Institutional Investors and Information Acquisition: Implications for Asset Prices and Informational Efficiency*

Matthijs Breugem Adrian Buss

This version: January 15, 2017

Abstract

Institutional investors nowadays account for a majority of the transactions and equity ownership. In this paper, we develop an asset pricing model with endogenous information acquisition that explicitly incorporates the incentives of institutions. This allows us to jointly determine equilibrium information and portfolio choices as well as resulting asset prices. We show that institutional investors' portfolios are less sensitive to private information. Thus, they value private information less and, consequently, acquire less of it. An increase in the fraction of institutional investors is accompanied by a decline in price informativeness which can induce a decline in stock price. Moreover, an increase in institutional ownership leads to higher return volatility and a lower Sharpe ratio.

Keywords: institutional investors, asset pricing, asset allocation, information acquisition, equilibrium, informational efficiency.

JEL: G11, G14, G23

*For useful comments and suggestions to this paper and its previous versions we thank Andrea Buffa (discussant), Will Cong (discussant), Bernard Dumas, Marcin Kacperczyk, Joel Peress, Zacharias Sautner, Larissa Schaefer, Günther Strobl, Stijn Van Nieuwerburgh, Laura Veldkamp, Grigory Vilkov, Jing Zeng and seminar participants at Frankfurt School of Finance and Management, INSEAD, the 2016 European Summer Symposium in Financial Markets, the 2017 Australasian Finance & Banking Conference and the 2017 Annual Meeting of the American Finance Association. Matthijs Breugem is affiliated with Frankfurt School of Finance & Management, Sonnemannstrasse 9-11, 60314 Frankfurt, Germany; Email: m.breugem@fs.de. Adrian Buss is affiliated with INSEAD, Boulevard de Constance, 77305 Fontainebleau, France; Email: adrian.buss@insead.edu.

1 Introduction

Over the last decades, financial markets have been transformed tremendously. Among others, the fraction of U.S. equity owned by institutional investors has risen steadily, from about 7% in 1950 to 67% in 2010 (French (2008), U.S. Securities and Exchange Commission (2013), Stambaugh (2014)). Similarly, institutional investors nowadays account for a majority of the transactions and trading volume in financial markets (Griffin, Harris, and Topaloglu (2003)).[1] Given this shift in the composition of market participants, it is of foremost importance to fully understand the behavior of institutional investors. Specifically, institutions are typically concerned about their performance relative to a benchmark (index) – due to explicit incentives, e.g., performance fees, or implicit incentives, e.g., the performance-flow relation. This salient feature of institutional investors may have a strong impact on their optimal behavior and, thus, on financial markets as a whole.

While there is now a growing literature studying the asset pricing implications of institutional investors,[2] this literature focuses on the case of symmetrically informed investors, i.e., abstracts from private information. With this paper, we are trying to fill this gap. That is, in a first step, we want to understand how performance concerns relative to a benchmark, i.e., "benchmarking," affects institutional investors' speculative activities as well as their incentives to acquire information. Second, we want to study how the growth of assets under management by institutions affects information acquisition and aggregation in equilibrium. Finally, we want to know how equilibrium asset prices are affected by the growth in institutional ownership – in the presence of endogenous information choice. Our analysis will also allow us to understand how other, non-benchmarked, investors optimally react to the growth of institutional investors.

For this purpose, we develop an asset pricing model with endogenous information choice and a continuum of investors that we separate into two heterogeneous groups: (1) *institutional investors*, and (2) other investors. Institutional investors have constant relative risk aversion utility and care about their performance relative to a benchmark or, formally,

[1] The worlds largest and most liquid exchange traded fund – the SPDR S&P 500 ETF – alone accounted for, on average, about 9% of NYSE volume in the last five years (Source: ArcaVision as of June 30, 2016).

[2] See, for example, Brennan (1993), Cuoco and Kaniel (2011), Basak and Pavlova (2013), Buffa, Vayanos, and Woolley (2014), Basak and Pavlova (2016) and Buffa and Hodor (2017).

their marginal utility is increasing in the benchmark and their utility is decreasing in the benchmark. All investors can trade two financial securities: A risk-free bond with exogenous interest rate and a stock, modeled as claim to a risky payoff. The stock represents the market as a whole and also serves as the benchmark index.

It is a static model that we break up into three (sub)-periods. In the first period, each investor can choose the precision of the private signal about the stock's payoff that he will receive in the second period. Higher precision will reduce the noise in the signal, but increases information acquisition costs. In the second period, each investor receives his private signal which he combines with the public signal – the equilibrium stock price – to form his posterior beliefs, using Bayes' law. Based on his beliefs, each investor then chooses his optimal portfolio consisting of the bond and the stock market. In the last period, payoffs are realized and investors consume. We impose market clearing for the stock and assume that its supply is random, so that the price is not fully revealing and, thus, preserve the incentives to acquire private information in the first place.

The three key ingredients of our model are: First, institutional investors are *concerned about their performance relative to a benchmark*; second, their utility exhibits *wealth effects*; and, third, *endogenous information acquisition.* Otherwise the model is kept as simple as possible to illustrate the impact of institutional investors on financial markets, but also to convey the intuition for the results. Due to our deviation from the CARA-normal framework, the equilibrium price function is non-linear, so that we rely on a new, exact numerical algorithm to solve for the equilibrium.

To provide clear intuition for the economic mechanisms that drive our equilibrium results, we first solve a "partial equilibrium" setting with a single institutional investor who learns exclusively from his private signal. Varying the investor's degree of benchmarking allows us to highlight the economic mechanisms through which performance concerns relative to a benchmark affect institutional investors' asset and information choices.

Benchmarking creates a hedging demand for assets that co-vary positively with the benchmark – the stock in our case – so that an *uninformed* institutional investor's stock demand is increasing in the degree of benchmarking.[3] Interestingly, the portfolio of an *informed* institutional investor, receiving private information, is less sensitive to the realization of the signal. For example, he less aggressively acquires shares of the stock following good news; and vice versa for bad news. This result is driven by two key mechanisms: First, the hedging demand for stock, which is also present in the case of asymmetric information, is information-insensitive because it is, by definition, designed to track and not to outdo the benchmark. Second, because an institutional investor's utility exhibits wealth effects, his speculative asset demand depends on the wealth available for speculation which is, however, limited by the hedging demand. Accordingly, his speculative activities in reaction to private information decline in the degree of benchmarking.

These changes in an institutional investor's portfolio have a direct impact on his information choice. That is, an institutional investor acquires less precise private information as the degree of benchmarking increases. Intuitively, because an institutional investor's trading is less sensitive to the realization of his signal, the marginal benefits from receiving a precise signal decline, and so do the incentives to acquire information.

While these partial equilibrium results are already quite intriguing, it is important to also study the equilibrium effects, incorporating the decisions of the other investors, that anticipate the behavior of the institutional investors. Particularly, varying the fraction of institutional investors in the economy allows us to study the implications of the growth of institutions on information acquisition and aggregation as well as on asset prices – in equilibrium.

We document that, as the fraction of institutional investors increases, both groups of investors choose a higher precision for their private signals. To understand this effect, recall from the preceding discussion that institutional investors acquire less information. Thus, an increase in the fraction of institutional investors implies a decline in aggregate information acquisition in the economy. Consequently, the marginal benefits from acquiring information go up, thereby increasing the incentives of all investors to choose a more precise signal. However, the increase in the precision of both market participants' signals is not enough

[3] This is a standard result in the asset pricing literature, confer, for example, the papers mentioned in footnote 2.

to off-set the shift from more informed, non-benchmarked investors towards less informed, institutional investors, so that *price informativeness declines*.[4]

Interestingly, the "information gap" between the two groups of investors widens as the fraction of institutional investors increases. That is, because less information is revealed through the public signal – the stock price – the fact that institutional investors acquire less information, i.e., have less precise private information, gains importance.

Turning to equilibrium asset prices, we first confirm that absent information acquisition the stock price is increasing in the share of institutional investors, driven by the positive hedging demand – a standard result from the asset pricing literature. However, with endogenous information choices, the *stock price may decline* in the size of the institutions. Particularly, the decline in price informativeness renders the stock more risky, because less precise information about its fundamentals is available. If this negative price effect dominates the positive effect arising from the hedging demand, the price declines and the expected stock return increases. Not surprisingly, the decline in price informativeness leads to higher stock return volatility.

Wealth effects are key to our findings. That is, without wealth effects, e.g., with CARA-utility, benchmarking would not affect the sensitivity of institutional investors' portfolios with respect to their private signals and their information choices. Accordingly, the fraction of institutional investors would be irrelevant for price informativeness and related quantities.

Finally, we study two extensions of our main analysis in which institutional investors are endowed with an informational advantage. First, a setting in which institutional investors face lower information acquisition costs than the other investors, for example, due to their eduction, experience or professional network. Second, we consider a case in which institutional investors are endowed with more initial wealth,[5] i.e., manage more capital, allowing them to distribute the information acquisition costs over larger amounts of capital. In both settings, price informativeness only increases in the fraction of institutional

[4]The economic importance of price informativeness is highlighted in the literature on "feedback effects," (see, for example, the survey by Bond, Edmans, and Goldstein (2012) or Chen, Goldstein, and Jiang (2007), Bakke and Whited (2010), Edmans, Goldstein, and Jiang (2012) as well as Foucault and Frésard (2012)) which shows that information about fundamentals contained in asset prices affects corporate decisions. Along these lines, our results would suggest that the decline in price informativeness would lead to less informed corporate decisions.

[5]Note, aggregate wealth in the economy is kept unchanged.

investors if institutional investors have a substantial informational advantage. In contrast, the stock price may already increase for a low and moderate informational advantage – due to the excess demand arising from hedging motives.

Empirical research lends support to our findings. For example, Israeli, Lee, and Sridharan (2016) and Ben-David, Franzoni, and Moussawi (2015) find that an increase in exchange traded fund ownership – a group of investors whose performance is closely linked to an index – is associated with less informative securities prices and higher stock return volatility, respectively. Moreover, our findings may help to explain why Bai, Philippon, and Savov (2016) find basically no improvement in price informativeness from 1980 to today – a period over which the share of institutional investors has grown substantially. That is, their negative impact on price informativeness may have off-set the positive effects arising from lower trading costs, more liquidity as well as easier and cheaper access to information.

Our paper combines insights from two streams of the literature. First, there is growing literature on the stock market implications of institutional investors.[6] Brennan (1993) shows that in a static, CARA-utility setup with performance concerns relative to a benchmark, a two-factor model arises, with one of the factors being the benchmark. Cuoco and Kaniel (2011) numerically solve a model of portfolio delegation with asset managers that have CRRA preferences and receive a management fee depending on their performance relative to a benchmark. They show that symmetric fees have an unambiguously positive impact on the price of assets in the benchmark and a negative impact on their Sharpe ratios. Basak and Pavlova (2013) provide analytical solutions for a dynamic, CRRA-utility setup with institutional investors that care about a benchmark and with multiple risky assets. They find that institutional investors over-weight stocks in the benchmark, creating upward price pressure for these assets, and an amplification of index stock volatilities. Buffa, Vayanos, and Woolley (2014) study the joint determination of managers' contracts and equilibrium prices in a dynamic setup with multiple risky assets and CARA-preferences. Agency frictions lead to contracts that depend on managers' performance relative to a benchmark and bias the aggregate market upwards. Buffa and Hodor (2017) study asset managers that are subject

[6]For an analysis of the impact of institutional investors on the commodity futures market confer Basak and Pavlova (2016) who show that "financialization" leads to an increase in commodity futures prices, volatilities, and correlations – particularly so for commodities that are included in a commodity index.

to different benchmarks and find that heterogeneous benchmarking leads to additional price pressure which amplifies return volatility.

In contrast to our paper, this literature focuses on the case of symmetrically informed investors, i.e., abstracts from the acquisition and aggregation of private information. Interestingly, while these papers find an unambiguously positive effect of institutional investors on the prices of assets included in the benchmark, we show that endogenous information acquisition can lead to a decline in price, driven by a decline in price informativeness. Similar to Basak and Pavlova (2013) we document an increase in return volatility and a decrease in Sharpe ratio in the presence of institutional investors. However, while these effects arise from hedging motives and dynamic wealth transfers in Basak and Pavlova (2013), they are due to a decline in information acquisition in our setting.

Second, our paper is closely related to the rational expectations equilibrium (REE) literature, starting from the early papers by Grossman (1976), Grossman and Stiglitz (1980), Hellwig (1980) and Verrecchia (1982) who study information aggregation in the CARA-normal framework, allowing for tractable solutions.[7] Part of this literature has started to focus on asset management in the presence of private information. For example, García and Vanden (2009) show that competition between fund managers makes price more informative. In contrast, Qiu (2012) finds ambiguous results for price informativeness if managers' performance is evaluated against their peers. Malamud and Petrov (2014) show that convex compensation contracts lead to equilibrium mis-pricing, but reduce price volatility. Sotes-Paladino and Zapatero (2016) show, in a partial equilibrium CRRA-setting, that a linear benchmark-adjusted component in managers' contracts benefits investors when fund managers are privately informed – absent moral hazard considerations. Kacperczyk, Van Nieuwerburgh, and Veldkamp (2016) show – theoretically and empirically – that fund managers optimally choose to process information about aggregate shocks in recessions and idiosyncratic shocks in booms.

[7]Recently, several studies have relaxed the joint CARA-normal assumption. For example, Barlevy and Veronesi (2000) and Albagli, Hellwig, and Tsyvinski (2014) study risk neutral investors; Peress (2003) studies general preferences using a (small risk) log-linearization; Nieuwerburgh and Veldkamp (2010) study a general form of utility function and multiple risky assets; Breon-Drish (2015) and Chabakauri, Yuan, and Zachariadis (2016) focus on distributions that are members of the "exponential family."

In our paper, we explicitly model institutional investors' performance concerns relative to a benchmark in a framework with wealth effects which allows us to make novel predictions about the relation between the size of institutional investors and equilibrium information acquisition and equilibrium asset prices. These changes make it necessary to solve the model numerically, so that our paper is also related to Bernardo and Judd (2000) which, however, consider only two investors instead of the continuum of investors in our economy. Moreover, we allow for heterogeneous signal precision.

The remainder of the paper is organized as follows. Section 2 describes the details of the model. Section 3 discusses the investors' optimization problems and defines the rational expectations equilibrium. Next, Section 4 discusses the implications of benchmarking for investors' asset and information demand in a "partial equilibrium" setting. Section 5 studies how the fraction of institutional investors affects information acquisition and asset prices in equilibrium. In section 6 we study two extensions of our main model. Finally, Section 7 concludes. In the Appendix we present our numerical solution approach.

2 Model

We study an asset pricing model with endogenous information acquisition, similar to Grossman and Stiglitz (1980) and Verrecchia (1982). It is a static model which we break up into three (sub-)periods: the information acquisition stage ($t = 1$), the trading stage ($t = 2$) and, finally, the consumption period ($t = 3$). There exist two groups of heterogeneous investors: *institutional investors* and other investors, e.g., retail investors. Institutional investors are concerned about their performance relative to a benchmark and their utility function gives rise to wealth effects.

2.1 Investment Opportunities

There exist two financial securities that are traded competitively in the market: first, a riskless asset (the "bond") and, second, a risky asset (the "stock"), representing the equity market as a whole.

The bond pays an exogenous risk-free interest rate r_f and is available in perfectly elastic supply. It also serves as a numeraire, with its price being normalized to one. The stock is modeled as a claim to the random payoff D, which is only observable in period 3. We assume that the payoff D follows a binomial distribution with high realization $D_H \equiv \mu_D + \sigma_D$ and low realization $D_L \equiv \mu_D - \sigma_D$, that are both equally likely: $\pi_k = 1/2$, $k \in \{H, L\}$.

The supply of the stock is assumed to be random and unobservable to prevent the price from fully revealing the information acquired by the investors and, thus, to preserve the incentives to acquire private information in first place.[8] Particularly, we assume that the aggregate supply of the stock, z, follows a normal distribution $\mathcal{N}(\mu_z, \sigma_z)$.

2.2 Information Structure and Learning

Investors are initially, i.e., in period 1, endowed with unbiased, but uninformative beliefs about the stock's payoff D. In period 1, investors can then spend time and resources to acquire private information about the stock. For example, they may study financial statements, gather information about consumers' taste, hire outside financial advisers or subscribe to proprietary databases. Particularly, each investor j can choose the precision of his private, binomial signal $S_j \in \{S_L, S_H\}$ about the payoff of the stock D, that he will receive in period 2. Higher precision will reduce the noise in the unbiased signal, but will increase the information acquisition costs.

Mathematically, let x_j denote the precision of investor j's signal and ρ_j describe the probability of a high (low) realization of the stock's payoff conditional on a high (low) realization of the signal:

$$\rho_j \equiv \mathbb{P}_j[D_H \mid S_H] = \mathbb{P}_j[D_L \mid S_L].$$

The precision x_j then translates into probability ρ_j as follows:

$$\rho_j(x_j) = \frac{1}{2} + \frac{1}{2}\sqrt{\frac{x_j}{x_j + 4}}.$$

[8] This is a common assumption in rational expectations equilibrium models, and is equivalent to the existence of noise (liquidity) traders with random, not explicitly modeled, demand, e.g., due to liquidity reasons.

A signal with precision x_j costs $C(x_j)$ dollars, where C is increasing and strictly convex in the precision level. These assumptions guarantee the existence of an interior solution and capture the idea that each new piece of information is more costly than the previous one. Particularly, we assume that the cost function C is given by:

$$C(x_j) = \kappa\, x_j^c \tag{1}$$

where κ defines the overall level of the information acquisition costs and $c > 1$ describes the degree of convexity.

Note, in case an investor chooses a precision of zero ($x_j = 0$), i.e., decides not to acquire any information, he receives an uninformative signal, $\rho_j(0) = 1/2$, at zero cost: $C(0) = 0$. At the other extreme, perfect foresight, $\rho_j(\infty) = 1$, could only be achieved with infinite precision ($x_j \to \infty$), and, thus infinite wealth ($C(\infty) \to \infty$).

Finally, in period 2, investor j receives his private signal with the chosen precision which he combines with the public signal – the stock price P – to update his prior beliefs using Bayes' law.

We denote investor j's expectation conditional on prior beliefs alone as $E_j[\,\cdot\,]$ and use $E_j[\,\cdot\,|\,\mathcal{F}_j]$ to denote the investor's expectation conditional on his information set $\mathcal{F}_j$ in period 2. Particularly, the information set contains an investor's private signal with precision x_j and the publicly observable stock price: $\mathcal{F}_j = \{S_j, P\}$. Note, because all probability distributions and other parameters of the economy are common knowledge, investors are only asymmetrically informed about the stock's payoff D.

2.3 Investors

There exists a continuum of atomless investors with mass one that we separate into two groups of market participants, $i \in \{\mathcal{I}, \mathcal{O}\}$: (1) a fraction Λ of *institutional investors* $\mathcal{I}$ and (2) a fraction $1 - \Lambda$ of *other investors* $\mathcal{O}$, e.g., retail investors. Each investor is endowed with the same initial wealth $W_{1,j}$, so that the only source of heterogeneity across investors is the investor type.

Note, Λ thus also represents the fraction of wealth managed by institutional investors – or equivalently, how large institutional investors are relative to the overall economy. Varying

Λ will be our most important comparative statics analysis, because it allows us to illustrate how the growth in assets under management by institutional investors influences information acquisition and asset prices.

Each investor j's objective is to maximize expected utility over time-3 wealth $W_{3,j}$, with the preferences being represented by utility function U_j. Particularly, investors being part of the group of other investors $\mathcal{O}$ have standard power utility over terminal wealth with risk-aversion γ:

$$U_{\mathcal{O}}(W_{3,j}) = \frac{W_{3,j}^{1-\gamma}}{1-\gamma}. \tag{2}$$

In contrast, the utility of investors being part of the group of institutional investors $\mathcal{I}$ is given by:

$$U_{\mathcal{I}}(W_{3,j}) = \frac{\big(\alpha + (1-\beta)\,W_{3,j} + \beta\,(W_{3,j} - B)\big)^{1-\gamma}}{1-\gamma}, \tag{3}$$

where B denotes the time-3 payoff of the benchmark against which the performance of the institutional investors is measured, $\beta \geq 0$ denotes the degree of benchmarking and $\alpha \geq 0$. Specifically, in our one-stock economy, the random payoff of the benchmark coincides with the payoff of the stock: $B = D$.[9]

Importantly, in contrast to the constant absolute risk aversion (CARA) assumption usually employed by the REE-literature, the utility functions of both groups of investors, $U_{\mathcal{I}}$ and $U_{\mathcal{O}}$, are of the constant relative risk aversion (CRRA) type, thus, incorporating *wealth effects*. Particularly, in contrast to the case of CARA-utility, with CRRA-preferences an investor's investment into the stock market will depend on his available wealth.

Our specification of institutional investors' utility function in (3) exhibits *three important characteristics of institutional investors contracts* that let them behave differently from other investors. First, institutional investors care about their performance relative to a benchmark, either due to implicit or explicit incentives. While explicit incentives arise from direct monetary rewards, e.g., performance fees, implicit incentives stem from the performance-flow relation. Particularly, it is well known that outperforming the benchmark

[9]Similarly, an institutional investor's desire to perform well relative to a benchmark may also be driven by social status, associated with a funds performance relative to the index, instead of monetary incentives.

leads to stronger inflows, and, in turn, higher fees from assets under management.[10] Second, institutional investors try to deliver a higher return when their benchmark is high than when it is low or, formally, their marginal utility of wealth is increasing in the benchmark index.[11] Third, institutional investor's utility function in (3) is decreasing in the level of the benchmark.[12]

Basak and Pavlova (2013) demonstrate these characteristics of institutional investors' utility functions formally using an agency-based argument. Moreover, in Buffa, Vayanos, and Woolley (2014) investors endogenously make managers' fees sensitive to the performance against a benchmark, due to agency frictions. Similarly, Sotes-Paladino and Zapatero (2016) show that including a linear benchmark-adjusted component into managers' contracts benefits investors when parties exhibit different risk preferences and managers are privately informed.

Comparing our specification to the literature, it closely resembles the utility used by Basak and Pavlova (2013) and is even suggested as an alternative specification in their paper.[13] However, in contrast to the tractable specification employed in Basak and Pavlova (2013) to study asset pricing implications with symmetric information, the utility in (3) is decreasing in the benchmark. This is crucial, because in contrast to asset pricing models in which only marginal utility matters, the investors' utility functions play a key role in models of information acquisition. Moreover, our specification is a special case of the utility defined over management fees used by Cuoco and Kaniel (2011). This allows the interpretation of α as a "load fee" independent of performance and of $\beta\,(W_{3,j} - B)$ as a linear performance fee in excess of the benchmark.[14] Finally, with $\alpha = 0$ and $\beta = 1$, our specification resembles the utility, defined over the difference between an investor's wealth and the benchmark, as used by Brennan (1993) and subsequent papers in CARA settings.

[10] See, for example, Chevalier and Ellison (1997) as well as Sirri and Tufano (1998) for mutual funds, and Guercio and Tkac (2002) for pension funds.

[11] The second derivative of the institutional investors' utility function in (3) with respect to wealth and the benchmark index is given by: $\frac{\partial^2 U_{\mathcal{I}}}{\partial W_{3,j}\partial B} = \beta\,\gamma \left(\alpha + (1-\beta)\,W_{3,j} + \beta\,(W_{3,j} - B)\right)^{-(\gamma+1)} > 0$ for $\beta \neq 0$ and $\alpha > (1-\beta)\,W_{3,j} + \beta\,(W_{3,j} - B)$.

[12] The derivative of the institutional investors' utility function in (3) with respect to the benchmark index is given by: $\frac{\partial U_{\mathcal{I}}}{\partial B} = -\beta \left(\alpha + (1-\beta)\,W_{3,j} + \beta\,(W_{3,j} - B)\right)^{-\gamma} < 0$ for $\beta \neq 0$ and $\alpha > (1-\beta)\,W_{3,j} + \beta\,(W_{3,j} - B)$.

[13] See Remark 1 on page 1735 in Basak and Pavlova (2013).

[14] These types of fees are known as fulcrum performance fees. The 1970 Amendment of the Investment Advisers Act of 1940 restricts mutual fund fees to be of the fulcrum type.

2.4 Timing

There exist three (sub-)periods. In period 1, the information acquisition stage, each investor chooses the precision x_j of his private signal about the stock's payoff subject to an increasing cost $C(x_j)$ for more precise information. In period 2, the trading stage, each investor observes his private signal. At the same time, markets open and investors observe the equilibrium stock price which acts as a public signal. Each investor then uses the public and private signals to form his conditional expectation $E_j[\,\cdot\,|\,\mathcal{F}_j]$ and, accordingly, chooses his portfolio. In period 3, the consumption period, investors receive asset payoffs and realize utility.

3 Equilibrium

In this section, we first discuss individual investors' optimization problems, and then define the equilibrium in our economy. Particularly, an investor's optimization problem follows the timing described in Section 2.4, and must be solved in two stages – working backwards from the trading period, in which an investor forms his posterior beliefs and chooses his portfolio, to the information acquisition stage, in which he choose the signal precision.

3.1 Posterior Beliefs – Learning from Price and Signal

At the beginning of period 2, each investor observes his private signal, S_j, with given precision x_j, and the stock price P. Because investors can submit demand schedules, i.e., condition their demand on the stock price, they *can learn from the equilibrium price* which partially reveals information about the other investors' private signals.

That is, any investor in the economy that receives an informative signal ($x_j > 0$) will use his private information to optimize his portfolio and buy more or less of the stock – depending on the signal realization. Because the supply of the stock is limited, the investor's demand will move the price and, hence, private information will get incorporated into the stock price. Accordingly, any rational investor will use the stock price together with his private signal to form his posterior beliefs about the stock's payoff D.

In our setting with a continuum of investors, the price is a function of the dividend and the supply – both unobservable – only: $P(D, z)$.[15] That is, because each investor is small, the distribution of the private signals and, accordingly, aggregate demand depends exclusively on the underlying payoff D. Consequently, for a given price P, each investor can easily back out the two combinations of dividend and noise, denoted by $\{(D_L, z_L), (D_H, z_H)\}$,[16] that are consistent with this price.[17] For example, a high stock price could be due to a high underlying payoff or a low supply.[18] Using the distribution of the noise, an investor can then compute the probability of the underlying payoff D.

Formally, investor j's posterior probability of a payoff realization D_k, $k \in \{L, H\}$, is given by:

$$\pi_{k,j} = \mathbb{P}(D_k \mid P, S_j) = \frac{f_z(z_k)\, \mathbb{P}(D_k \mid S_j)}{\sum_n f_z(z_n)\, \mathbb{P}(D_n \mid S_j)}, \tag{4}$$

where $f_z(\cdot)$ denotes the density function of the normally distribution noise z, and $\mathbb{P}(D_n \mid S_j)$ can be computed directly as:

$$\mathbb{P}(D_n \mid S_j) = \frac{\mathbb{P}(D_n, S_j)}{\sum_m \mathbb{P}(D_m, S_j)},$$

using the correlation ρ_j between investor j's private signal and the payoff:

$$\mathbb{P}(D_m, S_j) = \begin{cases} \rho_j/2 & \text{if } m = j, \\ (1-\rho_j)/2 & \text{if } m \neq j; \end{cases} \qquad \text{with } m, j \in \{L, H\}.$$

3.2 Portfolio Choice

Given the posterior beliefs $\pi_{\cdot,j}$ in (4) that describe an investor's expectation $E_j[\,\cdot \mid \mathcal{F}_j]$, the investor then chooses the fraction of wealth to be in the form of stocks, ϕ_j^1, to maximizes

[15] See also Hellwig (1980).

[16] The supply z_k, $k \in \{L, H\}$, is simply given by the aggregate demand in the economy at price P – conditional on D_k.

[17] See also the descriptions and derivations in Breugem (2016) for learning from price a dynamic setting with two investors.

[18] Note, if the supply were not random, the stock price would be a function of the payoff only. Accordingly, there would only be a single payoff realization consistent with a given price, so that prices would be fully revealing. In this case, there would be no trading in equilibrium (Milgrom and Stokey (1982)) and no incentives to acquire private information in the first place, so that no competitive equilibrium would exist (Grossman and Stiglitz (1980)).

his expected utility; taking the price P as given:

$$V(S_j, x_j, W_{2,j}; P) = \max_{\phi_j^1} E_j \big[U_i(W_{3,j}) \,|\, \mathcal{F}_j \big], \tag{5}$$

where $V(S_j, x_j, W_{2,j}; P)$ denotes the value function and $i \in \{\mathcal{I}, \mathcal{O}\}$ depending on the type of investor. The optimization is subject to the following budget equation:

$$W_{3,j} = W_{2,j} \left(1 + r_f + \phi_j^1 \, R^e \right),$$

where $R^e = \frac{D-P}{P} - r_f$ denotes the stock's excess return.

Substituting wealth $W_{3,j}$ into the optimization problem (5), yields the following first-order condition:

$$E_j \big[U_i' \big(W_{2,j} \, (1 + r_f + \phi_j^1 \, R^e) \big) \, W_{2,j} \, R^e \, \big| \, \mathcal{F}_j \big] = 0, \tag{6}$$

where $U_i'(\cdot)$ denotes the derivative of the investor's utility function with respect to wealth. Denoting the first two components as the stochastic discount factor, equation (6) gives the usual asset pricing interpretation that the "price" of the excess return R^e has to be zero.

3.3 Information Choice

At the information acquisition stage, $t = 1$, each investor then has to choose the precision of his private signal, x_j, in order to maximize expected utility over all possible realizations of S_j and z; taking $W_{1,j}$ as given:

$$\max_{x_j \geq 0} E_j \big[V \big(S_j, x_j, W_{2,j}; P \big) \big], \tag{7}$$

subject to the budget equation:

$$W_{2,j} = W_{1,j} - C(x_j).$$

Substitution wealth $W_{2,j}$ into the optimization problem (7), gives the following first-order condition:

$$E_j \left[\frac{\partial V(S_j, x_j, W_{2,j}; P)}{\partial x_j} - \frac{\partial V(S_j, x_j, W_{2,j}; P)}{\partial W_{2,j}} \frac{\partial C(x_j)}{\partial x_j} \right] = 0, \tag{8}$$

equating, in expectation, the marginal benefits of information, arising from more precise posterior beliefs, $\pi_{\cdot,j}(x_j)$ and, accordingly, a better portfolio choice, $\phi_j^1(S_j, x_j, W_{2,j}; P)$ to the marginal costs of information, arising from the information cost function $C(x_j)$.

3.4 Equilibrium

A rational expectations equilibrium is defined as a set of asset demand functions $\{\phi_j^1\}$ and signal precisions $\{x_j\}$ for all investors j as well as price functions $\{P\}$ such that:

1. $x_j(W_{1,j})$ and $\{\phi_j^1(S_j, x_j, W_{2,j}; P)\}$ solve investor j's maximization problems, given in (5) and (7), taking price P as given;

2. each investor has rational expectations, $E_j[\cdot \,|\, \mathcal{F}_j]$, formed according to (4) – conditioning on the public stock price P and his private signal S_j with precision $x_j(W_{1,j})$;

3. P clears the market for the risky asset, i.e., aggregate demand equals aggregate supply:

$$\int_0^1 \phi_j^1(S_j, x_j, W_{2,j}; P) \, \frac{W_{2,j}}{P} \, dj \;=\; z. \tag{9}$$

In equilibrium, the stock price plays a dual role: It clears the market for the stock and aggregates as well as transmits investors' private information. Because of our deviation from the standard CARA-normal framework, the price function is *non-linear*, so that we have to rely on a numerical algorithm to solve for the equilibrium. The Appendix provides details on the algorithm.

4 Asset and Information Demand

To provide clear intuition for the economic mechanisms that drive our equilibrium results, we first analyze an economy of the "partial equilibrium" type, focusing on an institutional investor's asset and information demand. Particularly, we work backwards through the two-stage optimization problem of a *single institutional investor*, solving first for the optimal portfolio choice in period 2 and, then, determining the optimal signal precision in period 1.

Our numerical illustrations are based on the following set of parameters: The mean and volatility of the stock's payoff, μ_D and σ_D, are set to 1.05 and 0.30, respectively. The risk-free rate, r_f, is set to zero. Investors have relative risk-aversion, γ, of 3 and for the institutional investors α is equal to zero.[19] Investors are endowed with an initial wealth,

[19] This slightly limits the range for β because the "inner component" of the utility function (3) should be positive. But, it guarantees that, as β approaches zero, institutional investors' utility function converges towards the one of the other investors.

Variable	Description	Value
Common Parameters		
μ_D	Mean of stock payoff D	1.05
σ_D	Volatility of stock payoff D	0.30
r_f	Risk-free rate	0
γ	Relative risk-aversion	3
α	Institutional investor's utility - fixed component	0.0
$W_{1,j}$	Initial wealth	1
c	Exponent of information cost function	2
κ	Level of information cost function	0.02
Parameters for Section 5 – "Equilibrium"		
μ_z	Mean of noisy supply z	1.00
σ_z	Volatility of noisy supply z	0.15
β	Degree of benchmarking	0.50

Table 1: Model Parameters. This table reports the parameter values used for our numerical illustrations. First, the common parameters and then the parameter values that are special to the equilibrium analysis, presented in Section 5.

$W_{1,j}$, of 1. Finally, we assume a quadratic information acquisition cost function ($c = 2$) with $\kappa = 0.02$. Table 1 provides a summary of the model parameters.

Based on these parameter choices, we then vary the degree of benchmarking β in the investor's utility function $U_{\mathcal{I}}$ to understand the impact of benchmarking on his asset and information demand.

4.1 Asset Demand

In a first step, we now determine the optimal portfolio share of the stock, ϕ_j^1, of an institutional investor who exclusively uses his private signal to update his prior beliefs, taking its precision x_j as given. Particularly, to illustrate the impact of benchmarking on an investor's portfolio in the absence of private information, we start with the case of the *uninformed* investor ($x_j = 0$), representing a simple portfolio optimization problem known from the asset pricing literature. Note, because the investor receives an uninformative signal, he does not update his prior beliefs and, thus, his expectation $E_j[\,\cdot\,|\,S_j]$ as well as his portfolio choice are independent of the realization of his signal, $S_j \in \{S_L, S_H\}$.

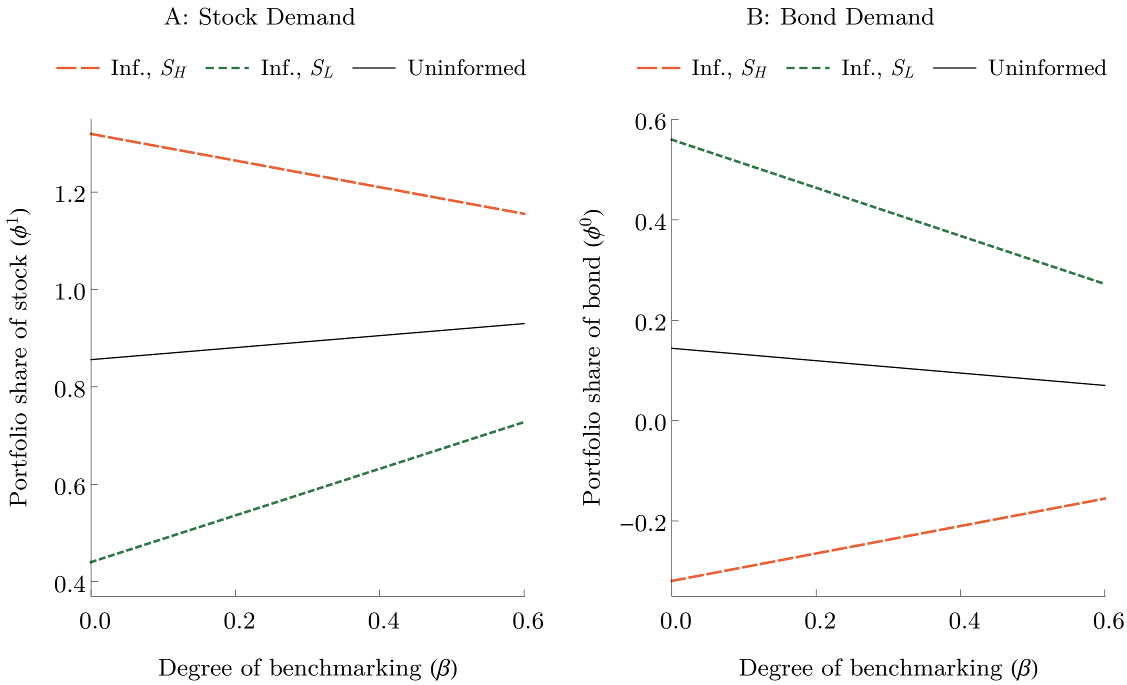

Figure 1: Asset Demand. The figure depicts the optimal period-2 portfolio choice of a single institutional investor, who takes the stock price P and the precision of his signal x_j as given, as a function of the degree of benchmarking β. The portfolio choice is shown for an "Uninformed" investor with a signal precision of zero ($x_j = 0$), and an informed investor ("Inf.") who receives an private signal with $x_j > 0$ – conditional on the realization of his signal $S_j \in \{S_H, S_L\}$. Panels A and B show the optimal portfolio share of the stock and bond, respectively. The results are based on the parameter values presented in Table 1.

As Panel A of Figure 1 illustrates, the uninformative investor's demand for the stock is monotonically increasing in the degree of benchmarking. The intuition for this effect is quite straightforward. That is, benchmarking creates an incentive for an investor to do well when the benchmark does well, which can be achieved by buying assets that co-vary positively with the benchmark. In our single-asset economy, the stock, which also serves as the benchmark, naturally co-varies positively with the benchmark. Consequently, this creates a positive hedging demand for the stock. This hedging demand increases with the degree of benchmarking, so that the uninformative investor's demand for the stock increases as well. Because initial wealth is unchanged, this additional demand for the stock needs to be financed. Accordingly, as Panel B of Figure 1 illustrates, the institutional investor's portfolio share of the bond, $\phi_j^0 = 1 - \phi_j^1$, is declining in the degree of benchmarking.

These results are fully consistent with the asset pricing literature that studies institutional investors, but with symmetric information. For example, Basak and Pavlova (2013) find that institutions optimally tilt their portfolios towards stocks that comprise their benchmark index and to do so increase their leverage. Similar findings are also reported by Cuoco and Kaniel (2011) and Buffa, Vayanos, and Woolley (2014). Moreover, these results also hold for settings with constant absolute risk aversion, as in Brennan (1993).

In the case of asymmetric information, an *informed* ($x_j > 0$) investor's expectation $E_j[\cdot \mid S_j]$ and, in turn, his portfolio choice, will depend on the signal realization $S_j \in \{S_L, S_H\}$. Panel A of Figure 1 shows that, as expected, a non-benchmarked investor, i.e., $\beta = 0$, over-weights the stock market in his portfolio relative to the uninformed investor following a positive signal, S_H; and vice versa for a negative signal, S_L. Consequently, a non-benchmarked institutional investor under-weights the bond following a positive signal and over-weights it following a negative signal (see Panel B).

We can now focus on the interaction between benchmarking and private information. As Panel A of Figure 1 illustrates, the absolute difference between the conditional stock demand of an informed institutional investor and the demand of an uninformed institutional investor is declining in the degree of benchmarking. For example, an institutional investor who is concerned about his performance relative to a benchmark has a lower demand for the stock following a positive signal than an investor who is not benchmarked ($\beta = 0$), and this effect strengthens with the degree of benchmarking β. Accordingly, the spread between an institutional investor's conditional stock demand following positive and negative signals narrows, i.e., the institutional investor speculates less – for a signal with given precision. Note, the asymmetry in the "slopes" of the institutional investor's conditional stock demand is driven by the underlying positive hedging demand. In Panel B one can observe off-setting effects in the bond holdings of the institutional investor.

This decline in the speculative activities of an institutional investor in reaction to private information is driven by two key mechanisms. First, the positive hedging demand for the stock stemming from benchmarking is information-insensitive. Particularly, the hedging component is, by definition, designed to closely track or, formally, co-vary with, the benchmark, so that the investor does well when the benchmark does well. It is not designed to out-perform the index. Accordingly, as the degree of benchmarking strengthens, *an increasing fraction of the investor's wealth becomes information-insensitive.* Second, be-

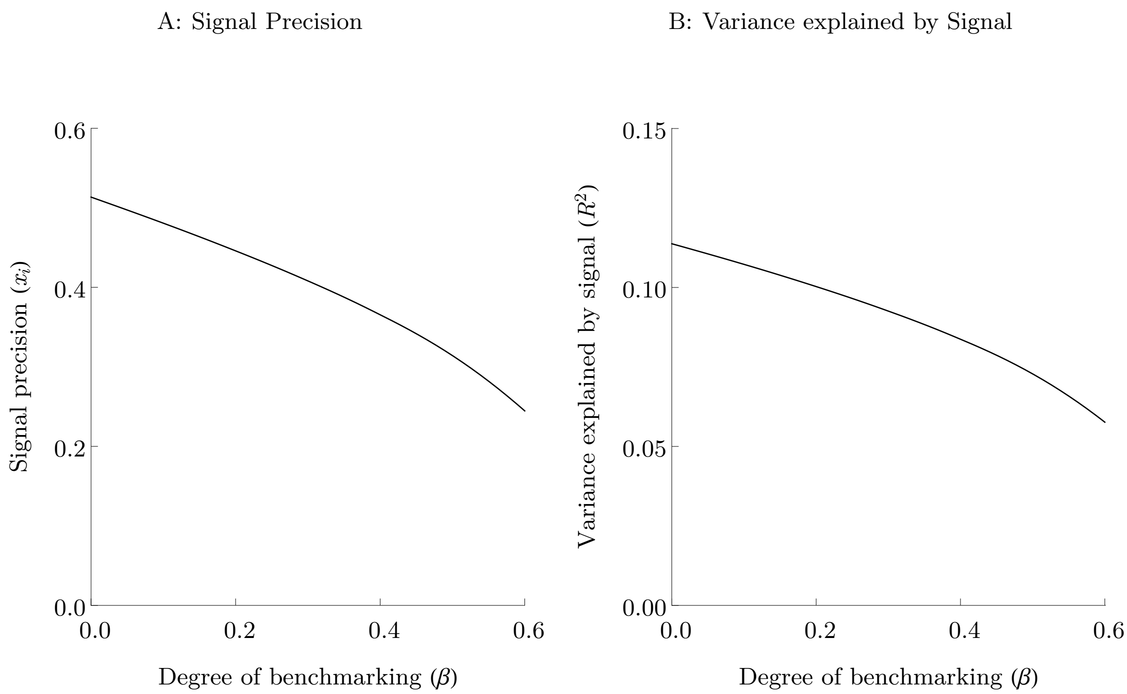

Figure 2: Information Demand. The figure shows the information choice of a single institutional investor in period 1 as a function of the degree of benchmarking β. Panels A and B depict the signal precision, x_j, chosen by the institutional investor and the fraction of the variance of the payoff that is explained by a signal with chosen signal precision, R^2, respectively. The results are based on the parameter values presented in Table 1.

cause institutional investors have utility with constant relative risk aversion, i.e., exhibit *wealth effects*, their speculative asset demand depends on the wealth available for speculation. Thus, as the investor's hedging component increases, and with it the wealth available for speculation declines, institutional investors' portfolios become less sensitive to private information as the degree of benchmarking increases.

4.2 Information Demand

Having determined the effect of benchmarking on an institutional investor's asset demand in period 2, i.e., after observing the private signal, we can now study his optimization problem (7) in period 1 – the information acquisition stage. At this point, the investor needs to choose the precision x_j of the private signal that he will receive in period 2, anticipating his optimal portfolio choice in period 2 in reaction to a signal realization with precision x_j.

As shown in Panel A of Figure 2, the precision that an institutional investor chooses for his private signal is declining monotonically in the degree of benchmarking. That is, he is less willing to invest into the acquisition of private information in period 1 and, thus, the signal that he will receive in period 2 will be less precise.

To understand this effect, recall from the preceding section that an investor's speculative activities in period 2 decline with the degree of benchmarking, i.e., his portfolio choice becomes less sensitive to the signal realization because his hedging component is information-insensitive. Thus, a signal with the same precision x_j is incorporated to a smaller degree into the portfolio of an institutional investor than into the portfolio of an investor who is not benchmarked. Accordingly, keeping signal precision unchanged, a signal has less value for an institutional investor because it has a smaller (positive) impact on his portfolio decision and, in turn, his terminal wealth as well as utility. This has a direct impact on the optimal choice of the signal precision in period 1, because it renders an institutional investor's expected utility less sensitive to the precision of the signal. Accordingly, he is less willing to costly acquire information in period 1, i.e., chooses a lower precision, explaining the decline of signal precision in the degree of benchmarking.

Importantly, this effect is unique to settings with *wealth effects*, e.g., with constant relative risk aversion, because in the absence of wealth effects, e.g., with constant absolute risk aversion, an investor's speculative demand is independent of his wealth and thus, his information choice is not affected by benchmarking.

To provide some intuition on the magnitude of the signal precision x_j, Panel B of Figure 2 also shows the R^2, i.e., the fraction of the variance of the payoff D that is explained by the investor's signal, as a function of the degree of benchmarking. The R^2 is one-to-one related to the signal precision through the investor's posterior and can be expressed as $R^2 = 1 - 4\,E[\pi_{1,j}\,\pi_{2,j}]$, where $\pi_{\cdot,j}(x_j)$ denotes the posterior probability given signal precision x_j, as specified in (4). Accordingly, the R^2 is also declining in the degree of benchmarking.

5 Information Acquisition and Asset Prices in Equilibrium

We now focus on how institutional investors affect information acquisition and asset prices in equilibrium. That is, instead of a single institutional investor, we now consider a continuum of atomless investors and impose market clearing. Thus, each investor can use the equilibrium stock price to learn about the private information acquired by the other investors in the economy which will, in turn, affect his asset and information demand.

Our main comparative statics parameter will be the fraction of institutional investors, Λ – or equivalently, how large the institutions are relative to the overall economy. This will allow us to illustrate how the rise of institutional investors (or more precisely, the growth in their assets under management) influences asset prices and informational efficiency.

For our numerical illustrations we are going to rely on the same set of model parameters as in Section 4. In addition, we assume that the mean and volatility of the normal distribution governing the noisy supply, z, are given by $\mu_z = 1$ and $\sigma_z = 0.15$. Table 1 provides a summary of the model parameters.

5.1 Information Acquisition and Price Informativeness

In a first step, we now study how changes in the fraction of institutional investors affect the optimal information acquisition of the two groups of market participants, i.e., the precision that investors choose for their private signal. As is shown in Panel A of Figure 3, *both groups of investors choose a higher precision* for their private signals, x_i, $i \in \{\mathcal{I}, \mathcal{O}\}$ – here again expressed in terms of R^2 – as the share of institutional investors increases.

To understand this effect, recall from the results in the preceding section that institutional investors, in general, value private information less and, thus, choose less precise signals. This was because the hedging component of their portfolio limits their speculative activities in the presence of wealth effects. For example, in Panel A of Figure 3, the variance explained by the institutional investors' signals $S_{\mathcal{I}}$ (or, implicitly, the signal precision) is always lower than for the other investors – regardless of the share of institutional investors. Now, imagine an increase in the fraction of institutional investors without a change in the precision of the investors' private signals ("off equilibrium"). This would imply a shift to-

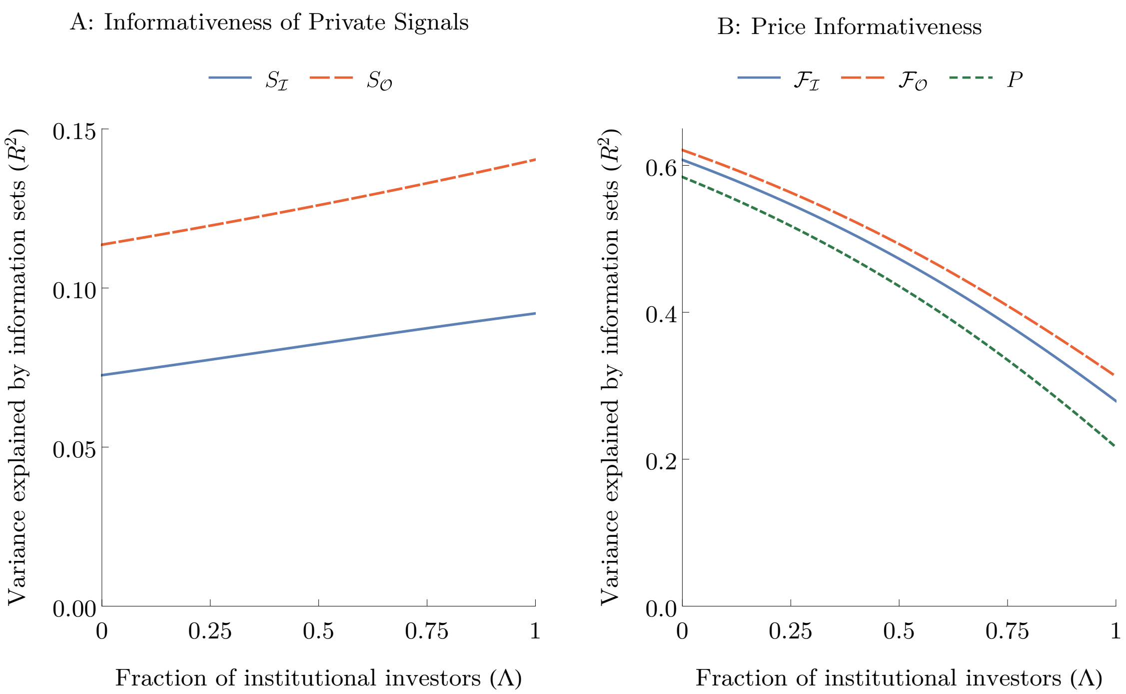

Figure 3: Informativeness of private signals and stock price. This figure shows the fraction of the variance of the payoff D that is explained by various information sets (R^2) as a function of the share of institutional investors Λ. Panel A shows the fraction of the variance that is explained by the individual investors' private signals S_i, $i \in \{\mathcal{I}, \mathcal{O}\}$, and Panel B shows the fraction of the variance that is explained by the stock price, P, as well as by the two groups of market participants' information sets, $\mathcal{F}_i = \{P, S_i\}$, $i \in \{\mathcal{I}, \mathcal{O}\}$. The results are based on the parameter values presented in Table 1.

wards less informed institutional investors and, in turn, a decline in aggregate information acquisition in the economy. Accordingly, the marginal benefit from an additional piece of information goes up, increasing the incentives for all investors to acquire more information, i.e., choose a more precise signal. This is exactly the "on-equilibrium" behavior of the two groups of investors, as shown in Panel A of Figure 3.

In equilibrium, financial markets aggregate the individual investors' private information through means of trading and market clearing. Accordingly, the equilibrium stock price partially reveals private information about the payoff of the stock D. Panel B of Figure 3 illustrates how this "price informativeness", measured as the fraction of the variance of the payoff of the stock, D, that can be explained by the stock price P alone and reflecting the information set of a (hypothetical) investor who does not receive an informative signal, changes with the fraction of institutional investors. Particularly, *price informativeness is declining in the share of institutional investors* – even though the precision of both groups' private signals is increasing in the fraction Λ. This means that prices become less informative as assets under management of institutional investors grow.

Intuitively, this effect can be explained by the fact that an increase in the share of institutional investors implies that more informed, other investors are replaced by less informed, institutional investors (cf. Panel A of Figure 3). Thus, on aggregate, less information is acquired, and, in turn, revealed through the stock price. The increase in the signal precision of each group of investors counter-acts this effect, but is not strong enough to overturn it, leading to the observed decline in price informativeness.

Panel B of Figure 3 also shows the fraction of the variance of the stock's payoff that can be explained by the full information set of each investor, $\mathcal{F}_i = \{P, S_i\}$, consisting of the publicly observable stock price P and his private signal S_i, $i \in \{\mathcal{I}, \mathcal{O}\}$. As discussed above, institutional investors always – independent of their size relative to the overall economy – choose a lower signal precision than the other investors, so that it is not surprising that they are less well informed. That is, the variance of the stock's payoff explained by institutional investors' information set $\mathcal{F}_{\mathcal{I}}$ is lower than the variance explained by the other investors' information set $\mathcal{F}_{\mathcal{O}}$.

Interestingly, the "gap" between the precision of two market participants' information sets widens as the fraction of institutional investors increases, i.e., the information advantage of the other investors strengthens. This is a direct consequence of the decline in price informativeness. That is, because less information is revealed through the public signal – the stock price – the precision of the investors' private information gains importance. Accordingly, the fact that the institutional investors acquire less information, i.e., have less precise signals, plays a more important role.

Recall from Section 4 that in the absence of wealth effects (e.g., CARA-utility), institutional investors' demand for information would not be affected by the degree of benchmarking. Accordingly, a change in the fraction of institutional investors would actually have no impact on investors' information choices and price informativeness, so that in this setting all quantities shown in Figure 3 would be independent of the share of institutional investors.

Investors' information choices and information sets are hardly observable. However, there exists empirical evidence that is consistent with our theoretical findings. For example, Israeli, Lee, and Sridharan (2016) find that an increase in exchange traded fund ownership – a group of institutional investors whose performance is closely linked to an index – is associated with less informative securities prices, i.e., a decline in price informativeness, as well as with a decline in analyst coverage, i.e., a decline in aggregate information acquisition. Moreover, while Bai, Philippon, and Savov (2016) document an increase in price informativeness, defined as the predicted variation in returns from prices, from 1960 to today, there is practically no improvement in price informativeness from 1980 to today. Over this period the share of institutional investors has grown substantially which may have counteracted the positive effects arising from lower trading costs, more liquidity as well as easier and cheaper access to information. Similarly, Bai, Philippon, and Savov (2016) find no improvement in price informativeness over the last 30 years for the (annually updated) group of stocks with an above-median share of institutional investors.

5.2 Asset Prices and Moments of Return

Next, we analyze how the fraction of institutional investors affects the stock price and the corresponding moments of the stock return in equilibrium. Particularly, Figure 4 depicts the equilibrium stock price, averaged over all possible realizations of the signal and the noisy supply, as a function of the share of institutional investors.

In the case without information acquisition, i.e., with symmetric information, the stock price is increasing in the share of institutional investors. Intuitively, the positive hedging demand of the institutional investors creates an "excess demand" for the stock which strengthens with the size of the institutional investors and, in turn, pushes up the stock price. This finding is similar to the results in standard asset pricing models with institutional investors absent information acquisition, as in in Basak and Pavlova (2013) or Buffa, Vayanos, and Woolley (2014).

Before turning to the implications of jointly modeling institutional investors and information acquisition, note that without institutional investors, i.e., $\Lambda = 0$, the stock price is higher with endogenous information acquisition than in the absence of information acquisi-

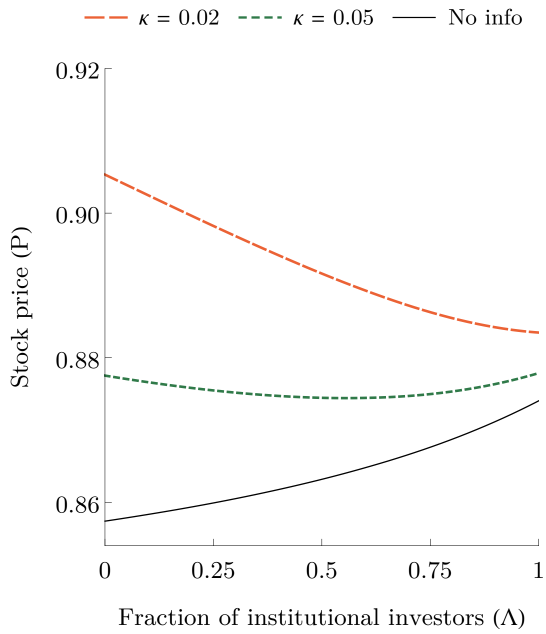

Figure 4: Stock Price. The figure shows the endogenous price of the stock, P, averaged over all possible realizations of the signals and noisy supply as a function of the share of institutional investors Λ. The stock price is depicted for the case without information acquisition ("No info"), i.e., with uninformed investors, as well as for the case with information acquisition, i.e., endogenous signal precision. Particularly, the price is shown for two levels of the information cost: $\kappa = 0.02$ and $\kappa = 0.05$. The results are based on the parameter values presented in Table 1.

tion. Particularly, in rational expectations models, private information as well as the public information revealed through the stock price render the stock less risky, as more precise information about its fundamentals is available. This, in turn, leads to a higher price in the economy with endogenous information, as is shown in Figure 4 for $\Lambda = 0$.

This effect also explains why the *price of the stock can decline in the fraction of institutional investors*, as shown in Figure 4 for information costs of $\kappa = 0.02$. Specifically, while the increasing "excess demand" created by the institutional investors' hedging motive pushes up the price – similar to the symmetric information case – the substantial decline in informativeness of the stock price as well as the investors' information sets dominates. Thus, on aggregate, the equilibrium price declines. Interestingly, in the case of higher information costs ($\kappa = 0.05$), the stock price is actually U-shaped in the size of the institutions. That is, for Λ below about 0.6, the negative price effect arising from a decline in price informativeness dominates, leading to a decline in stock price. For larger fractions of institutional investors, however, the positive price effect stemming from the hedging demand dominates, so that the stock price starts to increase.

As the underlying distribution of the stock's payoff D is unaffected by the share of institutional investors, the effects in the stock price naturally translate into changes in the expected stock return. Particularly, while the expected return is decreasing in the fraction of institutional investors in the case without information acquisition, the expected return might actually increase in the presence of institutional investors. This will be the case if the negative price effect created by the lower level of price informativeness dominates, as can be seen for the case of information costs of $\kappa = 0.02$ in Panel A of Figure 5. For the case of higher information costs ($\kappa = 0.05$), the expected return has an inverse U-shape – resembling the pattern of the stock price.

Not surprisingly, the stock return volatility is increasing in the share of institutional investors if one allows for endogenous information acquisition, as illustrated in Panel B.[20] Particularly, as was discussed in the preceding section, an increase in the size of the institutional investors leads to a decline in price informativeness, i.e., less of the variance of the stock's payoff can be explained by the equilibrium stock price. Accordingly, the deviation between the time-2 stock price and the payoff revealed in period 3 increases, implying a more volatile stock return – as shown in Panel B of Figure 5.

Interestingly, in all setups – with and without endogenous information acquisition and independent of the level of the information acquisition costs – the stock's Sharpe ratio declines in the share of the institutional investors (Panel C of Figure 5). In the case without information acquisition, this effect is driven by the decline in the stock's expected return. In contrast, in the case with endogenous information acquisition, the decline in the Sharpe ratio is caused by a stronger increase in return volatility than in expected stock return.

Consistent with our finding that an increase in the fraction of institutional investors leads to higher stock return volatility, Ben-David, Franzoni, and Moussawi (2015) find higher stock return volatility following an increase in ETF ownership, i.e., following an increase in investors that closely follow an index.

[20] While the stock return volatility is slightly declining in our static economy with symmetric information, Basak and Pavlova (2013) show that return volatility is increasing in the presence of institutional investors if one considers a dynamic setting.

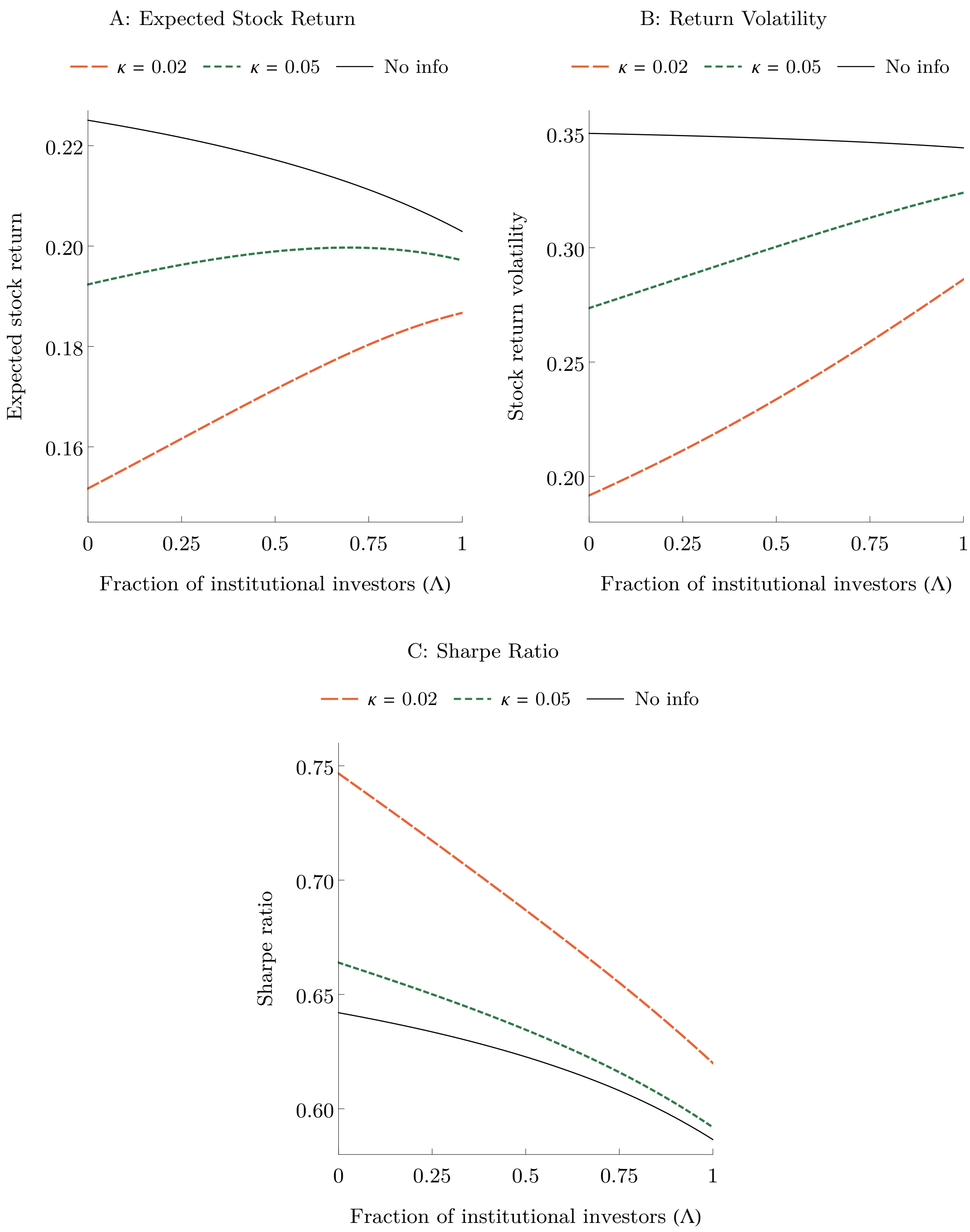

Figure 5: Moments of Stock Return. The figure shows the moments of the stock return as a function of the share of institutional investors, Λ. Panels A to C show the expected return, the return volatility and the Sharpe ratio, respectively. The return moments are depicted for the case without information acquisition, i.e., with uninformed investors, as well as for the case with information acquisition, i.e., endogenous signals precision. Particularly, the return moments are shown for two levels of the information cost: $\kappa = 0.02$ and $\kappa = 0.05$. The results are based on the parameter values presented in Table 1.

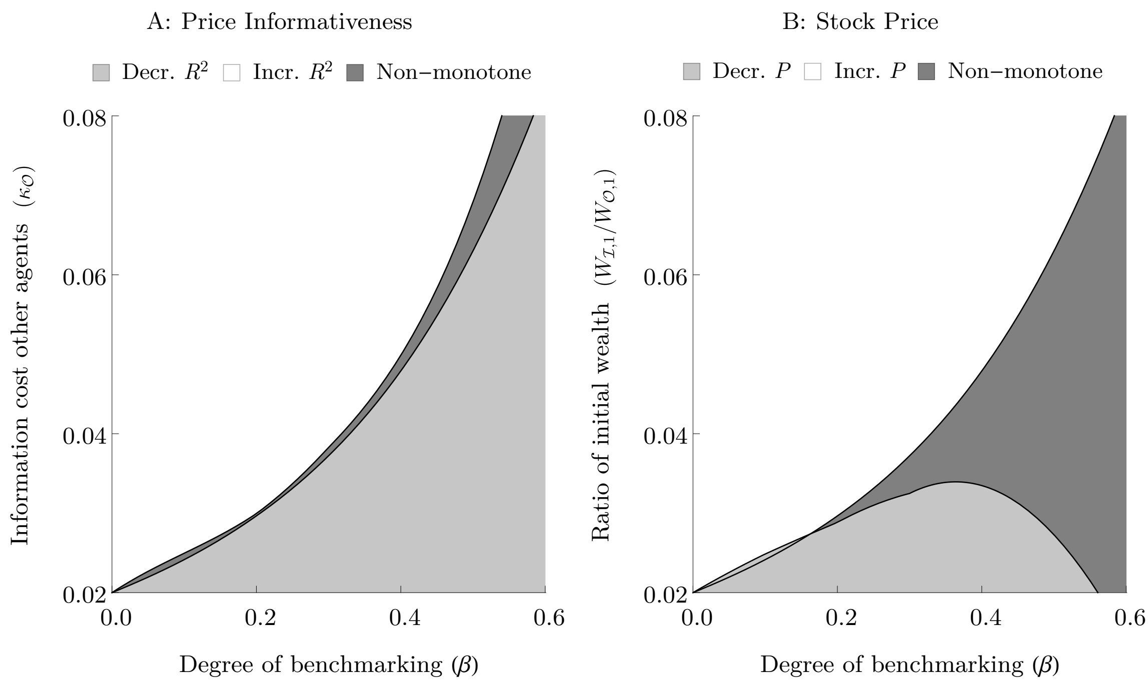

Figure 6: Informational Advantage of Institutional Investors: Lower Information Costs. This figure illustrates stock price informativeness and the stock price for a variety of combinations of the degree of benchmarking β and the level of the information cost of the other investors $\kappa_{\mathcal{O}}$. Particularly, Panels A and B depict the regions for which stock price informativeness, measured in terms of the fraction of the variance of the payoff that is explained by the price (R^2), and the stock price (P), averaged over all possible realizations of the signals and noisy supply, are monotonically decreasing, monotonically increasing or non-monotone in the fraction of institutional investors. The results are based on the parameter values presented in Table 1.

6 Informational Advantage of Institutional Investors

While in our main analysis institutional investors and the other investors face the same information acquisition costs, one might argue that – in reality – institutional investors have an advantage in gathering and processing information, e.g., due to their education or experience, or that they are able to "leverage" the acquired information, due to the larger amount of wealth that they manage.

In the following, we are going to analyze two extensions of our basic model in which we incorporate an *informational advantage of institutional investors.* Particularly, we want to understand under which conditions an increase in the fraction of institutional investors – even in the presence of benchmarking – will lead to an improvement in price informativeness or a higher stock price.

In the first extension of our model, we study a setting in which the other investors face higher information acquisition costs than the institutional investors: $\kappa_{\mathcal{O}} \geq \kappa_{\mathcal{I}} = 0.02$.[21] Panel A of Figure 6 illustrates the impact of varying the information acquisition costs of the other investors $\kappa_{\mathcal{O}}$ and the degree of benchmarking β on price informativeness. There exists a wide region, including our main setting with symmetric costs, in which price informativeness (R^2) is monotonically declining in the fraction of institutional investors. Only if the other investors have substantially higher information costs, e.g., $\kappa_{\mathcal{O}} \geq 0.07$ for $\beta = 0.5$, price informativeness is unambiguously increasing in the fraction of institutional investors. Obviously, the lower the degree of benchmarking, the smaller the informational advantage that is required for an increase in price informativeness. Interestingly, there exists a small region in which the relation between price informativeness and the size of the institutions relative to the overall economy is non-monotone. For example, in the case of an U-shaped relation between the share of institutional investors and price informativeness, this would imply that there exists an optimal fraction of institutions in the economy – in terms of price informativeness.

Panel B of Figure 6 shows the results for the stock price. Note that the region in which the stock price is monotonically decreasing in the fraction of institutional investors is considerably smaller than for the case of price informativeness. This is because benchmarking naturally creates an excess demand for the stock which pushes up the price. For example, for $\beta = 0.5$, the stock price is decreasing only for $\kappa_{\mathcal{O}} \leq 0.027$. Moreover, there exists a considerably larger region in which the stock price is non-monotone in the size of the institutional investors. Within this region, occasionally the positive hedging demand or the decline in price informativeness dominate.

Second, we study an extension of our model, in which institutional investors manage more capital or, formally, are endowed with more initial wealth:[22] $W_{\mathcal{I},1} \geq W_{\mathcal{O},1}$ – keeping overall wealth in the economy constant.[23] Panel A of Figure 7 illustrates the implications of

[21] An analysis with lower information costs for the institutional investors, instead of higher costs for the other investors, yields similar results.

[22] Note, for this application the presence of wealth effects is again crucial because otherwise, e.g., with CARA-utility, wealth would be irrelevant, so that increasing the wealth of institutional investors would have no effects.

[23] Peress (2003) studies a model of costly information acquisition in the presence of wealth effects, so that information generates increasing returns. He shows that this implies that investors with more wealth acquire more information and, accordingly, hold a larger fraction of their wealth in the stock market.

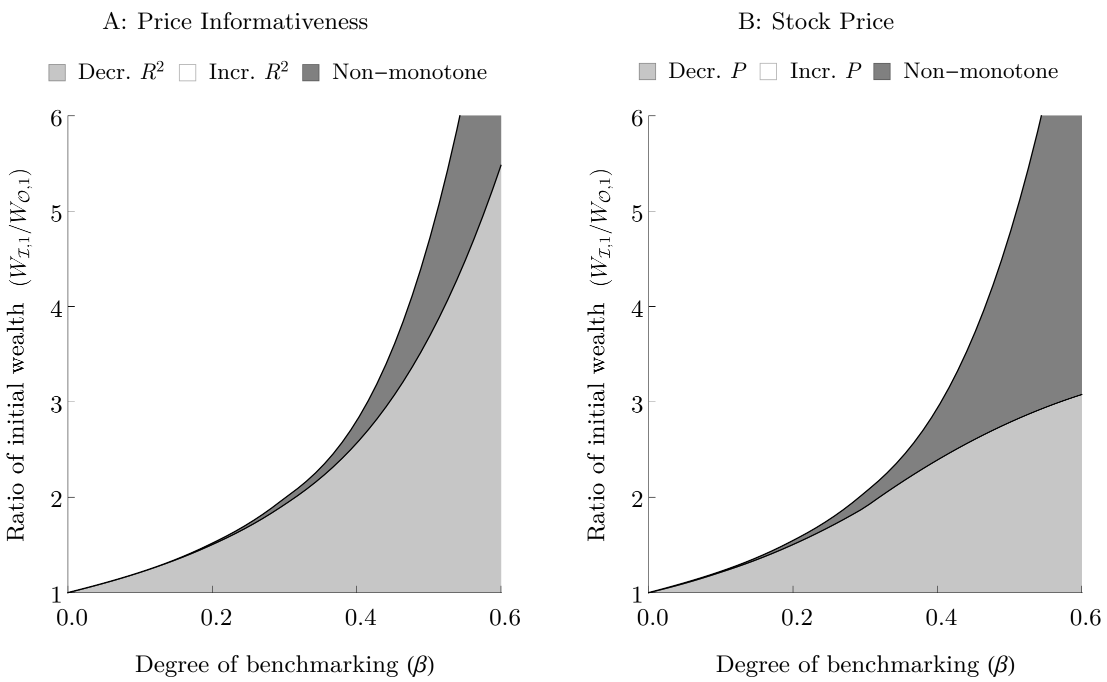

Figure 7: Informational Advantage of Institutional Investors: More Wealth. This figure illustrates stock price informativeness and the stock price for a variety of combinations of the degree of benchmarking β and the ratio of the two market participants' initial wealth $W_{\mathcal{I},1}/W_{\mathcal{O},1}$. Particularly, Panels A and B depict the regions for which stock price informativeness, measured in terms of the fraction of the variance of the payoff that is explained by the price (R^2), and the stock price (P), averaged over all possible realizations of the signals and noisy supply, are monotonically decreasing, monotonically increasing or non-monotone in the fraction of institutional investors. The results are based on the parameter values presented in Table 1.

changing the initial wealth of the institutional investors, here expressed as the ratio $\frac{W_{\mathcal{I},1}}{W_{\mathcal{O},1}}$, and the degree of benchmarking β for the price informativeness of the stock. Again, there exists a wide region in which price informativeness is monotonically declining in the fraction of institutional investors. For example, for $\beta = 0.5$, price informativeness is declining even if institutional investors have more than 3.5 times more initial wealth. Again, there exists a small region in which the price is non-monotone in the fraction of institutional investors. The findings for the stock price, shown in Panel B of Figure Figure 7, are comparable to the findings for the case of differential information costs, but with a larger region in which the stock price is monotonically declining.

In summary, our findings show that only if institutional investors have a substantial informational advantage, e.g., due to lower information costs or more initial wealth, price informativeness is increasing in the fraction of institutional investors. A smaller informational advantage is required to have the stock price increasing in the fraction of institutional investors, because the underlying excess demand arising from institutional investors' hedging motives implies a positive price pressure in any case.

7 Conclusion

In this paper, we *jointly* determine institutional investors' optimal portfolio and information choices in equilibrium. Particularly, we explicitly model one of the most prominent features of institutional investors incentives – their concern about their performance relative to a benchmark – within an asset pricing model with endogenous information acquisition. We show that in the presence of benchmarking institutional investors' portfolios are less sensitive to private information. This implies that private information has less value for institutional investors, thus, reducing their incentives to acquire private information in the first place.

By varying the fraction of institutional investors in our economy, we then study how the growth of institutional investors affects information acquisition and information aggregation as well as asset prices in equilibrium. We show that, even though an increase in the share of institutional investors strengthens the incentives of all investors to acquire more precise information, an increase in the fraction of institutional investors leads to a decline in price informativeness. This can be explained by the fact that less informed, institutional investors replace more informed, other investors. This decline in price informativeness, in turn, can lead to a decline in the equilibrium stock price as well as an increase in the expected stock return. Moreover, it leads to substantially higher return volatility. Empirical studies lend support to many of these results. Finally, in two extensions of our main setting, we document that a substantial informational advantage for institutional investors would be required to have price informativeness increasing in the fraction of institutional investors.

While there is a growing literature studying the asset pricing implications of institutional investors, our paper makes a first step in understanding the joint information acquisition and portfolio choice decisions of institutional investors. However, many aspects of institutional investors' impact on financial markets are not well understood yet. For example, extensions of our framework could be used to understand the optimal size of institutional or passive investors in the economy (Pástor and Stambaugh (2012)) or the "costs" of passive investing in terms of price informativeness (French (2008)). Moreover, the numerical algorithm that we use to solve for the equilibrium is quite flexible and allows to solve many other rational expectations models outside the CARA-normal framework.

A Appendix: Numerical Algorithm

Due to our deviation from the CARA-normal framework, the equilibrium price function in our economy is non-linear. Accordingly, we have to rely on a numerical algorithm to solve for the equilibrium. In the following, we are going to provide some details of the algorithm that we have developed.

Particularly, as described in Section 3.4, in equilibrium, each investor must have rational expectations as specified in (4), each investor must choose a portfolio to maximize (5) subject to his period-2 budget equation and the stock market needs to clear – for all realizations of the underlying (unobservable) payoff D and the (unobservable) noisy supply z. In addition, in period 1, each investor must choose a signal precision to maximizes (5) subject to his period-1 budget equation.

We discretize the state space for the noisy supply z, using N grid points. The full equation system then consists of the following set of equations: First, $2 \times 2 \times 2 \times N$ "posterior equations" (4), describing the posterior beliefs for the two groups of investors, the two (current) underlying payoff realizations, the two (future) possible realizations of the payoff and the N grid points of the supply. Second, $2 \times 2 \times N$ portfolio first-order conditions (6), again for the two groups of investors, the two underlying payoff realizations and the N grid points of the supply. Third, N market clearing condition (9) for the N grid points of the supply. Fourth, two information acquisition first-order conditions (8) for the two groups of investors. That is, in total, we arrive at $13N + 2$ equations.

The unknowns of the equation system are given by the following variables: First, $2 \times 2 \times 2 \times N$ posterior beliefs $\pi_{\cdot,k}$ for the two groups of investors, the two (current) underlying payoff realizations, the two (future) possible realizations of the payoff and the N grid points of the supply. Second, $2 \times 2 \times N$ portfolio shares of the stock ϕ_j^1 for the two groups of investors, the two underlying payoff realizations and the N grid points of the supply.[24] Third, N stock prices P for the N grid points of the supply. And, finally, 2 signal precisions x_j for the two groups of investors which makes in total $13N + 2$ variables.

[24] The portfolio shares of the bond are simply given by $\phi_j^0 = 1 - \phi_j^1$.

Note, the equation system cannot be solved recursively because the period-1 choice of the signal precision x_j affects the period-2 posterior beliefs and, in turn, the portfolio choices and market clearing. Accordingly, we solve this large fixed-point problem globally using Mathematica.

References

Albagli, E., C. Hellwig, and A. Tsyvinski, 2014, "Dynamic Dispersed Information and the Credit Spread Puzzle," *NBER Working Paper No. 19788.*

Bai, J., T. Philippon, and A. Savov, 2016, "Have financial markets become more informative?," *Journal of Financial Economics*, 122(3), 625 – 654.

Bakke, T.-E., and T. M. Whited, 2010, "Which Firms Follow the Market? An Analysis of Corporate Investment Decisions," *Review of Financial Studies.*

Barlevy, G., and P. Veronesi, 2000, "Information Acquisition in Financial Markets," *Review of Economic Studies*, 67(1), 79–90.

Basak, S., and A. Pavlova, 2013, "Asset Prices and Institutional Investors," *American Economic Review*, 103(5), 1728–1758.

——— , 2016, "A Model of Financialization of Commodities," *The Journal of Finance*, 71(4), 1511–1556.

Ben-David, I., F. A. Franzoni, and R. Moussawi, 2015, "Do ETFs Increase Volatility?," *NBER Working Paper No. 20071.*

Bernardo, A. E., and K. L. Judd, 2000, "Asset Market Equilibrium with General Tastes, Returns, and Informational Asymmetries," *Journal of Financial Markets*, 3(1), 17–43.

Bond, P., A. Edmans, and I. Goldstein, 2012, "The Real Effects of Financial Markets," *Annual Review of Financial Economics*, 4(1), 339–360.

Brennan, M., 1993, "Agency and Asset Pricing," *Unpublished Manuscript.*

Breon-Drish, B., 2015, "On Existence and Uniqueness of Equilibrium in a Class of Noisy Rational Expectations Models," *The Review of Economic Studies*, 82(3), 868–921.

Breugem, M., 2016, "On the Dispersion of Skil and Size in Active Management: Multi-Agent Dynamic Equilibrium with Endogenous Information," *Working Paper.*

Buffa, A., and I. Hodor, 2017, "Asset Pricing with Heterogeneous Benchmarking," *Working Paper.*

Buffa, A., D. Vayanos, and P. Woolley, 2014, "Asset Management Contracts and Equilibrium Prices," *CEPR Discussion Papers.*

Chabakauri, G., K. Yuan, and K. E. Zachariadis, 2016, "Multi-Asset Noisy Rational Expectations Equilibrium with Contingent Claims," *Working paper.*

Chen, Q., I. Goldstein, and W. Jiang, 2007, "Price Informativeness and Investment Sensitivity to Stock Price," *Review of Financial Studies*, 20(3), 619–650.

Chevalier, J., and G. Ellison, 1997, "Risk Taking by Mutual Funds as a Response to Incentives," *Journal of Political Economy*, 105(6), 1167–1200.

Cuoco, D., and R. Kaniel, 2011, "Equilibrium Prices in the Presence of Delegated Portfolio Management," *Journal of Financial Economics*, 101(2), 264–296.

Edmans, A., I. Goldstein, and W. Jiang, 2012, "The Real Effects of Financial Markets: The Impact of Prices on Takeovers," *The Journal of Finance*, 67(3), 933–971.

Foucault, T., and L. Frésard, 2012, "Cross-Listing, Investment Sensitivity to Stock Price, and the Learning Hypothesis," *Review of Financial Studies*.

French, K. R., 2008, "Presidential Address: The Cost of Active Investing," *The Journal of Finance*, 63(4), 1537–1573.

García, D., and J. M. Vanden, 2009, "Information Acquisition and Mutual Funds," *Journal of Economic Theory*, 144(5), 1965–1995.

Griffin, J. M., J. H. Harris, and S. Topaloglu, 2003, "The Dynamics of Institutional and Individual Trading," *The Journal of Finance*, 58(6), 2285–2320.

Grossman, S., 1976, "On the Efficiency of Competitive Stock Markets where Trades have diverse Information," *The Journal of Finance*, 31(2), 573–585.

Grossman, S. J., and J. E. Stiglitz, 1980, "On the Impossibility of Informationally Efficient Markets," *American Economic Review*, 70(3), 393–408.

Guercio, D. D., and P. A. Tkac, 2002, "The Determinants of the Flow of Funds of Managed Portfolios: Mutual Funds vs. Pension Funds," *The Journal of Financial and Quantitative Analysis*, 37(4), 523–557.

Hellwig, M. F., 1980, "On the Aggregation of Information in Competitive Markets," *Journal of Economic Theory*, 22(3), 477–498.

Israeli, D., C. M. Lee, and S. A. Sridharan, 2016, "Is There a Dark Side to Exchange Traded Funds (ETFs)? An Information Perspective," *Stanford University Graduate School of Business Research Paper No. 15-42*.

Kacperczyk, M., S. Van Nieuwerburgh, and L. Veldkamp, 2016, "A Rational Theory of Mutual Funds' Attention Allocation," *Econometrica*, 84(2), 571–626.

Malamud, S., and E. Petrov, 2014, "Portfolio Delegation and Market Efficiency," *Working Paper*.

Milgrom, P., and N. Stokey, 1982, "Information, Trade and Common Knowledge," *Journal of Economic Theory*, 26(1), 17–27.

Nieuwerburgh, S. V., and L. Veldkamp, 2010, "Information Acquisition and Under-Diversification," *Review of Economic Studies*, 77(2), 779–805.

Pástor, L., and R. F. Stambaugh, 2012, "On the Size of the Active Management Industry," *Journal of Political Economy*, 120(4), 740–781.

Peress, J., 2003, "Wealth, Information Acquisition, and Portfolio Choice," *Review of Financial Studies*, 17(3), 879–914.

Qiu, Z., 2012, "An Institutional REE Model with Relative Performance," *Working Paper.*

Sirri, E. R., and P. Tufano, 1998, "Costly Search and Mutual Fund Flows," *The Journal of Finance*, 53(5), 1589–1622.

Sotes-Paladino, J., and F. Zapatero, 2016, "A Rationale for Benchmarking in Money Management," *Working Paper.*

Stambaugh, R. F., 2014, "Presidential Address: Investment Noise and Trends," *The Journal of Finance*, 69(4), 1415–1453.

U.S. Securities and Exchange Commission, 2013, "Institutional Investors: Power and Responsibility," *Technical Report.*

Verrecchia, R. E., 1982, "Information Acquisition in a Noisy Rational Expectations Economy," *Econometrica*, 50(6), 1415–30.