel A, the differences in stock prices for low and large levels of passive ownership increases. In particular, while prices for stocks with a large average demand by passive investors increase as the share of passive investors rises, prices of stocks with low passive ownership decline. This divergence in stock prices is further illustrated in Panel C. In particular, the stock price of firms with larger passive ownership ($\bar{\theta}_n^{\mathcal{P}} \gg 1$) substantially diverges from those of the other firms; due to the increase in price informativeness (see Panel B of Figure 6).

A stock's expected excess return is given by $M_n \equiv E[X_n - P_n R_f] = \rho\, \bar{\theta}_n^{\mathcal{A}}\, (1/\bar{h})$. Hence, an increase in passive investors' average demand affects the excess return through two opposing forces. First, the resultant increase in capital allocation to growth opportunities increases fundamental variance and, hence, posterior variance, $1/\bar{h}_k$, which, in turn, leads to a higher excess return. Second, it lowers the expected number of shares to be held by active investors, $\bar{\theta}_n^{\mathcal{A}}$ and, thus, the price discount they command; thereby pushing down

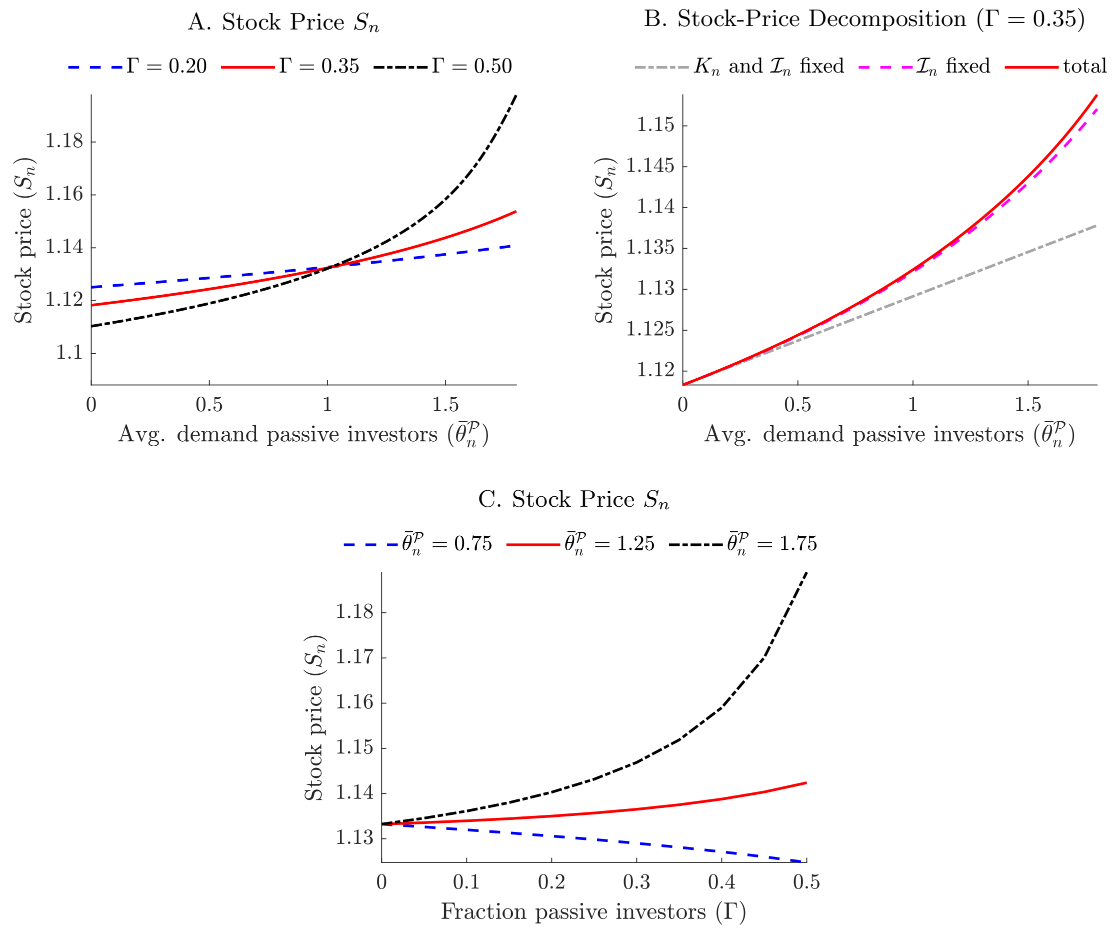

Figure 7: Stock Price. The figure depicts the impact of passive investing on the stock price. Panel A shows how the stock price varies with the average demand of passive investors $\bar{\theta}_n^{\mathcal{P}}$—for different degrees of passive investing in the economy. Panel B decomposes the effects for the case $\Gamma = 0.35$. Panel C illustrates the impact of a rise in the fraction of passive investors on the stock price—for different degrees passive ownership.

the excess return. As shown in Panel A of Figure 8, the first (positive) effect usually dominates such that stocks with large passive ownership have high expected excess returns; compared to identical stocks with less passive owners. Note also that this effect strengthens with the overall degree of passive investing, Γ. As the passive investors' aggregate demand approaches aggregate supply (equal to 1), the second (negative) effect starts to dominate, such that the excess return declines; as illustrated for the case of $\Gamma = 1/2$.[28]

Passive investing also affects stock-return variances:

[28] In fact, if passive investors' aggregate demand exceeds aggregate supply, the expected excess return turns negative because active investors have to be incentivised to go—on average—short the stock.

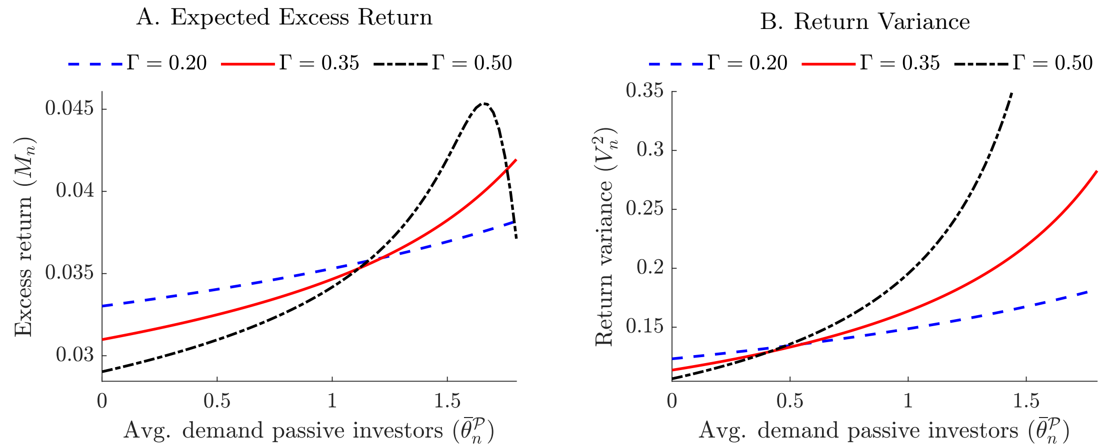

Figure 8: Return moments. This figure depicts the impact of an increase in the average demand of passive investors, $\bar{\theta}_n^{\mathcal{P}} > 0$, on the expected excess return M (Panel A) and stock-return variance V^2 (Panel B)—for three different levels of the share of passive investors in the economy Γ.

Theorem 8. *As passive investors' average demand, $\bar{\theta}_n^{\mathcal{P}}$, increases, the unconditional return variance $V_n^2 \equiv Var(X_n - P_n R_f)$ increases; formally, $dV_n^2/d\bar{\theta}_n^{\mathcal{P}} > 0$. The difference in return variance is increasing in the fraction of passive investors, Γ; formally, $d^2 V_n^2/(d\bar{\theta}_n^{\mathcal{P}}\, d\Gamma) > 0$.*

An increase in the proportion of shares held by passive investors affects stock-return variance through two opposing forces; both stemming from the larger capital allocation to growth opportunities for stocks with more passive ownership. While the resulting increase in fundamental variance pushes up the return variance, the resulting increase in price informativeness lowers return variance. In equilibrium, the first effect dominates and, hence, stock-return variance is higher for stocks with large proportion of shares in the hands of passive investors, as illustrated in Panel B of Figure 8.

An increase in the fraction of passive investors in the economy, Γ, strengthens both these effects but more so the first one. Hence, variations in stock-return variance increase. In addition, the resulting decline in price informativeness (cf. Panel B of Figure 6) pushes up return variance for all stocks such that stock-return variance rises for most levels of average demand as the share of passive investors increases.

5 Conclusion

The presence of passive investors has increased steadily in recent years and has raised many concerns regarding their impact on the ability of financial markets to reflect information and to efficiently allocate capital.

In this paper, we develop a novel economic framework in which firms' real-investment decisions, investors' portfolio and information choices as well as stock prices are determined jointly in equilibrium, while accounting for the presence of passive investors, such as ETFs and index funds. Key to the model is that firms take into account the ownership structure in their stock when selecting their capital allocation to growth opportunities.

We show that, when allowing for endogenous real-investment decisions, price informativeness *increases* in the proportion of shares held by passive investors. In particular, larger passive ownership encourages firms to allocate more capital to risky growth opportunities, which, in turn, increases the volatility of their fundamentals. As a result, active investors devote more resources to information acquisition, thereby increasing the informational content of the stock price (relative to that of otherwise identical firms with lower passive ownership). In addition, higher levels of passive ownership are associated with a higher stock price, higher stock-return variance, and (usually) a higher excess return. An increase in the share of aggregate capital managed by passive investors leads to an amplification of these effects.

Consistent with our theoretical framework, we provide new and robust empirical evidence that stocks with large passive ownership tend to have more informative prices; both in the U.S. and internationally. Our empirical findings are consistent with but complementary to the recent empirical evidence presented by Bai, Philippon, and Savov (2016) and Farboodi, Matray, Veldkamp, and Venkateswaran (2019) regarding the link between informational efficiency and institutional ownership as well as firm size, respectively.

Overall, our work highlights the importance of studying the implications of passive investing not only in the time-series but also in the *cross-section* of stocks. In particular, our findings suggest that, surprisingly, the putative adverse effects of passive investing are more pronounced for firms with a small proportion of shares in the hands of passive investors.

In contrast, for stocks with broad passive ownership, the biggest risks might stem from the risk-taking that passive ownership encourages.

Appendix

A Proofs

TBA

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