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Institutionalization, delegation, and asset prices [☆]

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Abstract

We study the effects of institutionalization on fund manager compensation and asset prices. Institutionalization raises the performance-sensitive component of the equilibrium contract, which makes institutional investors effectively more risk averse. Institutionalization affects market outcomes through two opposing effects. The direct effect is to bring in more informed capital, and the indirect effect is to make each institutional investor trade less aggressively on information through affecting the equilibrium contract. When there are many institutions and little noise trading in the market, the indirect contracting effect dominates the direct informed capital effect in determining market variables such as the cost of capital, return volatility, price volatility, and market liquidity. Otherwise, the direct informed capital effect dominates.

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1. Introduction

One salient trend in most modern financial markets is institutionalization.[1] Financial institutions such as mutual funds and hedge funds hold a majority of equities and represent most of the trading volume in financial markets.[2] Financial institutions do not trade their own money. Instead, they collect money from households and hire professional money managers to operate; therefore, there are agency and delegation issues in portfolio management. In this paper, we study how institutionalization affects manager compensation and asset prices by analyzing a financial market model with delegated portfolio management and endogenous information acquisition.

Our model features three types of players: financial institutions (funds), managers, and retail investors. The financial market has two assets, one risk-free asset and one risky asset. Each fund hires a portfolio manager to operate the fund and trade the assets. Retail investors trade assets on their own. We parameterize institutionalization as an increase in the number of funds (and a decrease in the number of retail investors). In our model, managers are able to produce superior information about the risky asset's payoff, which captures the fact that in practice, on average, financial institutions are more informed than individual investors. However, funds cannot observe managers' information-acquisition decisions and portfolio choices and thus, moral hazard arises (i.e., managers shirk from acquiring information and enjoy a quiet life). Each fund, therefore, designs an incentive contract to ensure that its hired manager exerts effort to acquire and trade on information.

We follow the literature and assume that the contract is linear in trading profits (e.g., Admati and Pfleiderer, 1997; Kyle, Ou-Yang, and Wei, 2011, KOW henceforth). The intercept term a in the linear contract provides a fixed salary. The slope term b in the contract corresponds to a proportional management fee that provides incentives and thus, we refer to it as the "incentive component" of the contract. As Admati and Pfleiderer (1997) show, a linear contract alone cannot induce a manager to exert effort because the manager can scale up or down the portfolio choice and undo the incentive of the linear contract. To circumvent this irrelevance result, some types of market frictions have to be introduced such that managers cannot freely undo the incentive. In our setup, the frictions are transaction costs, which can be construed as transaction taxes imposed by taxing authorities.

We show that institutionalization raises the incentive component b of the equilibrium contract. Intuitively, as more institutional investors are present in the market, their trading brings more information into the price (recall that, in equilibrium, institutions design contracts to motivate their

[1] In Campbell R. Harvey's Hypertextual Finance Glossary, institutionalization refers to "(t)he gradual domination of financial markets by institutional investors, as opposed to individual investors. This process has occurred throughout the industrialized world." (http://people.duke.edu/~charvey/Classes/wpg/bfglosi.htm).

[2] For instance, institutional investors accounted for more than 80% of US equity ownership in 2007, compared to 50% in 1980 (French, 2008; Stambaugh, 2014). According to TheCityUK, in 2013, approximately $87 trillion in assets (comparable to the global GDP) are managed by financial institutions globally.

managers to acquire information). This reduces the uncertainty faced by an uninformed investor and strengthens the incentive of a portfolio manager to deviate from acting as an informed investor. As a result, funds have to abandon a higher fraction of the trading profits to the managers to ensure that they continue to acquire and trade on information.

This incentive result implies that institutionalization has two competing effects on market variables. The direct effect is that institutionalization directly brings more informed traders into the market, and their trading directly injects information into the asset price. We label this effect the "informed capital effect". The indirect effect is that institutionalization raises the effective risk aversion of each institutional investor, since a hired manager has more skin in the game (due to the increased incentive variable b). This causes each institution to trade less aggressively on information. We call this indirect effect the "contracting effect".

We investigate five market variables that are often discussed in the literature (e.g., Vives, 2010; Easley et al., 2016; Goldstein and Yang, 2017; Dávila and Parlatore, 2018): price informativeness, the cost of capital, return volatility, price volatility, and market liquidity. We find that for price informativeness, the informed capital effect always dominates the contracting effect, such that institutionalization improves price informativeness. However, for other variables, the contracting effect can dominate, and thus, agency issues can qualitatively change the behavior of those variables.

In a benchmark economy without agency problems, only the informed capital effect is at work. In this case, institutionalization injects more information into the price and makes the current asset price closer to the future asset payoff, which therefore improves price informativeness and lowers return volatility. Institutionalization reduces the cost of capital by lowering the average perceived risk faced by investors: institutionalization directly brings in more institutional investors, who are informed and thus face less risk than uninformed retail investors; in addition, the improved price informativeness also reduces the risk perceived by the remaining retail investors. Institutionalization can affect price volatility and market liquidity in a non-monotonic pattern, as institutionalization, on the one hand, provides fundamental information and, on the other, worsens the adverse selection problem. Nonetheless, we can show that when the market is primarily dominated by institutional investors, institutionalization always decreases price volatility and increases market liquidity.

In an economy with agency problems, the contracting effect becomes operative, and it affects market variables differently from the informed capital effect. For instance, the informed capital effect decreases return volatility and the cost of capital, but the contracting effect increases return volatility and the cost of capital. The contracting effect dominates the informed capital effect when the number of institutions is large and the amount of noise trading is small. Since the contracting effect operates by changing the effective risk aversion of every institutional investor, this effect is particularly strong when many institutions are present in the market. Thus, it is more likely for the contracting effect to dominate in a more institutionalized market. When the amount of noise trading is small, the financial market effectively aggregates information, which implies that both the informed capital effect and the contracting effect can be strong. Nonetheless, the contracting effect is stronger than the informed effect. As a result, in a highly institutionalized market with little noise trading, institutionalization increases the cost of capital, return volatility, and price volatility, while it decreases market liquidity. This pattern is the opposite of that in a benchmark economy without delegation.

We also analyze a few extended economies. In Section 5, we consider a finite economy such that institutions are "large" and have price impacts. This extension allows us to consider two dimensions of institutionalization: an increase in institutionalized capital can be due to an increase in either the number of institutions or the size of each institution. We show that our results remain the same under both interpretations of institutionalization. The analysis of fund size also suggests an explanation for the fact that as the institutional sector has grown, fees for active management have declined in recent years.

We report other extensions in the Online Appendix. In one extension, we allow portfolio managers to pay a higher cost to acquire a more precise signal. We find that institutionalization increases the precision of information acquired in equilibrium. In another extension, we consider multiple types of institutions to separate the delegation role from the information-acquisition role of portfolio managers. We find that both delegation and informed trading are important in driving our results, which suggests that our model is more applicable to active funds. In the last extension, we endogenize institutionalization by allowing ex ante identical investors to choose to become an institution, and examine the implications of institutionalization driven by different forces.

Related literature. Our paper contributes to the literature studying the implications of institutional investors for asset markets. Most of the existing studies cast their analyses in settings with symmetric information (e.g., Gabaix et al., 2006; Kaniel and Kondor, 2012; Basak and Pavlova, 2013). In contrast, our paper explores asset markets with asymmetric information. Below, we discuss a few studies that also analyze asymmetric information settings and are thus the most closely related to our paper.

Three recent papers have explored the implications of institutional investors for price informativeness. KOW (2011) develop a setting with a single fund. The fund's trading has price impacts, which breaks down the irrelevance result highlighted by Stoughton (1993) and Admati and Pfleiderer (1997). Our study differs from and complements KOW (2011) in two important ways. First, the channels are quite different in these two papers. The channel in KOW (2011) operates through the information acquisition of the informed institution, and adding delegation only amplifies this information-acquisition channel. In our setting, the channel operates by changing the contract incentive b, which in turn is driven by uninformed investors free riding on price information. This free-riding problem is absent in KOW (2011), because there is only one informed trader in their setting. Second, the focus is different: the primary focus of KOW (2011) is price informativeness and the existence of equilibrium; in contrast, the novel results in our paper are not about price informativeness but other financially interesting variables such as the cost of capital, return volatility, price volatility, and market liquidity.

Breugem and Buss (2019) study the joint portfolio and information choice problem of institutional investors. In their setup, some institutional investors care about their performance relative to a benchmark, and such a relative performance concern can make institutional investors more risk averse in the case of power utility (but not in the case of exponential utility, or constant absolute risk aversion (CARA) utility). Our model complements their study by providing a different channel that is related to moral hazard rather than benchmarking concerns. Our channel operates in the case of CARA utility. These two channels can have different implications for price informativeness and asset prices. For instance, Breugem and Buss (2019) predict that benchmarking-driven institutionalization monotonically decreases price informativeness and increases return volatility. By contrast, our model predicts that institutionalization increases price informativeness and can non-monotonically affect return volatility.

Kacperczyk, Nosal, and Sundaresan (2018, KNS henceforth) explore the market power of institutional investors and price informativeness. They show that the size and concentration of institutional investors have the opposite effects on price informativeness. Our study complements

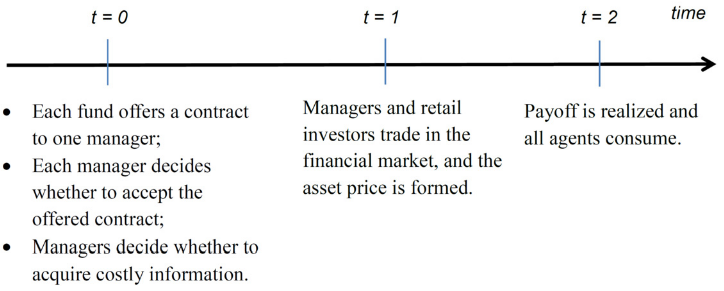

Fig. 1. Model timeline.

KNS (2018) because we consider some dimensions that they do not and they consider some dimensions that we do not. For instance, our channel works through moral hazard, which is absent in KNS (2018), and our novel results concern variables other than price informativeness, such as the cost of capital and return volatility. KNS (2018) consider multiple assets and the choice between active and passive investing, which is absent from our main analysis.

Two additional papers studying moral hazard and asset markets are Huang (2016) and Sockin and Xiaolan (2019). Huang (2016) considers a buy-side analyst setting in which the agent only acquires information but does not trade. This leads to different contract implications from ours. Sockin and Xiaolan (2019) connect the incentive equilibrium with moral hazard to financial market equilibrium, but their focus is on the link between a model-implied measure and several widely adopted empirical statistics capturing managerial ability.

2. A model of financial institutionalization

The economy lasts for three periods: $t = 0$, 1, and 2. The timeline of the economy is depicted in Fig. 1. On date 1, a financial market operates. Financial institutions and retail investors trade financial assets that will deliver payoffs on date 2. We can interpret financial institutions as mutual funds or hedge funds. To facilitate the exposition, we simply refer to institutions as funds and use these two words interchangeably. We normalize the total mass of institutional and retail investors as 1. We use $\lambda \in (0, 1)$ to denote the mass of funds, and the remaining mass $1 - \lambda$ is reserved for retail investors. Parameter λ controls the degree of financial institutionalization in our setting. We will follow Basak and Pavlova (2013) and conduct comparative statics analysis with respect to parameter λ to examine the implications of institutionalization. On date 0, each fund hires a portfolio manager who is capable of developing costly information that is useful for the later trading in the financial market. Effort undertaken to acquire and trade on information is unobservable, which leads to a moral hazard problem. Therefore, funds need to design incentive contracts to motivate their hired managers to work at acquiring information.

2.1. Financial market and retail investors

Two assets, a risky asset and a risk-free asset, are traded in the date-1 financial market. The risk-free asset pays a constant return, which is normalized to 0 for simplicity. The risky asset, which can be interpreted as an index or a single stock, has an endogenous prevailing price $\tilde{p}$. It pays a liquidation value $\tilde{f}$ on date 2,

$$\tilde{f} \equiv \tilde{v} + \tilde{\varepsilon}, \qquad (1)$$

where $\tilde{v} \sim N(0, \tau_v^{-1})$ and $\tilde{\varepsilon} \sim N(0, \tau_\varepsilon^{-1})$ with $\tau_v, \tau_\varepsilon \in (0, \infty)$. The variable $\tilde{v}$ is the learnable element, and the variable $\tilde{\varepsilon}$ is the non-learnable element. The supply of the risky asset is given by $Q - \tilde{\xi}$, where $Q > 0$ is a constant and $\tilde{\xi} \sim N(0, \tau_\xi^{-1})$ with $\tau_\xi \in (0, \infty)$. The random variables $(\tilde{v}, \tilde{\varepsilon}, \tilde{\xi})$ are mutually independent. The variable $\tilde{\xi}$ represents a demand shock, which can be viewed as random floating shares changing from the perspective of rational investors.[3] As standard in the literature, noisy supply/demand provides the randomness necessary to make our rational expectations equilibrium (REE) partially revealing.

Financial institutions (with mass λ) and retail investors (with mass $1 - \lambda$) trade assets to maximize their conditional expected utilities. Trading is costly for both types of investors in the economy. We introduce transaction costs to avoid the irrelevance result highlighted by Admati and Pfleiderer (1997) (see Remark 1). We assume that transaction costs are quadratic in an investor's demand D_i as follows:

$$\frac{1}{2} T \times D_i^2, \tag{2}$$

where T is a positive constant. The quadratic form of transaction costs is commonly adopted in the literature as a reduced form to model trading frictions, which can be interpreted as transaction taxes charged by taxing authorities or commission fees charged by brokerage firms (e.g., Subrahmanyam, 1998; Dow and Rahi, 2000; Gârleanu and Pedersen, 2013; Vives, 2017; Dávila and Parlatore, 2019). As in Subrahmanyam (1998), transaction costs do not influence the behavior of noisy demand $\tilde{\xi}$, since by construction, noisy demand operates in a price-inelastic fashion.

Retail investors are risk averse and have CARA utility functions over their final date-2 wealth $\tilde{W}_R : -e^{-\gamma \tilde{W}_R}$, where γ is the risk aversion parameter. Let D_R denote a retail investor's demand for the risky asset. Given the transaction cost function (2), we have

$$\tilde{W}_R = D_R(\tilde{f} - \tilde{p}) - \frac{1}{2} T D_R^2, \tag{3}$$

where we have normalized the investor's initial wealth as 0, which is without loss of generality under CARA preferences. Retail investors do not receive any private information when trading, although they can actively extract information from the asset price $\tilde{p}$.

2.2. *Financial institutions and agency problems*

Financial institutions have to hire portfolio managers to acquire information and trade. Managers have the skills to acquire private information about the asset payoff $\tilde{f}$ and trade assets based on this private information. We assume that the pool of managers is sufficiently large that each fund can hire one manager on date 0. Then, a hired manager can pay cost $c > 0$ to observe element $\tilde{v}$ in the asset payoff $\tilde{f}$ in (1) before trading in the date-1 financial market.[4] The cost c

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[3] Alternatively, the noisy demand can come from the trading of "sentiment traders", who trade on noise as though it were information (e.g., Mendel and Shleifer, 2012; Peress, 2014; Banerjee and Green, 2015; Rahi and Zigrand, 2018). These traders are irrational individuals since they have incorrect beliefs. The retail investors analyzed in our setting represent rational individuals who have correct beliefs and actively infer information from the price.

[4] We here assume that all managers acquire a common signal with a given precision level. In the Online Appendix, we consider an extension in which managers acquire heterogeneous signals and can pay a cost to improve the precision of the acquired information. We show that our results are robust to this extension. An additional result is that institutionalization encourages information acquisition through the incentive channel highlighted by our analysis.

can represent a manager's time spent conducting fundamental research, money spent on firm visits, or forgone private benefits from shirking. We focus on the scenario in which hired managers are incentivized to acquire information $\tilde{v}$ in equilibrium, meaning that institutional investors are more informed than retail investors.[5]

Because funds cannot observe whether fund managers exert effort to acquire information, a principal-agent problem arises. To solve the agency problem, each fund (the principal) designs an incentive contract to motivate its hired manager (the agent) to undertake effort. We now describe the incentive contracts and trading behavior of institutions.

Let us consider fund $i \in [0, \lambda]$. The fund's manager invests in D_i shares of risky assets, which incurs transaction costs $\frac{1}{2}TD_i^2$ and generates the following trading profits:

$$\tilde{W}_i = D_i(\tilde{f} - \tilde{p}) - \frac{1}{2}TD_i^2. \tag{4}$$

In practice, fund managers' contracts are based on assets under management. This may imply that funds' initial sizes matter for compensation, which makes the model intractable. We therefore follow the literature (e.g., KOW, 2011) and consider contracts under which the manager's compensation $S(\tilde{W}_i)$ linearly depends on the fund's trading profits $\tilde{W}_i$ as follows:

$$S(\tilde{W}_i) = a_i + b_i\tilde{W}_i, \tag{5}$$

where a_i and b_i are two endogenous constants. In particular, the slope b_i of the linear contract determines the sensitivity of manager compensation to fund profits, which is expected to provide incentive for the manager to work hard. We can interpret b_i as the proportional management fee and refer to it as the incentive component of the contract. Linear incentive contracts are widely used in the industry (Massa and Patgiri, 2008) and receive substantial attention in the principal-agent literature (e.g., Admati and Pfleiderer, 1997; Stoughton, 1993; Bolton et al., 2006; KOW, 2011). As standard in this literature, we restrict $b_i \in [0, 1]$ to make the problem economically meaningful.

Managers derive expected utility over final wealth according to CARA utility functions with a common risk aversion coefficient γ. All managers have the same reservation wage $\bar{W}$, which can be interpreted as the best alternative opportunity that managers can achieve. Recall that acquiring information costs c. Thus, for fund i's manager with compensation $S(\tilde{W}_i)$, her final wealth on date 2 is

$$S(\tilde{W}_i) - cI_{\{\text{effort}\}}, \tag{6}$$

where $I_{\{\text{effort}\}}$ is an indicator function defined as

$$I_{\{\text{effort}\}} \equiv \begin{cases} 1, & \text{if fund } i\text{'s manager exerts effort to acquire information,} \\ 0, & \text{otherwise.} \end{cases} \tag{7}$$

We seek an equilibrium in which the incentive contract (5) solves the moral hazard problem. That is, in equilibrium, fund i designs an optimal contract to motivate its manager to exert effort to acquire information $\tilde{v}$. Thus, in the date-1 financial market, fund i's manager has information set $\{\tilde{v}, \tilde{p}\}$, and the manager chooses the optimal demand for the risky asset as follows:

[5] In the Online Appendix, we consider a setting with multiple types of institutions, in which some institutions, such as active funds, engage in both delegated trading and information acquisition, while others, such as passive funds, only engage in delegated trading but do not produce information. We find that both delegation and information acquisition are important in driving our results.

$$D_i^* = \arg\max_{D_i} E\left[-e^{-\gamma[S(\tilde{W}_i)-c]}\middle|\, \tilde{v}, \tilde{p}\right]. \tag{8}$$

On date 0, when solving for the principal's optimal contract, we need to consider two additional constraints: the incentive compatibility (IC) constraint and the participation constraint (PC). The IC constraint states that the manager's expected utility with information acquisition (observing $\{\tilde{v}, \tilde{p}\}$) exceeds her expected utility without information acquisition (observing $\tilde{p}$), that is,

$$E\left[\max_{D_i} E(-e^{-\gamma[S(\tilde{W}_i)-c]}|\tilde{v}, \tilde{p})\right] \geqslant E\left[\max_{D_i} E(-e^{-\gamma S(\tilde{W}_i)}|\tilde{p})\right]. \tag{9}$$

Given the reservation wage $\bar{W}$ (e.g., from outside options), a manager accepts fund i's contract (5) if her expected utility from accepting the contract exceeds her reservation utility from consuming the reservation wage $\bar{W}$, leading to the following PC:

$$E\left[\max_{D_i} E(-e^{-\gamma[S(\tilde{W}_i)-c]}|\tilde{v}, \tilde{p})\right] \geqslant E(-e^{-\gamma \bar{W}}). \tag{10}$$

After paying its manager compensation $S(\tilde{W}_i)$, fund i is left with payoff

$$\tilde{W}_i - S(\tilde{W}_i). \tag{11}$$

We follow the literature (e.g., KOW, 2011) and assume that funds as principals are risk neutral.[6] On date 0, fund i chooses contract parameters a_i and b_i to maximize

$$E\left[\tilde{W}_i - S(\tilde{W}_i)\right], \tag{12}$$

where $\tilde{W}_i$ and $S(\tilde{W}_i)$ are given by equations (4) and (5), respectively. The principal's optimal contract is chosen subject to three constraints imposed by the agent: the optimal portfolio investment (8), the IC constraint (9), and the PC (10). Since there are infinitely many funds (and managers) in the economy, we consider a competitive incentive equilibrium, in which each fund i chooses its contract parameters a_i and b_i and takes as given other funds' contracting problems and other managers' trading strategies. In Section 5, we consider a variation with a finite number of noncompetitive funds and show that our results are robust.

2.3. Equilibrium concept

The overall equilibrium in our model is composed of two subequilibria. On date 1, the financial market forms a noisy rational expectations equilibrium (noisy-REE). On date 0, each fund chooses an optimal contract $\left(a_i^*, b_i^*\right)$ to motivate its hired manager to acquire information. We consider symmetric equilibria at the incentive stage; that is, $a_i^* = a_j^* = a^*$ and $b_i^* = b_j^* = b^*$ for $i \neq j$ and $i, j \in [0, \lambda]$.

Definition 1. A symmetric equilibrium consists of a date-0 contract, (a^*, b^*); a date-1 price function, $p(\tilde{v}, \tilde{\xi}) : \mathbb{R}^2 \to \mathbb{R}$; a date-1 demand function of informed institutions, $D_I(\tilde{v}, \tilde{p}) : \mathbb{R}^2 \to \mathbb{R}$; and a date-1 demand function of retail investors, $D_R(\tilde{p}) : \mathbb{R} \to \mathbb{R}$, such that:

[6] Stoughton (1993) uses a Wilson (1968) syndicate to justify this risk-neutral assumption. That is, most pension and mutual funds are composed of many investors. In this sense, a fund can be viewed as a Wilson (1968) syndicate formed by many risk-averse individual principals. The syndicate's risk tolerance is equal to the sum of the individual risk tolerances. As such, in the limit, as the number of individuals becomes large, the syndicate's risk aversion goes to zero.

1. (Incentive equilibrium) On date 0, given that other funds choose (a^*, b^*), contract (a^*, b^*) maximizes fund i's expected payoff (12) subject to optimal portfolio investment (8), the IC constraint (9), and the PC (10).
2. (Financial market equilibrium) On date 1, informed managers and retail investors submit their optimal portfolio choices $D_I(\tilde{v}, \tilde{p})$ and $D_R(\tilde{p})$ to maximize their respective expected utilities conditional on their respective information sets. The equilibrium price $p(\tilde{v}, \tilde{\xi})$ clears the asset market almost surely:

$$\lambda D_I(\tilde{v}, \tilde{p}) + (1-\lambda) D_R(\tilde{p}) = Q - \tilde{\xi}. \quad (13)$$

2.4. *Discussions on institutions and institutionalization*

We use this subsection to discuss the concepts of institutions and institutionalization. This discussion serves to clarify what key features of these two concepts are captured by our analysis and what features are crucial in driving our results.

In practice, relative to retail investors who self-direct their trades, an institution has the following three salient features:

- *Delegation and informed trading*. Consider a mutual fund as an example. A mutual fund can be construed as a company. The clients of a mutual fund are its shareholders. The fund manager, who can be viewed as a chief executive officer (CEO), is hired by a board of directors who work in the best interests of mutual fund shareholders. Thus, as standard in corporate theory, there is a principal-agent problem between the fund shareholders (principal) and the fund manager (agent). The hired portfolio manager is incentivized to spend effort researching securities and devising investment strategies. Our model follows Stoughton (1993) and KOW (2011) and captures this feature of institutions. Specifically, in our setup, studying securities is modeled as information acquisition; after acquiring information, an informed agent sells her private information in the form of a fund in which a representative, uninformed, risk-neutral client (principal) entrusts her money to the informed trader, who serves as the fund manager (agent); the principal designs an optimal linear sharing rule to induce the agent to exert effort on both information acquisition and subsequent trading in the risky asset (see also KOW (2011, pp. 3782–3783)). In our baseline model, institutions feature both delegation and informed trading. In the Online Appendix, we consider an extension to accommodate institutions such as passive funds that only engage in delegated trading but do not provide information, and we find that our results are driven by both delegation and informed trading.
- *Size and price impact*. Institutions typically manage money from a large number of individuals; hence, their trading moves prices (e.g., KOW, 2011; KNS, 2018). KOW (2011) use this price-impact feature to break down the "undo effect" discussed by Admati and Pfleiderer (1997). In our baseline model, for the sake of tractability, we specify that institutions are atomistic and use transaction costs as a reduced form to circumvent the "undo effect" (see Remark 1). Transaction costs are also empirically relevant and can be interpreted as transaction taxes imposed by taxing authorities. In Section 5, we consider a variation that assumes "large" institutions with an endogenous price impact and demonstrate that our results remain robust.
- *Benchmarking*. Fund managers care about their performance relative to a certain index, due to explicit incentives such as performance fees or implicit incentives such as reputation con-

cerns. This feature has been extensively analyzed in the literature (e.g., Leippold and Rohner, 2011; Basak and Pavlova, 2013; Breugem and Buss, 2019). To make our results transparent, we do not consider this benchmarking feature in the baseline model. Nonetheless, in the Online Appendix, we analyze a setting that uses benchmarking to define institutions and find that benchmark concerns alone are unable to deliver our results.

Institutionalization refers to the increase in the capital controlled by institutions. An increase in the institutionalized capital can come from two channels:

- *An increase in the number of funds*. For instance, based on the CRSP mutual fund dataset, in 1998, there were approximately 850 domestic equity funds in the US market, and this number had grown to approximately 12,000 in 2017. Our baseline model in Section 2 captures this feature of institutionalization.
- *An increase in the size of each fund*. KNS (2018) document that in the US stock market, the equity holdings by ten largest institutional investors have increased substantially over the last three decades. Our baseline model in Section 2 does not capture this feature of institutionalization. Nonetheless, this feature is explored by the variation setting presented in Section 5, and our results are robust to this fund-size interpretation of institutionalization.

3. Equilibrium

We solve the equilibrium backward. We first compute the noisy-REE in the date-1 financial market under any given incentive contract (a, b). We then return to date 0 to compute the equilibrium incentive contract (a^*, b^*).

3.1. Financial market equilibrium

In the date-1 financial market, retail investors and institutions trade assets against noise trading. Retail investors are uninformed investors. Institutions are informed because the equilibrium contract motivates portfolio managers to acquire information $\tilde{v}$. Thus, the trading from portfolio managers injects information $\tilde{v}$ into the asset price $\tilde{p}$. In addition, the price $\tilde{p}$ is affected by noise trading $\tilde{\xi}$. As standard in the noisy-REE literature, we consider the following linear price function:

$$\tilde{p} = a_0 + a_v \tilde{v} + a_\xi \tilde{\xi}, \tag{14}$$

where the a coefficients are endogenous.

The demand function $D_I(\tilde{v}, \tilde{p})$ of a typical portfolio manager is determined by (8). After some algebra, we can compute

$$D_I(\tilde{v}, \tilde{p}) = \frac{E(\tilde{f}|\tilde{v}) - \tilde{p}}{\gamma b Var(\tilde{f}|\tilde{v}) + T}. \tag{15}$$

In a standard CARA-normal setting without transaction costs and delegation problems, an informed CARA investor's demand would be

$$D_{PT}(\tilde{v}, \tilde{p}) = \frac{E(\tilde{f}|\tilde{v}) - \tilde{p}}{\gamma Var(\tilde{f}|\tilde{v})}, \tag{16}$$

where the subscript "PT" refers to "proprietary trading".

We see that $D_I(\tilde{v}, \tilde{p})$ and $D_{PT}(\tilde{v}, \tilde{p})$ differ in the expressions of their denominators. First, the introduction of transaction costs T causes the investor to trade less aggressively. As we will see shortly in Remark 1, transaction costs are necessary for the linear contract to be effective at motivating the manager to acquire information. Second, from expression (15), the effective risk aversion of a financial institution is the product of the manager's risk aversion γ and the incentive component b of the contract:

$$\text{Effective Risk Aversion of Institutions} = \gamma \times b. \tag{17}$$

Thus, a change in the equilibrium contract b will change the effective risk aversion γb of institutions, which will in turn affect market outcomes.

Each retail investor observes $\tilde{p}$ and chooses demand D_R to maximize $E(-e^{-\gamma \tilde{W}_R}|\tilde{p})$ with $\tilde{W}_R$ given by (3). Similar to a portfolio manager's optimization problem, we can derive a typical retail investor's optimal demand as follows:

$$D_R(\tilde{p}) = \frac{E(\tilde{f}|\tilde{p}) - \tilde{p}}{\gamma Var(\tilde{f}|\tilde{p}) + T}. \tag{18}$$

Retail investors make inference from the asset price $\tilde{p}$. According to price function (14), the price $\tilde{p}$ is equivalent to the following signal in predicting the asset payoff $\tilde{f}$:

$$\tilde{s}_p \equiv \frac{\tilde{p} - a_0}{a_v} = \tilde{v} + \frac{a_\xi}{a_v}\tilde{\xi}, \tag{19}$$

which has precision τ_p in predicting $\tilde{v}$:

$$\tau_p \equiv \frac{1}{Var\left(\frac{a_\xi}{a_v}\tilde{\xi}\right)} = \left(\frac{a_v}{a_\xi}\right)^2 \tau_\xi. \tag{20}$$

We use Bayes' rule to compute the expressions for $D_I(\tilde{v}, \tilde{p})$ and $D_R(\tilde{p})$ in (15) and (18), respectively. We then insert these expressions into the market-clearing condition (13) to derive the price as a function of $\tilde{v}$ and $\tilde{\xi}$. Comparing this implied price function with the conjectured price function (14), we can solve for the a coefficients.

Lemma 1 *(Financial market equilibrium). There exists a unique linear noisy-REE in the date-1 financial market, with price function given by equation (14), where*

$$a_0 = -\frac{Q}{A_I + A_R}, a_v = \frac{A_I + A_v}{A_I + A_R}, a_\xi = \frac{A_v/A_I + 1}{A_I + A_R}, \tag{21}$$

with $A_I = \frac{\lambda}{\frac{b\gamma}{\tau_\varepsilon} + T}$, $A_R = \frac{(1-\lambda)(\tau_v + \tau_p)}{\gamma + \gamma\frac{\tau_v + \tau_p}{\tau_\varepsilon} + T(\tau_v + \tau_p)}$, $A_v = \frac{(1-\lambda)\tau_p}{\gamma + \gamma\frac{\tau_v + \tau_p}{\tau_\varepsilon} + T(\tau_v + \tau_p)}$, *and*

$$\tau_p = \frac{(\lambda\tau_\varepsilon)^2 \tau_\xi}{(\gamma b + T\tau_\varepsilon)^2}. \tag{22}$$

3.2. Incentive equilibrium

On date 0, funds design optimal contracts to motivate their portfolio managers to acquire information and trade on this information. Formally, fund i chooses (a_i, b_i) to maximize its expected payoff (12) subject to optimal portfolio investment (8), the IC constraint (9), and the PC

(10). When making this optimal choice, each fund takes as given the other funds' choices (a^*, b^*) and the financial market equilibrium. The idea of computing such an incentive equilibrium is to use the IC constraint (9) to determine the slope b of the linear contract and to use the PC (10) to determine the intercept a of the contract. Our main focus is on the determination of b since it determines the manager's incentive to acquire and trade on private information.

To check the IC constraint (9), we need to derive the expected utility of a portfolio manager who acquires information and that of a manager who does not acquire information. We follow Grossman and Stiglitz (1980) to compute these expected utilities and then show that the IC constraint for fund i's manager is equivalent to the following condition:

$$\frac{\gamma b_i \tau_\varepsilon}{(\gamma b_i + T\tau_\varepsilon)\left(\tau_v + \tau_p\right)} \geqslant e^{2\gamma c} - 1, \tag{23}$$

where τ_p, given by (22), is taken to be exogenous from the perspective of an individual fund and its manager. Apparently, the left-hand side (LHS) of the IC constraint (23) is increasing in b_i. We can show that for any individual fund i, its expected utility is decreasing in b_i, and thus, each fund will optimally set b_i at a value such that the IC constraint (23) holds with equality. In a symmetric equilibrium, $b_i = b^*$ for any $i \in [0, \lambda]$. Thus, replacing b_i with b^* and inserting the expression for τ_p into the LHS of (23) and setting (23) with equality, we establish the following condition that determines the equilibrium incentive b^*:

$$\frac{\gamma b^* \tau_\varepsilon}{(\gamma b^* + T\tau_\varepsilon)\left[\tau_v + \frac{(\lambda\tau_\varepsilon)^2\tau_\xi}{(\gamma b^* + T\tau_\varepsilon)^2}\right]} = e^{2\gamma c} - 1. \tag{24}$$

Lemma 2 *(Incentive equilibrium). Suppose that*

$$\frac{\tau_\varepsilon}{\tau_v} > e^{2\gamma c} - 1, \tag{25}$$

and

$$2(\gamma + T\tau_\varepsilon)\left[\tau_\varepsilon - \tau_v\left(e^{2\gamma c} - 1\right)\right] > T\tau_\varepsilon^2 + \tau_\varepsilon\sqrt{4\lambda^2\tau_\xi\left(e^{2\gamma c} - 1\right)\left[\tau_\varepsilon - \tau_v\left(e^{2\gamma c} - 1\right)\right] + T^2\tau_\varepsilon^2}. \tag{26}$$

Then, there exists a unique date-0 contract (a^*, b^*) in a symmetric equilibrium in which all institutions hire managers to acquire information, where

$$b^* = \frac{T\tau_\varepsilon\left[2\tau_v\left(e^{2\gamma c} - 1\right) - \tau_\varepsilon\right] + \tau_\varepsilon\sqrt{4\lambda^2\tau_\xi\tau_\varepsilon\left(e^{2\gamma c} - 1\right) - 4\lambda^2\tau_\xi\tau_v\left(e^{2\gamma c} - 1\right)^2 + T^2\tau_\varepsilon^2}}{2\gamma\left[\tau_\varepsilon - \tau_v\left(e^{2\gamma c} - 1\right)\right]} \in (0, 1), \tag{27}$$

and

$$a^* = c + \bar{W} - A, \tag{28}$$

where the expression of A is given by equation (A.8) in the Appendix.

Conditions (25) and (26) are rather technical. Condition (25), which intuitively states that the information-acquisition cost is relatively small, ensures that the optimal incentive b^* exists and is positive. Under condition (26), the value of b^* is smaller than 1, which guarantees the empirical relevance of the incentive contract.

Remark 1 *(Transaction costs and the "undo effect").* Stoughton (1993) and Admati and Pfleiderer (1997) show that a linear contract is irrelevant to the manager's effort to acquire information in a competitive market without transaction costs. This is because the manager's portfolio choice is undertaken after information acquisition, and she can freely scale up or down her portfolio choice to "undo" the incentive effect of the linear contract. In the presence of transaction costs (such as transaction taxes or commission fees), the undo effect breaks down. We formalize this intuition by examining condition (23). Consider any individual fund i. The LHS of condition (23) measures the manager's benefit from acquiring information, while the right-hand side (RHS) measures the cost of acquiring information. If $T = 0$, then the LHS of condition (23) is independent of b_i, meaning that the fund cannot use b_i to influence the manager's information-acquisition behavior. By contrast, if $T > 0$, then the LHS of condition (23) is increasing in b_i, and thus, the manager's information-acquisition incentive is indeed affected by the contract slope b_i.

4. Implications of institutionalization

We interpret institutionalization as an increase in the mass λ of institutional investors active in the financial market. We now follow Basak and Pavlova (2013) and conduct comparative statics analysis with respect to λ to examine the implications of institutionalization for manager compensation and asset prices.[7] For manager compensation, we will focus on the incentive component b. For asset prices, we will explore the following variables that attract extensive attention from academics and regulators (see Easley et al. (2016) and Goldstein and Yang (2017) for further discussion of these variables):

- Price informativeness (PI). Price informativeness is a measure of market efficiency. We follow the literature and measure price informativeness as the precision of the posterior about the asset payoff $\tilde{f}$ conditional on its price,

$$PI \equiv \frac{1}{Var(\tilde{f}|\tilde{p})} = \frac{1}{\left(\tau_v + \tau_p\right)^{-1} + \tau_\varepsilon^{-1}}. \tag{29}$$

- The cost of capital (CC). The cost of capital is the expected difference between the cash flow $\tilde{f}$ generated by the risky asset and its price $\tilde{p}$:

$$CC \equiv E(\tilde{f} - \tilde{p}) = |a_0|, \tag{30}$$

  where the second equality follows from price function (14).
- Return volatility ($RetVol$). One unit of asset costs $\tilde{p}$ on date 1, and it pays $\tilde{f}$ on date 2. Thus, the return on the risky asset is $\tilde{f} - \tilde{p}$. Return volatility can be measured by

$$RetVol \equiv \sqrt{Var(\tilde{f} - \tilde{p})} = \sqrt{(1 - a_v)^2\, \tau_v^{-1} + a_\xi^2 \tau_\xi^{-1} + \tau_\varepsilon^{-1}}. \tag{31}$$

- Price volatility ($PriceVol$). Price volatility is the standard deviation of price $\tilde{p}$,

$$PriceVol \equiv \sqrt{Var(\tilde{p})} = \sqrt{a_v^2 \tau_v^{-1} + a_\xi^2 \tau_\xi^{-1}}. \tag{32}$$

[7] In the Online Appendix, we analyze an extension to endogenize λ and consider the implications of institutionalization driven by different forces.

- Market liquidity ($Liquidity$). The literature has used the coefficient a_ξ in the price function to inversely measure market liquidity: a smaller a_ξ means that noise trading $\tilde{\xi}$ has a smaller price impact and hence that the market is deeper and more liquid. That is,

$$Liquidity \equiv a_\xi^{-1}. \tag{33}$$

This measure of market liquidity is often referred to as Kyle's (1985) lambda.

To clarify the role of moral hazard, we benchmark our analysis against an economy without agency problems.

4.1. Benchmark economy without agency problems

4.1.1. Setting and equilibrium

Our benchmark economy follows the analysis of the "first best" case in Stoughton (1993). In this case, managers' information acquisition and trading behavior are observable and contractible. In designing contracts, a fund need not consider its manager's IC constraint, and only considers the manager's PC. The fund ensures that its manager acquires information (since effort is observable and contractible), and based on the developed information, the fund trades by itself to maximize the principal's utility. Now, fund i's problem becomes

$$\max_{(a_i,b_i)} E\left[\tilde{W}_i - S(\tilde{W}_i)\right]$$

subject to the definitions $\tilde{W}_i$ and $S(\tilde{W}_i)$ in (4) and (5), the PC (10), as well as the optimal portfolio rule D_i^* set by the principal, which is given by

$$D_i^* = \arg\max_{D_i} E\left[\tilde{W}_i - S(\tilde{W}_i)\middle| \tilde{v}, \tilde{p}\right].$$

On date 1, a unique linear noisy-REE with price function given by (14) exists in the financial market. On date 0, we can show that the expected utility of fund i decreases with b_i. Thus, fund i will optimally set b_i at 0. Intuitively, since a fund can perfectly observe its manager's effort, the fund does not need to provide variable compensation to motivate its manager, and therefore, fixed compensation is in the fund's best interest. We use superscript "B" to denote the equilibrium variables in the benchmark economy, and hence, we have $b^B = 0$. After pinning down the slope b^B of the linear contract, we can use the PC (10) to determine the intercept a^B of the contract.

Lemma 3 *(Equilibrium in the benchmark economy). In the benchmark economy, we have the following:*

1. *On date 1, there exists a unique linear noisy-REE with price function given by equation (14), where*

$$a_0 = -\frac{Q}{\lambda/T + A_R^B}, a_v = \frac{\lambda/T + A_R^v}{\lambda/T + A_R^B}, a_\xi = \frac{A_R^v T/\lambda + 1}{\lambda/T + A_R^B} \tag{34}$$

with $A_R^B = \frac{(1-\lambda)\left(\tau_v+\tau_p^B\right)}{\gamma+\gamma\frac{\tau_v+\tau_p^B}{\tau_\varepsilon}+T(\tau_v+\tau_p^B)}$, $A_v^B = \frac{(1-\lambda)\tau_p^B}{\gamma+\gamma\frac{\tau_v+\tau_p^B}{\tau_\varepsilon}+T(\tau_v+\tau_p^B)}$, *and*

$$\tau_p^B = \frac{\lambda^2}{T^2}\tau_\xi. \tag{35}$$

2. *On date 0, funds choose a linear contract with fixed compensation, that is,* $b^B = 0$.

4.1.2. Implications of institutionalization without agency problems

In the benchmark economy, the incentive component b^B is not affected by the mass λ of institutional investors, and thus the contracting channel is shut down. Consequently, the implications of institutionalization are similar to those of changing the mass of informed traders in a standard Grossman and Stiglitz (1980) setting.

Institutionalization improves price informativeness PI^B and reduces return volatility $RetVol^B$ and the cost of capital CC^B. Intuitively, institutions are informed investors, and thus, having more informed investors incorporates more information into the price, which improves price informativeness. This in turn reduces the difference between the future value of the asset and its current price, thereby decreasing return volatility. Institutionalization reduces the cost of capital for two mutually reinforcing reasons. First, informed institutions trade more aggressively than uninformed retail investors. Second, the improved price informativeness reduces the risk perceived by retail investors.

For market liquidity $Liquidity^B$ and price volatility $PriceVol^B$, the patterns depend on the precision τ_ξ of noise trading. Institutionalization affects market liquidity through two opposing channels: the price efficiency channel and the adverse selection channel. On the one hand, as price informativeness improves with institutionalization, the current price is closer to the future asset fundamental, which reduces the price impact of exogenous noise trading. On the other hand, institutional investors have private information, and thus, institutionalization worsens the adverse selection problem faced by uninformed retail investors, which harms market liquidity. When there is considerable noise trading in the market, the adverse selection concern is weak, and thus institutionalization monotonically improves liquidity. By contrast, when the level of noise trading is low, both channels are strong, and institutionalization can non-monotonically affect market liquidity.

By improving price informativeness, institutionalization also affects price volatility through two channels: the noise reduction channel and the equilibrium learning channel (see Dávila and Parlatore, 2018). The former tends to reduce price volatility, because an increase in price informativeness is directly associated with reduced noise in the price. The latter can increase price volatility by varying investors' equilibrium signal-to-price sensitivities. Again, when the level of noise trading is high, only the former effect is strong, meaning that institutionalization monotonically reduces price volatility.

Proposition 1 *(Institutionalization without agency problems). In the benchmark economy, the following hold:*

1. *Institutionalization improves price informativeness and reduces return volatility and the cost of capital. That is,* $\frac{dPI^B}{d\lambda} > 0$, $\frac{dRetVol^B}{d\lambda} < 0$, *and* $\frac{dCC^B}{d\lambda} < 0$.
2. *(a) If* $\tau_v\tau_\xi < (\gamma + \gamma\frac{\tau_v}{\tau_\varepsilon})(\gamma + T\tau_v + \gamma\frac{\tau_v}{\tau_\varepsilon})$, *then* $\frac{dLiquidity^B}{d\lambda} > 0$.

   (b) If $\tau_v\tau_\xi > (\gamma + \gamma\frac{\tau_v}{\tau_\varepsilon})(\gamma + T\tau_v + \gamma\frac{\tau_v}{\tau_\varepsilon})$, *then* $\frac{dLiquidity^B}{d\lambda} > 0$ *when the market is primarily dominated by institutional investors, and* $\frac{dLiquidity^B}{d\lambda} < 0$ *when the market is primarily dominated by retail investors.*

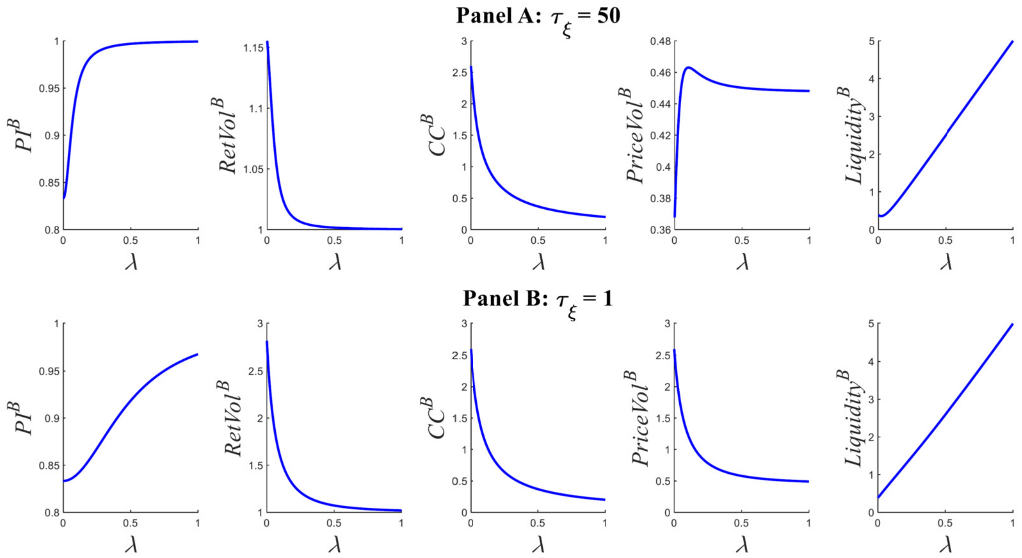

Fig. 2. Implications of institutionalization in the benchmark economy.

3. *(a) When the market is primarily dominated by institutional investors,* $\frac{dPriceVol^B}{d\lambda} < 0$.
   (b) When the market is primarily dominated by retail investors, $\frac{dPriceVol^B}{d\lambda} < 0$ *if and only if* $\tau_v \tau_\xi < (\gamma + \gamma \frac{\tau_v}{\tau_\varepsilon})(\gamma + T\tau_v + \gamma \frac{\tau_v}{\tau_\varepsilon})$.

Fig. 2 graphically illustrates Proposition 1 under the parameter configuration $\tau_v = 5, \tau_\varepsilon = 1, c = 0.02, T = 0.2, \gamma = 2$, and $Q = 1$. In Panel A, the level of noise trading is relatively low ($\tau_\xi^{-1} = 0.02$), while in Panel B, the level of noise trading is relatively high ($\tau_\xi^{-1} = 1$). Consistent with Proposition 1, in both panels, price informativeness PI^B monotonically increases with λ, and return volatility $RetVol^B$ and the cost of capital CC^B monotonically decrease with λ. In Panel A where τ_ξ is relatively high (and the level of noise trading is low), price volatility $PriceVol^B$ and market liquidity $Liquidity^B$ can exhibit non-monotone patterns with respect to λ. In contrast, in Panel B where τ_ξ is relatively low, $PriceVol^B$ decreases with λ and market liquidity $Liquidity^B$ increases with λ.

Note that in both panels, when λ is close to 1, $PriceVol^B$ monotonically decreases with λ and $Liquidity^B$ monotonically increases with λ. This case may be empirically relevant, as the modern market is primarily dominated by institutional investors.

4.2. *Implications of institutionalization with agency problems*

We now turn to examine our baseline model with moral hazard problems. We use the superscript "$*$" to denote the equilibrium variables in this economy. The key observation is that institutionalization λ affects the incentive component b^* of the equilibrium contract, which in turn changes the effective risk aversion γb^* of financial institutions. This gives rise to an additional effect on market outcomes, which can dramatically change many results in the benchmark economy described above.

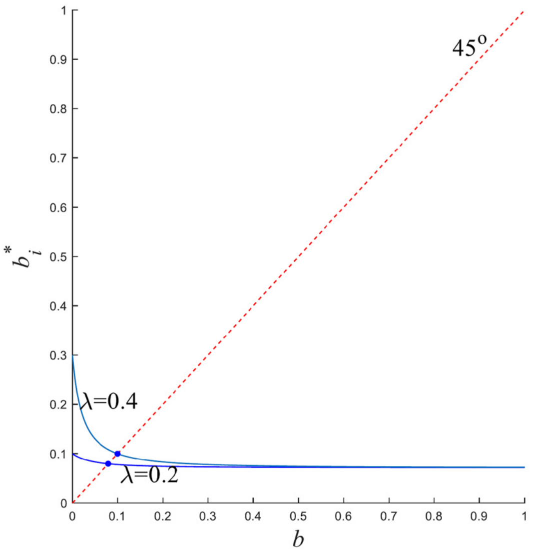

Fig. 3. Best response functions.

4.2.1. *Implications for contracting incentives*

In the presence of moral hazard, institutionalization increases the incentive component b^* of the equilibrium contract. To illustrate the intuition, we consider fund i's optimal choice regarding its contract b_i^* given other institutions' choices b and the mass of institutional investors λ. As discussed in Section 3.2, the best response b_i^* is established by the IC condition (23) holding with equality. That is,

$$b_i^* = \frac{\left(e^{2\gamma c}-1\right)\frac{\tau_v+\tau_p}{\tau_\varepsilon}T\tau_\varepsilon}{\gamma\left(1-\left(e^{2\gamma c}-1\right)\frac{\tau_v+\tau_p}{\tau_\varepsilon}\right)} = \frac{\left(e^{2\gamma c}-1\right)T\tau_\varepsilon\left[\tau_v+\frac{(\lambda\tau_\varepsilon)^2\tau_\xi}{(\gamma b+T\tau_\varepsilon)^2}\right]}{\gamma\left[\tau_\varepsilon-\left(e^{2\gamma c}-1\right)\left(\tau_v+\frac{(\lambda\tau_\varepsilon)^2\tau_\xi}{(\gamma b+T\tau_\varepsilon)^2}\right)\right]}, \tag{36}$$

where the second equality follows from the expression for τ_p.

Note that in equation (36), b and λ affect b_i^* only through τ_p, a variable that is positively related to price informativeness (see equation (29)). Intuitively, the contract is designed to motivate fund i's manager to acquire information, and the incentive component b_i^* is set at a value such that the manager just has no incentive to deviate. The payoff for the manager to deviate from acquiring information is to remain uninformed and save effort. An uninformed manager still actively makes inference from the asset price; formally, she extracts signal $\tilde{s}_p$ with precision τ_p from the price. In this sense, τ_p serves as an endogenous outside option for fund i's manager, and hence if τ_p increases, fund i has to raise the profit share b_i to restore its manager's information-acquisition incentive.

Fig. 3 plots the best response functions for two different values of λ: 0.2 and 0.4. The other parameter values are the same as in Fig. 2, i.e., $\tau_v = 5$, $\tau_\varepsilon = \tau_\xi = 1$, $c = 0.02$, $T = 0.2$, $\gamma = 2$, and $Q = 1$. In a symmetric equilibrium, the incentive component b^* of the contract is determined by the intersections of the best response functions with the 45° line. The best response functions are decreasing in b. This is because an increase in b increases institutional investors' effective risk aversion γb, which reduces price informativeness and the manager's outside option. In contrast, an increase in the mass λ of institutions increases the amount of informed capital and

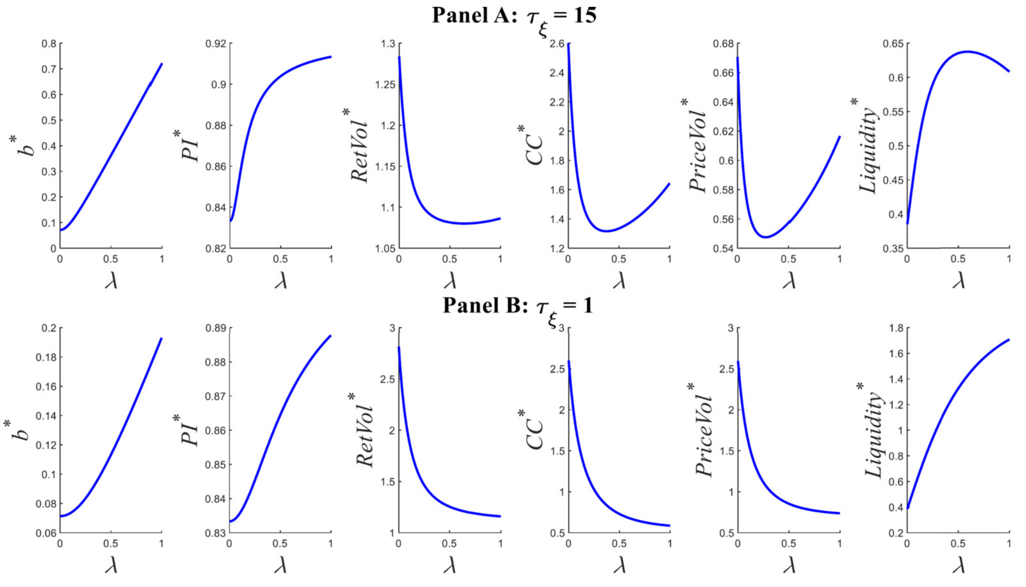

Fig. 4. Implications of institutionalization in the agency economy.

thereby price informativeness. This increased outside option value motivates fund i to increase b_i^*, shifting upward the entire best response function. This result is reflected in Fig. 3: the best response function for $\lambda = 0.4$ lies above the best response function for $\lambda = 0.2$, and as a result, the equilibrium value of b^* increases from 0.08 to 0.10.

The left two panels of Fig. 4 graphically demonstrate that as λ continuously rises from 0 toward 1, the incentive component b^* of the equilibrium contract increases. The other parameter values are $\tau_v = 5$, $\tau_\varepsilon = 1$, $c = 0.02$, $T = 0.2$, $\gamma = 2$, $Q = 1$, and $\tau_\xi \in \{1, 15\}$.

Proposition 2 *(Incentives). In the economy with an agency problem, institutionalization increases the incentive component b^* of the equilibrium contract. That is,* $\frac{db^*}{d\lambda} > 0$.

4.2.2. Implications for asset prices

Institutionalization affects asset prices through two effects, one direct and one indirect. The direct effect is also present in the benchmark economy: institutions are informed investors, and thus, institutionalization directly increases the amount of informed capital. We label this direct effect the "informed capital effect". The indirect effect of institutionalization operates by increasing the incentive component b^* of the equilibrium contract and hence the effective risk aversion of institutions. We refer to this indirect effect as the "contracting effect". Formally, for any market variable $M^* \in \{PI^*, RetVol^*, CC^*, PriceVol^*, Liquidity^*\}$, the total effect of institutionalization can be decomposed as follows:

$$\underbrace{\frac{dM^*}{d\lambda}}_{\text{total effect}} = \underbrace{\frac{\partial M^*}{\partial \lambda}}_{\text{informed capital effect}} + \underbrace{\frac{\partial M^*}{\partial b^*}\frac{\partial b^*}{\partial \lambda}}_{\text{contracting effect}} . \tag{37}$$

The informed capital effect $\frac{\partial M^*}{\partial \lambda}$ is a partial derivative that requires that b^* remains constant, and hence this effect captures only the direct effect of an increase in λ. The contracting effect reflects itself as the chain rule $\frac{\partial M^*}{\partial b^*}\frac{\partial b^*}{\partial \lambda}$, and it captures how an increase in λ affects M^* by increasing the equilibrium value b^*.

Price informativeness. The informed capital effect improves price informativeness by directly injecting more information into the price through the trading of institutional investors. In contrast, the contracting effect reduces price informativeness, because the increased effective risk aversion γb^* of institutional investors causes them to trade less aggressively on their information. Nonetheless, we can show that overall, the positive informed capital effect dominates, such that institutionalization generally improves price informativeness. This result is consistent with the recent empirical evidence that price informativeness for firms in S&P500 has increased since 1960, which overlaps with the trend of institutionalization (e.g., Bai et al., 2016; Farboodi et al., 2018) and that price informativeness and institutional ownership are positively correlated in the cross section (e.g., Boehmer and Kelley, 2009; KNS, 2018). Fig. 4 graphically illustrates this price informativeness result.

Proposition 3 *(Price informativeness). In the economy with agency problems, the informed capital effect increases price informativeness, the contracting effect decreases price informativeness, and overall, institutionalization improves price informativeness PI^*. That is, $\frac{\partial PI^*}{\partial \lambda} > 0$, $\frac{\partial PI^*}{\partial b^*}\frac{\partial b^*}{\partial \lambda} < 0$, and $\frac{dPI^*}{d\lambda} > 0$.*

Return volatility. As in the benchmark economy, the informed capital effect reduces return volatility. The contracting effect tends to increase return volatility by making institutional investors trade less aggressively on their information. Unlike price informativeness, we show that the contracting effect can dominate the informed capital effect, meaning that, overall, institutionalization can increase return volatility. This result arises when the market is primarily dominated by institutional investors (λ is close to 1) and the precision τ_ξ of noise trading is high. The intuition is as follows. First, since the contracting effect operates by changing the effective risk aversion of each institution, it is particularly strong when there are many institutions in the market (λ is close to 1). By contrast, when λ is close to 0, the contracting effect almost vanishes. Second, when there is little noise trading (τ_ξ is high), the market effectively aggregates information. This immediately leads to a strong informed capital effect (the market effectively aggregates information from informed capital and reduces return volatility). More important, the contracting effect is also strong, because the efficient market implies a precise price signal $\tilde{s}_p$, which improves managers' outside option value and hence worsens the agency problem faced by institutions. Ultimately, the contracting effect is stronger than the informed capital effect in this case.

Proposition 4 *(Return volatility). In the economy with agency problems, the following hold:*

1. *When the market is primarily dominated by retail investors, the informed capital effect decreases return volatility, and it dominates the contracting effect, meaning that, overall, institutionalization decreases return volatility. That is, when λ is close to 0, $\frac{dRetVol^*}{d\lambda} \approx \frac{\partial RetVol^*}{\partial \lambda} < 0$.*
2. *When the market is primarily dominated by institutional investors, the informed capital effect decreases return volatility and the contracting effect increases return volatility. The informed capital effect dominates if there is substantial noise trading, and the contracting effect dominates if there is little noise trading. That is, when λ is close to 1, we have the following: (a)*

$\frac{\partial RetVol^*}{\partial\lambda} < 0$; (b) $\frac{\partial RetVol^*}{\partial b^*}\frac{\partial b^*}{\partial\lambda} > 0$; and (c) $\frac{dRetVol^*}{d\lambda} < 0$ if τ_ξ is small, and $\frac{dRetVol^*}{d\lambda} > 0$ if τ_ξ is large.

In Fig. 4, we plot $RetVol^*$ for two values of τ_ξ : 1 and 15. The high value of τ_ξ is smaller than its high value of 50 in Fig. 2, because setting τ_ξ at 50 violates condition (26) in Proposition 2, leading to equilibrium values of b^* higher than 1. We observe that in Fig. 4, independent of the value of τ_ξ, $RetVol^*$ always decreases with λ when λ is small, which exhibits the same patterns as in the benchmark economy as depicted by Fig. 2. When λ is close to 1, the patterns change depending on the value of τ_ξ: when τ_ξ is high, the contracting effect dominates, meaning that $RetVol^*$ increases with λ, which is the opposite of the results in Fig. 2; by contrast, when τ_ξ is low, the informed capital effect dominates and $RetVol^*$ still decreases with λ, which is the same as the findings in Fig. 2. As a result, in the economy with agency problems, the global pattern of $RetVol^*$ is either decreasing in λ (when τ_ξ is low) or U-shaped in λ (when τ_ξ is high).

The U-shaped relation between $RetVol^*$ and λ suggests an explanation for the existing findings on return volatility and institutional ownership. For instance, Brandt et al. (2007) find that among low-priced stocks, a higher level of institutional ownership predicts lower idiosyncratic volatility and that among high-priced stocks, the opposite is true. Since low-priced stocks are dominated by retail traders and high-priced stocks are dominated by institutional investors, the finding of Brandt et al. (2007) suggests a U-shaped relation between return volatility and institutional ownership. In addition, Lee and Liu (2011) document a U-shaped relation between price informativeness and return volatility. This is consistent with Panel A of Fig. 4, where price informativeness increases with λ and return volatility is U-shaped in λ.

The cost of capital. For the cost of capital, the informed capital effect and the contracting effect still work in opposite directions: the informed capital effect reduces the cost of capital, but the contracting effect raises the cost of capital. The result and intuition are also very similar to those in the case of return volatility. When the market is primarily dominated by institutional investors (λ is close to 1) and the market aggregates information effectively (τ_ξ is high), the contracting effect dominates the informed capital effect, and the total effect of institutionalization is to increase the cost of capital. Otherwise, the informed capital effect dominates, meaning that institutionalization decreases the cost of capital. As a result, in Panel A of Fig. 4 where τ_ξ is high, the cost of capital CC^* is U-shaped in λ, which differs from the benchmark economy as depicted by Fig. 2. In Panel B of Fig. 4 where τ_ξ is low, CC^* decreases with λ, which exhibits the same pattern as Fig. 2.

Proposition 5 *(Cost of capital). In the economy with agency problems, the following hold:*

1. *When the market is primarily dominated by retail investors, the informed capital effect decreases the cost of capital, and it dominates the contracting effect, such that, overall, institutionalization decreases the cost of capital. That is, when λ is close to 0, $\frac{dCC^*}{d\lambda} \approx \frac{\partial CC^*}{\partial\lambda} < 0$.*
2. *When the market is primarily dominated by institutional investors, the informed capital effect decreases the cost of capital and the contracting effect increases the cost of capital. The informed capital effect dominates if there is substantial noise trading, and the contracting effect dominates if there is little noise trading. That is, when λ is close to 1, we have the following: (a) $\frac{\partial CC^*}{\partial\lambda} < 0$; (b) $\frac{\partial CC^*}{\partial b^*}\frac{\partial b^*}{\partial\lambda} > 0$; and (c) $\frac{dCC^*}{d\lambda} < 0$ if τ_ξ is small, and $\frac{dCC^*}{d\lambda} > 0$ if τ_ξ is large.*

Price volatility. When the market is primarily dominated by retail investors (λ is close to 0), the contracting effect is minimal and only the informed capital effect is operative. Thus, the patterns are the same as those in the benchmark economy as depicted by Fig. 2.

Suppose that the market is primarily dominated by institutions (λ is close to 1). Now both the informed capital effect and the contracting effect are pronounced. From the analysis in the benchmark economy, we know that the informed capital effect reduces price volatility. In contrast, the contracting effect tends to increase price volatility by making institutions trade less aggressively on information. Again, when there is little noise trading in the market (τ_ξ is high), the market effectively aggregates information. Both the informed capital effect and the contracting effect are strong, but the latter is stronger, meaning that the overall effect of institutionalization is to increase price volatility.

Due to the interactions between the informed capital effect and the contracting effect, price volatility $PriceVol^*$ can exhibit various patterns that are different from those in the benchmark economy. For example, in Panel A of Fig. 4 where τ_ξ is high, $PriceVol^*$ is U-shaped in λ, which differs from the benchmark economy as depicted in Fig. 2. In Panel B of Fig. 4 where τ_ξ is low, $PriceVol^*$ decreases with λ, which is the same as Fig. 2.

Proposition 6 *(Price volatility). In the economy with agency problems, the following hold:*

1. *When the market is primarily dominated by retail investors, the informed capital effect dominates, and it decreases price volatility if and only if there is substantial noise trading in the market. That is, when λ is close to 0, we have the following: (a) $\frac{dPriceVol^*}{d\lambda} \approx \frac{\partial PriceVol^*}{\partial \lambda} < 0$ if $\tau_\xi \tau_v < \gamma(\gamma + T\tau_v + \gamma\frac{\tau_v}{\tau_\varepsilon})$; (b) $\frac{dPriceVol^*}{d\lambda} \approx \frac{\partial PriceVol^*}{\partial \lambda} > 0$ if $\tau_\xi \tau_v > (\gamma + \gamma\frac{\tau_v}{\tau_\varepsilon})(\gamma + T\tau_v + \gamma\frac{\tau_v}{\tau_\varepsilon})$.*
2. *When the market is primarily dominated by institutional investors, the informed capital effect decreases price volatility and the contracting effect increases price volatility. The informed capital effect dominates if there is substantial noise trading, and the contracting effect dominates if there is little noise trading. That is, when λ is close to 1, we have the following: (a) $\frac{\partial PriceVol^*}{\partial \lambda} < 0$; (b) $\frac{\partial PriceVol^*}{\partial b^*}\frac{\partial b^*}{\partial \lambda} > 0$; and (c) $\frac{dPriceVol^*}{d\lambda} < 0$ if τ_ξ is small, and $\frac{dPriceVol^*}{d\lambda} > 0$ if τ_ξ is large.*

Market liquidity. The result and intuition for market liquidity parallel those for price volatility. When there are a few institutions in the market (λ is close to 0), the contracting effect is weak, meaning that the overall liquidity effect of institutionalization is similar to that in the benchmark economy.

When there is a large mass of institutional investors (λ is close to 1), the informed capital effect tends to improve market liquidity, but the contracting effect harms market liquidity. If the level τ_ξ^{-1} of noise trading is low (τ_ξ is high), the market effectively aggregates information, meaning that the contracting effect becomes stronger than the informed capital effect. As a result, $Liquidity^*$ decreases with λ when λ is close to 1 and τ_ξ is high.

In Panel A of Fig. 4 where τ_ξ is high, $Liquidity^*$ is hump-shaped in λ. This pattern differs from that in the benchmark economy in Fig. 2. In Panel B of Fig. 4 where τ_ξ is low, $Liquidity^*$ is increasing in λ. This pattern is similar to that in the benchmark economy in Fig. 2.

Proposition 7 *(Market liquidity). In the economy with agency problems, the following hold:*

1. *When the market is primarily dominated by retail investors, the informed capital effect dominates, and it improves market liquidity if and only if there is substantial noise trading in the market. That is, when* λ *is close to* 0*, we have the following: (a)* $\frac{dLiquidity^*}{d\lambda} \approx \frac{\partial Liquidity^*}{\partial\lambda} > 0$ *if* $\tau_\xi\tau_v < \gamma(\gamma + T\tau_v + \gamma\frac{\tau_v}{\tau_\varepsilon})$*; (b)* $\frac{dLiquidity^*}{d\lambda} \approx \frac{\partial Liquidity^*}{\partial\lambda} < 0$ *if* $\tau_\xi\tau_v > (\gamma + \gamma\frac{\tau_v}{\tau_\varepsilon})(\gamma + T\tau_v + \gamma\frac{\tau_v}{\tau_\varepsilon})$.
2. *When the market is primarily dominated by institutional investors, the informed capital effect increases market liquidity and the contracting effect decreases market liquidity. The informed capital effect dominates if there is substantial noise trading, and the contracting effect dominates if there is little noise trading. That is, when* λ *is close to* 1*, we have the following: (a)* $\frac{\partial Liquidity^*}{\partial\lambda} > 0$*; (b)* $\frac{\partial Liquidity^*}{\partial b^*}\frac{\partial b^*}{\partial\lambda} < 0$*; and (c)* $\frac{dLiquidity^*}{d\lambda} > 0$ *if* τ_ξ *is small, and* $\frac{dLiquidity^*}{d\lambda} < 0$ *if* τ_ξ *is large.*

5. Large institutions

In this section, we consider a variant of the model in which institutions (funds) are "large" and thus have price impacts. This variant allows us to explore the two dimensions of institutionalization mentioned in Section 2: the institutional sector can grow either due to an increase in the number of institutions or due to an increase in the size of each institution. We show that our results are robust under both interpretations of institutionalization. In addition, since this setting with large institutions is more realistic, analyzing it sharpens the interpretation of the incentive component b of the contract and suggests an explanation for the empirically observed pattern of management fees and fund size.

5.1. Setup and analysis

Our variant closely follows the setup proposed by KNS (2018) but extends it to incorporate the contracting problems of fund managers. The basic environment regarding assets and preferences is the same as in our baseline model in Section 2, but now we consider a finite number of players. There are N funds, and each fund has K clients, where both N and K are positive integers. The parameter K captures the size of each fund, and thus the size of the entire institutional sector is captured by NK. There is a finite number M of retail investors. Similar to Section 2, we define the institutionalization parameter λ as the fraction of players in the institutional sector:

$$\lambda \equiv \frac{NK}{NK + M}. \tag{38}$$

We follow KNS (2018) and assume that funds behave strategically but that retail investors behave competitively. The baseline model in Section 2 corresponds to the limiting economy in which K is set to 1 and M and N approach ∞ at the same rate.

The overall equilibrium is composed of the date-0 incentive equilibrium and the date-1 financial market equilibrium. Both subequilibria have to be modified to capture the strategic interactions among the N funds. In computing the date-1 financial market equilibrium, we need to factor in institutional investors' price impacts. In computing the date-0 incentive equilibrium, we need to accommodate the consequences of one fund's possible deviations in its contract offers (and the resulting information-acquisition behavior of its manager) for other investors' date-1 trading behaviors. In doing so, we will assume that these deviations are not observable so that other investors' trading strategies remain unchanged, which appears realistic. On both dates, we consider symmetric equilibria in which all funds choose the same contract on date 0 and the same trading strategy on date 1.

We first compute the date-1 financial market equilibrium given the funds' symmetric contract choice. In the date-1 financial market, the asset price $\tilde{p}$ depends on information $\tilde{v}$ and noise trading $\tilde{\xi}$. We still consider a linear price function as given by equation (14). We conjecture that institutional investor i specifies the following demand schedule for each of its K clients[8]:

$$D_i(\tilde{v}, \tilde{p}) = D_I(\tilde{v}, \tilde{p}) = \phi(\tilde{v} - \tilde{p}), \text{ for } i \in \{1, ..., N\}, \tag{39}$$

where $\phi > 0$ is an endogenous coefficient. Computing the financial market equilibrium reduces to finding the price coefficients (a's) in (14) and the coefficient ϕ in (39).

Retail investors are competitive and maximize their conditional expected utility given price $\tilde{p}$. Their demand function $D_R(\tilde{p})$ is still given by equation (18). That is,

$$D_R(\tilde{p}) = \frac{E(\tilde{f}|\tilde{p}) - \tilde{p}}{\gamma Var(\tilde{f}|\tilde{p}) + T} = \frac{\frac{\tau_p}{\tau_v + \tau_p}\frac{\tilde{p} - a_0}{a_v} - \tilde{p}}{\gamma\left(\frac{1}{\tau_v + \tau_p} + \frac{1}{\tau_\varepsilon}\right) + T}, \tag{40}$$

where the second equality follows from the expressions for $E(\tilde{f}|\tilde{p})$ and $Var(\tilde{f}|\tilde{p})$.

Institutional investors behave strategically and account for their price impacts. Let us consider fund i. Its portfolio manager takes as given other institutions' demand function (39) and the retail demand function (40), and she chooses a demand schedule $D_i(\tilde{v}, \tilde{p})$ to maximize her conditional expected utility,

$$E\left[-e^{-\gamma[S(K\tilde{W}_i) - c]}|\tilde{v}\right],$$

where $\tilde{W}_i$ is fund i's trading profit per client, given by equation (4), and $S(K\tilde{W}_i)$ is its manager's compensation, given by

$$S(K\tilde{W}_i) = \hat{a}_i + \hat{b}_i K\tilde{W}_i, \tag{41}$$

where $\hat{a}_i$ and $\hat{b}_i$ are endogenous constants. Similar to the fee structure (5) in the baseline model, the manager's compensation in (41) still linearly depends on the fund's total trading profits. The slope $\hat{b}_i$ still captures the incentive component, which can be interpreted as management fees such as expense ratios. The first-order condition delivers the manager's optimal demand as follows:

$$D_i^* = \frac{E(\tilde{f}|\tilde{v}) - \tilde{p}}{\gamma\hat{b}_i K Var(\tilde{f}|\tilde{v}) + T + \frac{\partial\tilde{p}}{\partial D_i}} = \frac{\tilde{v} - \tilde{p}}{\frac{\gamma\hat{b}_i K}{\tau_\varepsilon} + T + \frac{\partial\tilde{p}}{\partial D_i}}. \tag{42}$$

As in Kyle (1989), we compute the price impact $\frac{\partial\tilde{p}}{\partial D_i}$ using the residual supply function faced by fund i. Specifically, inserting the demand function of other institutional investors' demand function (39) and the demand function (40) of retail investors into the market-clearing condition,[9]

$$KD_i + K\sum_{j=1, j\neq i}^{N} D_j(\tilde{v}, \tilde{p}) + MD_R(\tilde{p}) = (Q - \tilde{\xi})(NK + M), \tag{43}$$

[8] In principal, we can specify a more general trading strategy, such as $D_I(\tilde{v}, \tilde{p}) = \phi_0 + \phi_1\tilde{v} + \phi_2\tilde{p}$. Nonetheless, the derived demand function in (42) implies that $\phi_0 = 0$ and $\phi_1 = -\phi_2$.

[9] Note that in this finite economy, the noisy supply $Q - \tilde{\xi}$ is defined in a per capita sense. Thus, the RHS of equation (43) is the aggregate supply.

we can compute the residual supply curve faced by fund i as follows:

$$\tilde{p} = \frac{\frac{K}{NK+M}D_i + \left[\frac{(N-1)K}{NK+M}\phi\tilde{v} + \tilde{\xi}\right] - \left[\frac{(1-\lambda)\tau_p\frac{a_0}{a_v}}{\gamma\left(1+\frac{\tau_v+\tau_p}{\tau_\varepsilon}\right)+T(\tau_v+\tau_p)} + Q\right]}{\frac{(N-1)K}{NK+M}\phi + \frac{(1-\lambda)\left(\tau_v+\tau_p-\frac{\tau_p}{a_v}\right)}{\gamma\left(1+\frac{\tau_v+\tau_p}{\tau_\varepsilon}\right)+T(\tau_v+\tau_p)}}. \tag{44}$$

From (44), we have

$$\frac{\partial\tilde{p}}{\partial D_i} = \frac{\frac{K}{NK+M}}{\frac{(N-1)K}{NK+M}\phi + \frac{(1-\lambda)\left(\tau_v+\tau_p-\frac{\tau_p}{a_v}\right)}{\gamma\left(1+\frac{\tau_v+\tau_p}{\tau_\varepsilon}\right)+T(\tau_v+\tau_p)}}. \tag{45}$$

We plug the above expression for $\frac{\partial\tilde{p}}{\partial D_i}$ into (42) to compute the optimal demand of fund i, which is in turn compared with the conjectured trading strategy (39), yielding the following fixed-point equation that determines coefficient ϕ:

$$\phi = \frac{1}{\frac{\gamma\hat{b}K}{\tau_\varepsilon} + T + \frac{\frac{K}{NK+M}}{\frac{(N-1)K}{NK+M}\phi + \frac{(1-\lambda)\left(\tau_v+\tau_p-\frac{\tau_p}{a_v}\right)}{\gamma\left(1+\frac{\tau_v+\tau_p}{\tau_\varepsilon}\right)+T(\tau_v+\tau_p)}}}, \tag{46}$$

where on the RHS, we have replaced $\hat{b}_i$ with $\hat{b}$ given that in a symmetric equilibrium, $\hat{b}_i = \hat{b}$ for $i \in \{1, ..., N\}$.

Inserting the expressions for $D_i(\tilde{v}, \tilde{p})$ and $D_R(\tilde{p})$ into the market-clearing condition, we can find the implied price function. We then compare the implied price function with the conjectured price function (14) to obtain the system for characterizing the price coefficients:

$$a_0 = -\frac{Q}{\lambda\phi + \frac{(1-\lambda)(\tau_v+\tau_p)}{\gamma+T(\tau_v+\tau_p)+\gamma\frac{\tau_v+\tau_p}{\tau_\varepsilon}}}, \tag{47}$$

$$a_v = \frac{\lambda\phi + \frac{(1-\lambda)\tau_p}{\gamma+T(\tau_v+\tau_p)+\gamma\frac{\tau_v+\tau_p}{\tau_\varepsilon}}}{\lambda\phi + \frac{(1-\lambda)(\tau_v+\tau_p)}{\gamma+T(\tau_v+\tau_p)+\gamma\frac{\tau_v+\tau_p}{\tau_\varepsilon}}}, \tag{48}$$

$$a_\xi = \frac{\frac{(1-\lambda)\tau_p}{\gamma+T(\tau_v+\tau_p)+\gamma\frac{\tau_v+\tau_p}{\tau_\varepsilon}}\frac{1}{\lambda\phi} + 1}{\lambda\phi + \frac{(1-\lambda)(\tau_v+\tau_p)}{\gamma+T(\tau_v+\tau_p)+\gamma\frac{\tau_v+\tau_p}{\tau_\varepsilon}}}. \tag{49}$$

The date-1 financial market equilibrium is characterized by equations (46)–(49) in four unknowns (ϕ, a_0, a_v, a_ξ).

On date 0, each fund designs a contract $(\hat{a}_i, \hat{b}_i)$ to maximize the expected utility of its clients by motivating its portfolio manager to acquire and trade on information. Formally, fund i's problem is:

$$\max_{(\hat{a}_i, \hat{b}_i)} E\left[K\tilde{W}_i - S(K\tilde{W}_i)\right] \tag{50}$$

subject to

$$E\left[\max_{D_i(\tilde{v},\tilde{p})} E(-e^{-\gamma[S(K\tilde{W}_i)-c]}|\tilde{v})\right] \geqslant E\left[\max_{D_i(\tilde{p})} E(-e^{-\gamma S(K\tilde{W}_i)})\right], \tag{51}$$

$$E\left[\max_{D_i(\tilde{v},\tilde{p})} E(-e^{-\gamma[S(K\tilde{W}_i)-c]}|\tilde{v})\right] \geqslant E(-e^{-\gamma\bar{W}}), \tag{52}$$

where (51) and (52) are the IC constraint and the PC, respectively. When making the choice of $(\hat{a}_i, \hat{b}_i)$, fund i takes as given the other funds' date-0 contract choices $(\hat{a}, \hat{b})$ and their date-1 trading strategies (39) as well as the retail investors' date-1 demand schedule (40), since fund i's contract choice is not observable to other investors.

The "large" feature of institutions differentiates the current setup from the baseline model in Section 2 in two ways. First, in the IC condition (51), the uninformed manager reads information from her residual supply curve (44). This information is equivalent to a signal of the form $\tilde{v} + \frac{NK+M}{(N-1)K\phi}\tilde{\xi}$, which is less informative than retail investors' perceived price signal $\tilde{s}_p \equiv \frac{\tilde{p}-a_0}{a_\xi} = \tilde{v} + \frac{NK+M}{NK\phi}\tilde{\xi}$. In contrast, in the baseline model with a continuum of funds, both an uninformed manager and a retail investor perceive that the price has the same amount of information. Second, in the objective function (50), the principal also takes into account the effect of changing $(\hat{a}_i, \hat{b}_i)$ on the price function, while in the baseline model in Section 2, the price function is not affected by the behavior of a single fund.

The idea of computing the incentive equilibrium is similar to the baseline model. That is, given symmetry, we have $\hat{b}_i = \hat{b}$ for $i \in \{1, ..., N\}$, and thus we use the IC constraint (51) to compute the equilibrium value of $\hat{b}^*$. We then use the PC (52) to determine the value of $\hat{a}^*$. To ensure that the IC constraint is binding in equilibrium, we finally verify that the expected utility (50) of fund i is decreasing in $\hat{b}_i$ when other funds and retail investors maintain their equilibrium behavior.

5.2. Results

We now examine the implications of institutionalization in this finite economy with price impacts. By equation (38), an increase in the institutionalization parameter λ can be due to an increase in either the number N of funds or the fund size K. We therefore conduct comparative statics with respect to both parameters. In this exercise, we fix the total size $NK + M$ of the economy. That is, in the definition of λ given by equation (38), we increase the numerator and fix the denominator. The complexity of the setting precludes analytical results, and we thus rely on numerical analysis.

We report the results in Figs. 5 and 6. In both figures, we fix $NK + M = 10^8$, which is of a reasonable order for the number of individuals participating in the US market. The other parameter values are the same as those in Fig. 4: $\tau_v = 5$, $\tau_\varepsilon = 1$, $\tau_\xi = 5$, $c = 0.02$, $T = 0.2$, $\gamma = 2$, and $Q = 1$. In Fig. 5, we fix the fund size K at $10,000$ and vary the value of N from 100 to $10,000$ (which is equivalent to varying the value of λ from a value close 0 to 1). In Fig. 6, we fix the number N of funds at 500 and vary the value of K from 2000 to $200,000$ (which is again equivalent to varying the value of λ from a value close 0 to 1). In each figure, we report the following seven variables: $\hat{b}^*$, $K\hat{b}^*$, PI^*, $RetVol^*$, CC^*, $PriceVol^*$, and $Liquidity^*$. We report the value of $K\hat{b}^*$, because a comparison between a large institution's demand (42) and an atomistic institution's demand (15) reveals that the effective risk aversion of a large institution is $\gamma K\hat{b}$ and thus, $K\hat{b}$ in this variant setting plays the same role as b in the baseline setting.

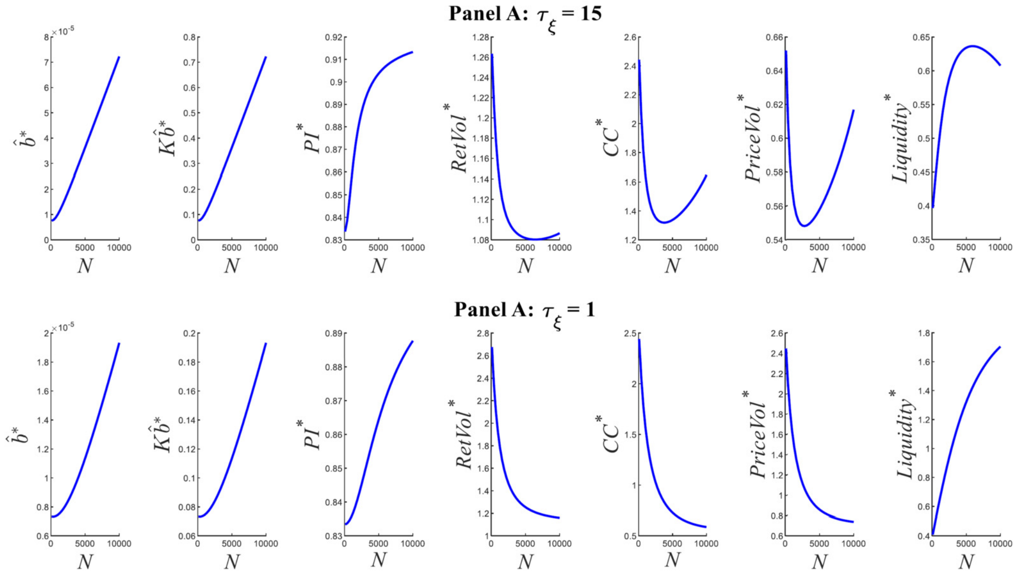

Fig. 5. Effects of N in economies with large institutions.

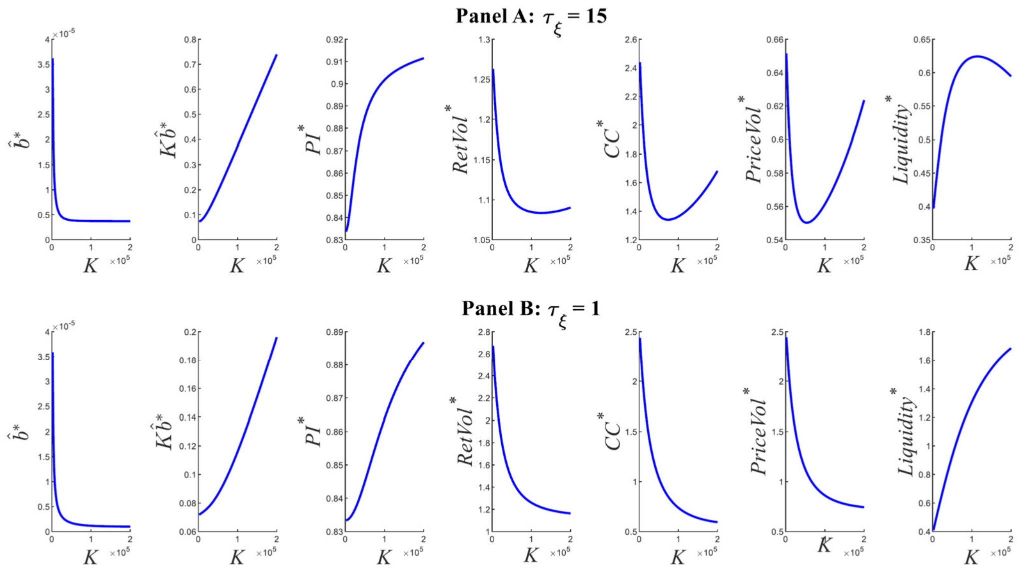

Fig. 6. Effects of K in economies with large institutions.

We find that in terms of $\{K\hat{b}^*, PI^*, RetVol^*, CC^*, PriceVol^*, Liquidity^*\}$, the two figures exhibit identical patterns as in Fig. 4 in our baseline model. For instance, in Figs. 5 and 6, price informativeness increases in N and K independent of the values of τ_ξ, but return volatility is U-shaped in N and K for high τ_ξ and downward-sloping in N and K for low τ_ξ. The intuitions are the same as before. These observations suggest that our results are robust to both interpretations of institutionalization and to price impact considerations.

A new result emerges in Fig. 6: the incentive component $\hat{b}^*$ of the equilibrium contract decreases with the fund size K. The intuition is as follows. When each fund becomes larger, a fund needs to transfer a higher fraction of its total trading profits to the manager. Now since there are more clients in each fund, each client can forgo a smaller fraction of her individual profits, but in aggregate, the manager can still collect a larger fraction of the total profits. This result helps to explain real-world observations that while the institutional sector grows due to the size of each institution, the fees for active management have trended down since 2000 (see the 2019 Investment Company Fact Book).

6. Conclusion

We develop a model of delegated portfolio management to analyze the effects of institutionalization on the asset management industry and asset prices. We find that institutionalization raises the incentive component of the equilibrium contract, which increases the effective risk aversion of institutional investors. Thus, institutionalization has two opposing effects on market outcomes. First, institutionalization directly brings more informed traders (and information) into the market, because in equilibrium portfolio managers are motivated to acquire and trade on private information. Second, by raising the incentive component of the contract, institutionalization makes each institutional investor more risk averse and trade less aggressively on information. When a market is highly institutionalized and very effective at aggregating information, the contracting effect dominates the informed capital effect in determining the behavior of market variables such as the cost of capital, return volatility, price volatility, and market liquidity. Otherwise, the informed capital effect is dominant in determining market behavior. Although we generate contrasting effects based on delegation and informed trading, similar competing forces might arise under alternative defining features of institutions, and so the tension highlighted by our analysis may be general. For instance, if we define institutions as large traders and allow them to acquire information and trade on their own (as in KNS, 2018), then on the one hand, an increase in fund size may be associated with an increase in capital allocated to information acquisition (which brings more informed trading), while on the other, each fund becomes more concerned about its price impact and so trades more cautiously (a risk aversion effect).

Appendix A. Proofs

A.1. Proof of Lemma 1

The CARA-normal setup implies that the demand functions of institutions and of retail investors are, respectively,

$$D_I(\tilde{v}, \tilde{p}) = \frac{E(\tilde{f}|\tilde{v}) - \tilde{p}}{b\gamma Var(\tilde{f}|\tilde{v}) + T},$$

$$D_R(\tilde{p}) = \frac{E(\tilde{f}|\tilde{p}) - \tilde{p}}{\gamma Var(\tilde{f}|\tilde{p}) + T}.$$

We can directly compute the conditional moments of institutional investors as follows:

$$E(\tilde{f}|\tilde{v}, \tilde{p}) = E(\tilde{f}|\tilde{v}) = \tilde{v} \text{ and } Var(\tilde{f}|\tilde{v}, \tilde{p}) = Var(\tilde{f}|\tilde{v}) = \frac{1}{\tau_\varepsilon}.$$

For retail investors, note that their information $\tilde{p}$ is equivalent to signal $\tilde{s}_p$, which is defined by (19). Applying Bayes' rule, we can compute

$$E(\tilde{v}|\tilde{p}) = \frac{\tau_p}{\tau_v + \tau_p}\tilde{s}_p \text{ and } Var(\tilde{f}|\tilde{p}) = \frac{1}{\tau_v + \tau_p} + \frac{1}{\tau_\varepsilon}.$$

Inserting these moment expressions into the respective demand functions and then plugging the demand expressions into the market-clearing condition, we obtain

$$\tilde{p} = \frac{\frac{\lambda}{\frac{b\gamma}{\tau_\varepsilon}+T}\tilde{v} + \frac{(1-\lambda)\tau_p}{\gamma+T(\tau_v+\tau_p)+\gamma\frac{\tau_v+\tau_p}{\tau_\varepsilon}}\left(\tilde{v} + \frac{a_\xi}{a_v}\tilde{\xi}\right) + \tilde{\xi} - Q}{\frac{\lambda}{\frac{b\gamma}{\tau_\varepsilon}+T} + \frac{(1-\lambda)(\tau_v+\tau_p)}{\gamma+T(\tau_v+\tau_p)+\gamma\frac{\tau_v+\tau_p}{\tau_\varepsilon}}}. \tag{A.1}$$

By comparing (A.1) with the conjectured price function (14), we have the expressions for the as in Lemma 1.

Note that in (21), τ_p and $\frac{a_\xi}{a_v}$ remain unknown. To identify these variables, we divide the expression for a_ξ by the expression for a_v to yield

$$\frac{a_\xi}{a_v} = \frac{\frac{(1-\lambda)\tau_p}{\gamma+T(\tau_v+\tau_p)+\gamma\frac{\tau_v+\tau_p}{\tau_\varepsilon}}\frac{a_\xi}{a_v} + 1}{\frac{\lambda}{\frac{b\gamma}{\tau_\varepsilon}+T} + \frac{(1-\lambda)\tau_p}{\gamma+T(\tau_v+\tau_p)+\gamma\frac{\tau_v+\tau_p}{\tau_\varepsilon}}},$$

which implies

$$\frac{a_\xi}{a_v} = \frac{1}{\lambda}\left(\frac{b\gamma}{\tau_\varepsilon} + T\right).$$

Inserting the above expression into (20), we have the expression for τ_p in (22).

A.2. *Proof of Lemma 2*

In the contract determination stage, we seek a symmetric equilibrium with the following two features: (1) all institutions design contracts to motivate their managers to acquire and trade on information; (2) the incentive component b^* of the equilibrium is empirically relevant, i.e., $b^* \in (0, 1)$.

Consider fund $i \in [0, \lambda]$. The fund chooses (a_i, b_i) to maximize its expected payoff (12) subject to the optimal portfolio investment rule, the IC constraint, and the PC. We can compute the PC as follows:

$$-\frac{1}{\sqrt{1 + \frac{b_i\gamma}{\frac{b_i\gamma}{\tau_\varepsilon}+T}\beta}}\exp\left(-a_i\gamma - \frac{1}{2}\frac{b_i\gamma}{\frac{b_i\gamma}{\tau_\varepsilon}+T}\frac{\alpha^2}{1 + \frac{b_i\gamma}{\frac{b_i\gamma}{\tau_\varepsilon}+T}\beta}\right) \geqslant -e^{-\gamma c-\gamma\bar{W}},$$

where

$$\alpha \equiv E(\tilde{v} - \tilde{p}) \text{ and } \beta \equiv Var(\tilde{v} - \tilde{p}).$$

Fund i always sets the fixed component a_i of compensation at a value such that the PC is binding. Hence, we have

$$a_i = c + \bar{W} - A_i, \tag{A.2}$$

where

$$A_i \equiv \frac{1}{2\gamma}\left[\ln\left(1+\frac{b_i\gamma}{\frac{b_i\gamma}{\tau_\varepsilon}+T}\beta\right)+\frac{b_i\gamma}{\frac{b_i\gamma}{\tau_\varepsilon}+T}\frac{\alpha^2}{1+\frac{b\gamma}{\frac{b_i\gamma}{\tau_\varepsilon}+T}\beta}\right]. \tag{A.3}$$

Inserting (A.2) and (A.3) into fund i's objective function, we can express fund i's payoff as a function of b_i and show that fund i's payoff is decreasing in b_i. Specifically, fund i's expected payoff (12) is

$$\begin{aligned}
E\left[\tilde{W}_i - S(\tilde{W}_i)\right] &= E\left\{(1-b_i)\left[D_i(\tilde{f}-\tilde{p})-\frac{1}{2}TD_i^2\right]\right\}-a_i\\
&=(1-b_i)\,E\left\{\frac{(\tilde{v}-\tilde{p})}{\frac{b_i\gamma}{\tau_\varepsilon}+T}(\tilde{f}-\tilde{p})-\frac{1}{2}T\left[\frac{(\tilde{v}-\tilde{p})}{\frac{b_i\gamma}{\tau_\varepsilon}+T}\right]^2\right\}-a_i\\
&=(1-b_i)\,E\left\{E\left[\frac{(\tilde{v}-\tilde{p})}{\frac{b_i\gamma}{\tau_\varepsilon}+T}(\tilde{f}-\tilde{p})-\frac{1}{2}T\left[\frac{(\tilde{v}-\tilde{p})}{\frac{b_i\gamma}{\tau_\varepsilon}+T}\right]^2\middle|\,\tilde{p}\right]\right\}-a_i\\
&=(1-b_i)\left[\frac{2\frac{b_i\gamma}{\tau_\varepsilon}+T}{2\left(\frac{b_i\gamma}{\tau_\varepsilon}+T\right)^2}\right]E\left[(\tilde{v}-\tilde{p})^2\right]-a_i\\
&=(1-b_i)\left[\frac{2\frac{b_i\gamma}{\tau_\varepsilon}+T}{2\left(\frac{b_i\gamma}{\tau_\varepsilon}+T\right)^2}\right]\left(\alpha^2+\beta\right)-a_i.
\end{aligned}$$

With (A.2) and (A.3), we can express a_i in terms of b_i, which is then inserted into the above expression, implying that fund i's problem becomes:

$$\max_{b_i} h(b_i),$$

subject to the IC constraint (9), and where the objective function $h(b_i)$ is defined as follows:

$$h(b_i)\equiv(1-b_i)\left[\frac{2\frac{b_i\gamma}{\tau_\varepsilon}+T}{2\left(\frac{b_i\gamma}{\tau_\varepsilon}+T\right)^2}\right]\left(\alpha^2+\beta\right)+\frac{1}{2\gamma}\left[\begin{array}{c}\ln\left(1+\frac{b_i\gamma}{\frac{b_i\gamma}{\tau_\varepsilon}+T}\beta\right)\\ +\frac{b_i\gamma}{\frac{b_i\gamma}{\tau_\varepsilon}+T}\frac{\alpha^2}{1+\frac{b_i\gamma}{\frac{b_i\gamma}{\tau_\varepsilon}+T}\beta}\end{array}\right].$$

Taking the derivative, we can compute

$$\begin{aligned}
h'(b_i) &= -\frac{\gamma b_i\tau_\varepsilon\left(\begin{array}{c}\gamma^2 b_i^2\left(\begin{array}{c}2\gamma\left(\alpha^2+\beta\right)(\beta\tau_\varepsilon+1)^2\\ +T\tau_\varepsilon\left(\beta\tau_\varepsilon\left[3\beta\left(\alpha^2+\beta\right)\tau_\varepsilon+6\alpha^2+5\beta\right]+2\left(\alpha^2+\beta\right)\right)\end{array}\right)+\\ T\gamma b_i\tau_\varepsilon\left(\begin{array}{c}4\gamma\left(\alpha^2+\beta\right)(\beta\tau_\epsilon+1)+\\ T\tau_\varepsilon\left(\beta\tau_\varepsilon\left(\beta\left(\alpha^2+\beta\right)\tau_\varepsilon+8\alpha^2+6\beta\right)+4\left(\alpha^2+\beta\right)\right)\end{array}\right)+\\ T^2\tau_\varepsilon^2\left(2\gamma\left(\alpha^2+\beta\right)+T\tau_\varepsilon\left(\beta\left(2\alpha^2+\beta\right)\tau_\varepsilon+2\left(\alpha^2+\beta\right)\right)\right)\end{array}\right)}{2\left(\gamma b_i+T\tau_\varepsilon\right)^3\left[\gamma b_i\left(\beta\tau_\varepsilon+1\right)+T\tau_\varepsilon\right]^2}\\
&< 0.
\end{aligned}$$

Note that the IC constraint imposes a lower bound on the choice of b_i. Specifically, we can follow Grossman and Stiglitz (1980) and compute the IC constraint as expression (23). The LHS of (23) is increasing in b_i, and thus, fund i will choose an equilibrium value of b_i^* such that the IC constraint holds with equality. We consider a symmetric equilibrium with $b_i^* = b^*$ for $i \in [0, \lambda]$. Thus, using the expression for τ_p in (22) and with expression (23) holding with equality, we know that b^* is determined by equation (24). We can further simplify (24) as a quadratic equation

$$G(b) \equiv B_1 b^2 + B_2 b + B_3 = 0, \tag{A.4}$$

where

$$B_1 = \gamma^2 \left[\left(e^{2\gamma c} - 1 \right) \tau_v - \tau_\varepsilon \right], \tag{A.5}$$

$$B_2 = \gamma T \tau_\varepsilon \left[2 \left(e^{2\gamma c} - 1 \right) \tau_v - \tau_\varepsilon \right], \tag{A.6}$$

$$B_3 = \left(e^{2\gamma c} - 1 \right) \tau_\varepsilon^2 \left(\tau_v T^2 + \lambda^2 \tau_\xi \right). \tag{A.7}$$

If $B_1 > 0$, then $B_2 > 0$. Since $B_3 > 0$, we have $G(b) > 0$ for all $b > 0$. As we consider an equilibrium with $b^* > 0$, we require $B_1 < 0$, which is equivalent to condition (25).

When $B_1 < 0$, the quadratic function $G(b)$ has two roots, one positive and one negative. The positive root of (A.4) delivers the expression for b^* in equation (27). Condition (26) in Lemma 2 is imposed to ensure that $b^* < 1$.

After we determine the value of b^*, the value of a^* is given by equation (A.2) with

$$A = \frac{1}{2\gamma} \left[\ln \left(1 + \frac{b^*\gamma}{\frac{b^*\gamma}{\tau_\varepsilon} + T} \beta \right) + \frac{b^*\gamma}{\frac{b^*\gamma}{\tau_\varepsilon} + T} \frac{\alpha^2}{1 + \frac{b^*\gamma}{\frac{b^*\gamma}{\tau_\varepsilon} + T} \beta} \right]. \tag{A.8}$$

A.3. Proof of Lemma 3

Proof of Part 1. At the date-1 trading stage, the demand function for fund i is

$$D_I(\tilde{v}, \tilde{p}) \equiv \arg\max_{D_i} E\left[\tilde{W}_i - S(\tilde{W}_i) \middle| \tilde{v} \right] = \frac{\tilde{v} - \tilde{p}}{T}.$$

For an uninformed investor, we compute the demand function as

$$D_R(\tilde{p}) = \frac{\tau_p \tilde{s}_p - \left(\tau_v + \tau_p^B \right) \tilde{p}}{\gamma + \gamma \frac{\tau_v + \tau_p^B}{\tau_\varepsilon} + T(\tau_v + \tau_p^B)}.$$

Inserting the above demand functions into the market-clearing condition (13), we compute the implied price function as follows:

$$\tilde{p} = \frac{\frac{\lambda}{T}\tilde{v} + \frac{(1-\lambda)\tau_p^B}{\gamma + \gamma\frac{\tau_v + \tau_p^B}{\tau_\varepsilon} + T(\tau_v + \tau_p^B)} \left(\tilde{v} + \frac{a_\xi}{a_v}\tilde{\xi} \right) + \tilde{\xi} - Q}{\frac{\lambda}{T} + \frac{(1-\lambda)\left(\tau_v + \tau_p^B\right)}{\gamma + \gamma\frac{\tau_v + \tau_p^B}{\tau_\varepsilon} + T(\tau_v + \tau_p^B)}}.$$

Comparing the above price function with the conjectured price function (14), we have the expressions for the as in Lemma 3.

Using the expression for a_v and the expression for a_ξ in (34), we can show

$$\frac{a_\xi}{a_v} = \frac{T}{\lambda}.$$

Thus,

$$\tau_p^B = \left(\frac{a_\xi}{a_v}\right)\tau_\xi = \frac{\lambda^2}{T^2}\tau_\xi. \tag{A.9}$$

Proof of Part 2. Managers' information-acquisition and trading behaviors are observable and contractible, meaning that there is no moral hazard. Therefore, fund i's problem is

$$\max_{(a_i,b_i)} E\left[\tilde{W}_i - S(\tilde{W}_i)\right]$$

subject to

$$\begin{aligned}
\tilde{W}_i &= D_i^*(\tilde{f} - \tilde{p}) - \frac{1}{2}T D_i^{*2},\\
S(\tilde{W}_i) &= a_i + b_i \tilde{W}_i,\\
D_i^* &= \arg\max_{D_i} E\left[\tilde{W}_i - S(\tilde{W}_i)\middle|\, \tilde{v}, \tilde{p}\right] = \frac{\tilde{v} - \tilde{p}}{T},
\end{aligned}$$

$$E\left[-e^{-\gamma\left(a_i + b_i\tilde{W}_i - c\right)}\right] \geqslant E\left(-e^{-\gamma\bar{W}}\right).$$

Similar to the setting with moral hazard (see the proof of Lemma 2), each fund will choose a_i such that the PC holds with equality. That is,

$$a_i = c + \bar{W} - A_i, \tag{A.10}$$

where

$$A_i = \frac{1}{2\gamma}\left[\ln\left[1 + \frac{\gamma b_i}{T}\left(1 - \frac{\gamma b_i}{T\tau_\varepsilon}\right)\beta\right] + \frac{\gamma b_i}{T}\left(1 - \frac{\gamma b_i}{T\tau_\varepsilon}\right)\frac{\alpha^2}{1 + \frac{\gamma b_i}{T}\left(1 - \frac{\gamma b_i}{T\tau_\varepsilon}\right)\beta}\right], \tag{A.11}$$

where $\alpha = E(\tilde{v} - \tilde{p})$ and $\beta = Var(\tilde{v} - \tilde{p})$. Inserting the above two equations into fund i's objective function $E\left[\tilde{W}_i - S(\tilde{W}_i)\right]$, we can express $E\left[\tilde{W}_i - S(\tilde{W}_i)\right]$ as a function of b_i only, denoted by $H(b_i)$. With some algebra, we can show that $H'(b_i) < 0$. Thus, all funds optimally set $b^B = 0$, which is the empirically relevant lower bound of b.

A.4. Proof of Proposition 1

Proof of Part 1. From the expression for τ_p^B in (35), we have $\frac{d\tau_p^B}{d\lambda} = \frac{2\lambda}{T^2}\tau_\xi > 0$. Since PI^B is positively related to τ_p^B, we have $\frac{dPI^B}{d\lambda} > 0$.

In equilibrium, we have $CC^B = |a_0|$. From the expression for a_0 in (34), direct computation shows that $\frac{dCC^B}{d\lambda} < 0$.

The return variance is $Var(\tilde{v}-\tilde{p})=\frac{(1-a_v)^2}{\tau_v}+\frac{a_v^2}{\tau_p^B}$. Using the expressions for a_v and τ_p^B, we can compute

$$\frac{dVar(\tilde{v}-\tilde{p})}{d\lambda} = -\frac{2T^2\left(\begin{array}{c}\gamma^3\left[\lambda^2\tau_\xi+T^2(\tau_v+\tau_\varepsilon)\right]^3+\lambda T^3\tau_\xi\tau_\varepsilon^3\left(\tau_\xi+T^2\tau_v\right)\left(\lambda^2\tau_\xi+T^2\tau_v\right)\\ +T\gamma^2\tau_\varepsilon\left[\lambda^2\tau_\xi+T^2(\tau_v+\tau_\varepsilon)\right]\left(\begin{array}{c}3\lambda^3\tau_\xi^2+2T^4\tau_v(\tau_v+\tau_\varepsilon)\\ +\lambda T^2\tau_\xi\left[(4\lambda+1)\tau_v+3\tau_\varepsilon\right]\end{array}\right)\\ +T^2\gamma\tau_\varepsilon^2\left(\begin{array}{c}3\lambda^4\tau_\xi^3+T^6\tau_v^2(\tau_v+\tau_\varepsilon)+\\ \lambda T^4\tau_\xi\tau_v\left[(3\lambda+2)\tau_v+4\tau_\epsilon\right]+\\ \lambda^2T^2\tau_\xi^2\left\{\left[2\lambda(\lambda+1)+3\right]\tau_v+3\tau_\varepsilon\right\}\end{array}\right)\end{array}\right)}{\tau_\xi\left\{T^2\left[\lambda\gamma(\tau_v+\tau_\varepsilon)+T\tau_v\tau_\varepsilon\right]+\lambda^2\tau_\xi(\lambda\gamma+T\tau_\varepsilon)\right\}^3}<0.$$

Proof of Part 2. Market liquidity is $Liquidity^B=a_\xi^{-1}$. Using the expression for a_ξ in (34), we can compute

$$\frac{dLiquidity^B}{d\lambda}=\frac{D_1D_2-D_3}{\{[\gamma+T(\tau_v+\tau_p^B)+\gamma\frac{\tau_v+\tau_p^B}{\tau_\varepsilon}]+\frac{\lambda(1-\lambda)\tau_\xi}{T}\}^2T} \tag{A.12}$$

where

$$D_1\equiv\gamma+T\tau_p^B+\frac{\gamma\left(\tau_v+\tau_p^B\right)}{\tau_\varepsilon}+\frac{\lambda(1-\lambda)\tau_\xi}{T}, \tag{A.13}$$

$$D_2\equiv\gamma+T(\tau_v+\tau_p^B)+\frac{\gamma\left(\tau_v+\tau_p^B\right)}{\tau_\varepsilon}+\frac{\lambda(1-\lambda)\tau_\xi}{T}, \tag{A.14}$$

$$D_3\equiv(1-\lambda)\tau_v\tau_\xi+\frac{\gamma\tau_v}{\tau_\varepsilon}\frac{2\lambda(1-\lambda)\tau_\xi}{T}. \tag{A.15}$$

Proof of Part (2a). Given $\tau_p>0$, we have

$$D_1D_2>\left(\gamma+\frac{\gamma\tau_v}{\tau_\varepsilon}\right)\left(\gamma+T\tau_v+\frac{\gamma\tau_v}{\tau_\varepsilon}\right)+2\frac{\gamma\tau_v}{\tau_\varepsilon}\frac{\lambda(1-\lambda)\tau_\xi}{T},$$

and hence

$$D_1D_2-D_3>\left(\gamma+\frac{\gamma\tau_v}{\tau_\varepsilon}\right)\left(\gamma+T\tau_v+\frac{\gamma\tau_v}{\tau_\varepsilon}\right)-(1-\lambda)\tau_v\tau_\xi. \tag{A.16}$$

Thus, if

$$\left(\gamma+\frac{\gamma\tau_v}{\tau_\varepsilon}\right)\left(\gamma+T\tau_v+\frac{\gamma\tau_v}{\tau_\varepsilon}\right)>\tau_v\tau_\xi,$$

then the RHS of (A.16) is positive, and hence $D_1D_2-D_3>0$, which implies that $\frac{dLiquidity^B}{d\lambda}>0$.

Proof of Part (2b). Now suppose that $\left(\gamma+\frac{\gamma\tau_v}{\tau_\varepsilon}\right)\left(\gamma+T\tau_v+\frac{\gamma\tau_v}{\tau_\varepsilon}\right)<\tau_v\tau_\xi$.

At $\lambda = 1$, we have $D_1 D_2 - D_3|_{\lambda=1} > 0$, and thus $\left.\frac{dLiquidity^B}{d\lambda}\right|_{\lambda=1} > 0$.

At $\lambda = 0$, we have $D_1 D_2 - D_3|_{\lambda=0} = \left(\gamma + \frac{\gamma\tau_v}{\tau_\varepsilon}\right)\left(\gamma + T\tau_v + \frac{\gamma\tau_v}{\tau_\varepsilon}\right) - \tau_v\tau_\xi < 0$. Thus, $\left.\frac{dLiquidity^B}{d\lambda}\right|_{\lambda=0} < 0$.

Proof of Part 3. The price variance is $Var(\tilde{p}) = \frac{a_v^2}{\tau_v} + \frac{a_v^2}{\tau_p^B}$. Hence,

$$\frac{dVar(\tilde{p})}{d\lambda} = 2a_v \frac{\partial a_v}{\partial\lambda}\frac{1}{\tau_v} + 2a_v \frac{1}{\tau_p^B}\frac{\partial a_v}{\partial\lambda} - a_v^2 \frac{1}{\tau_p^{B2}}\frac{\partial \tau_p^B}{\partial\lambda}. \tag{A.17}$$

Proof of Part (3a). When $\lambda = 1$, we have $a_v|_{\lambda=1} = 1$, $\left.\tau_p^B\right|_{\lambda=1} = \frac{\tau_\xi}{T^2}$ and $\left.\frac{\partial a_v}{\partial\lambda}\right|_{\lambda=1}$ is finite. Inserting these expressions into (A.17) yields:

$$\begin{aligned}\left.\frac{dVar(\tilde{p})}{d\lambda}\right|_{\lambda=1} &= 2\frac{T}{\gamma + \gamma\frac{\tau_v + \left.\tau_p^B\right|_{\lambda=1}}{\tau_\varepsilon} + \left(\tau_v + \left.\tau_p^B\right|_{\lambda=1}\right)T} \\ &\quad - \frac{2T^2}{\tau_\xi}\frac{\gamma + \gamma\frac{\tau_v + \left.\tau_p^B\right|_{\lambda=1}}{\tau_\varepsilon} + \left.\tau_p^B\right|_{\lambda=1} T}{\gamma + \gamma\frac{\tau_v + \left.\tau_p^B\right|_{\lambda=1}}{\tau_\varepsilon} + \left(\tau_v + \left.\tau_p^B\right|_{\lambda=1}\right)T} \\ &< 0.\end{aligned}$$

Proof of Part (3b). When $\lambda = 0$, we can compute $a_v|_{\lambda=0} = 0$, $\left.\tau_p^B\right|_{\lambda=0} = 0$ and $\left.\frac{\partial a_v}{\partial\lambda}\right|_{\lambda=0} = 1 + \frac{1}{\tau_v T}\left(\gamma + \gamma\frac{\tau_v}{\tau_\varepsilon}\right)$. Thus,

$$\begin{aligned}\left.\frac{dVar(\tilde{p})}{d\lambda}\right|_{\lambda=0} &= 2a_v \frac{1}{\tau_v}\frac{\partial a_v}{\partial\lambda} - 2\frac{1}{Liquidity^3}\frac{1}{\tau_\xi}\left.\frac{dLiquidity}{d\lambda}\right|_{\lambda=0} \\ &= -2\frac{1}{Liquidity^3}\frac{1}{\tau_\xi}\left.\frac{dLiquidity}{d\lambda}\right|_{\lambda=0}.\end{aligned}$$

Thus, the sign of $\left.\frac{dVar(\tilde{p})}{d\lambda}\right|_{\lambda=0}$ is the opposite of the sign of $\left.\frac{dLiquidity}{d\lambda}\right|_{\lambda=0}$.

A.5. Proof of Proposition 2

The equilibrium value b^* is determined by the IC constraint, which is given by equation (24). Let us define

$$g(b, \tau_p) \equiv \left(\gamma + \frac{T\tau_\varepsilon}{b}\right)(\tau_v + \tau_p), \tag{A.18}$$

and equation (24) becomes

$$\frac{\gamma\tau_\varepsilon}{g(b,\tau_p)} = e^{2\gamma c} - 1 \Rightarrow g(b,\tau_p) = \frac{\gamma\tau_\varepsilon}{e^{2\gamma c} - 1}, \tag{A.19}$$

which implies that $g(b, \tau_p)$ is a constant. Applying the implicit function theorem to $g(b, \tau_p)$, we can show that $\frac{db^*}{d\lambda} > 0$.

A.6. *Proof of Proposition 3*

Note that by equation (29), price informativeness PI^* is positively related to τ_p^*. From the expression for τ_p in (22), we have

$$\frac{\partial \tau_p^*}{\partial \lambda} = \frac{2\lambda \tau_\varepsilon^2 \tau_\xi}{(\gamma b + T\tau_\varepsilon)^2} > 0,$$
$$\frac{\partial \tau_p^*}{\partial b}\frac{db^*}{d\lambda} = -\frac{2(\lambda\tau_\varepsilon)^2 \tau_\xi \gamma}{(\gamma b + T\tau_\varepsilon)^3}\frac{db^*}{d\lambda} < 0,$$

because $\frac{db^*}{d\lambda} > 0$.

We prove the dominance of the contracting effect by contradiction. In equilibrium, $g(b^*, \tau_p^*)$ is maintained at a constant. Specifically, by equations (A.18) and (A.19), we have

$$\left(\gamma + \frac{T\tau_\varepsilon}{b^*}\right)\left(\tau_v + \tau_p^*\right) = \frac{\gamma\tau_\varepsilon}{e^{2\gamma c} - 1}. \tag{A.20}$$

Suppose that τ_p is non-increasing with λ. By Proposition 2, we know that b^* increases with λ. Thus, if $\frac{d\tau_p^*}{d\lambda} \leqslant 0$, then the LHS of (A.20) decreases with λ. A contradiction. Thus, we must have $\frac{d\tau_p^*}{d\lambda} > 0$.

A.7. *Proof of Proposition 4*

The return variance is

$$Var(\tilde{f} - \tilde{p}) = (1 - a_v)^2 \frac{1}{\tau_v} + a_\xi^2 \frac{1}{\tau_\xi} + \frac{1}{\tau_\varepsilon}.$$

Thus, taking derivatives yields:

$$\frac{dVar(\tilde{f} - \tilde{p})}{d\lambda} = \underbrace{-2(1 - a_v)\frac{1}{\tau_v}\frac{\partial a_v}{\partial \lambda} + 2a_\xi \frac{1}{\tau_\xi}\frac{\partial a_\xi}{\partial \lambda}}_{\text{informed capital effect}} + \underbrace{\left[-2(1 - a_v)\frac{1}{\tau_v}\frac{\partial a_v}{\partial b}\right]\frac{\partial b}{\partial \lambda} + 2a_\xi \frac{1}{\tau_\xi}\frac{\partial a_\xi}{\partial b}\frac{\partial b}{\partial \lambda}}_{\text{contracting effect}}. \tag{A.21}$$

Proof of Part 1. Suppose that $\lambda = 0$. We obtain the following expression:

$$-2(1 - a_v)\frac{1}{\tau_v}\frac{\partial a_v}{\partial b}\bigg|_{\lambda=0} = 0; \quad \frac{\partial a_\xi}{\partial b} = 0.$$

Thus, the contracting effect vanishes, and only the informed capital effect prevails in (A.21). The direct computation of $\frac{dVar(\tilde{f}-\tilde{p})}{d\lambda}\Big|_{\lambda=0}$ shows that

$$\left.\frac{dVar(\tilde{f}-\tilde{p})}{d\lambda}\right|_{\lambda=0} = \frac{2\left[\gamma_A(\tau_v+\tau_\epsilon)+T\tau_v\tau_\epsilon\right]^2\begin{pmatrix} T\gamma_A\tau_v\tau_\epsilon\left[2\tau_v\left(e^{2c\gamma_A}-1\right)-\tau_\epsilon\right]+\tau_v\sqrt{T^2\gamma_A^2\tau_\epsilon^4} \\ +2\gamma_A^2(\tau_v+\tau_\epsilon)\left[\tau_v\left(e^{2c\gamma_A}-1\right)-\tau_\epsilon\right]\end{pmatrix}}{\tau_\xi\tau_v^3\tau_\epsilon^2\left(\sqrt{T^2\gamma_A^2\tau_\epsilon^4}+T\gamma_A\tau_\epsilon^2\right)}. \tag{A.22}$$

Comparing (A.22) and (A.33) in the proof the Part 1 of Proposition 5, we find that $\left.\frac{dVar(\tilde{f}-\tilde{p})}{d\lambda}\right|_{\lambda=0}$ has the same sign as $\left.\frac{dCC}{d\lambda}\right|_{\lambda=0}$ (shown in (A.33)). Following Part 1 of Proposition 5, we can conclude that the informed capital effect is negative, as is the total effect.

Proof of Part 2. Suppose that $\lambda = 1$. We compute that

$$-2(1-a_v)\frac{1}{\tau_v}\left.\frac{\partial a_v}{\partial\lambda}\right|_{\lambda=1}=0 \text{ and } -2(1-a_v)\frac{1}{\tau_v}\left.\frac{\partial a_v}{\partial b}\right|_{\lambda=1}=0.$$

As a result,

$$\text{Informed capital effect} = \frac{2a_\xi\left(\frac{b\gamma}{\tau_\varepsilon}+T\right)^2}{\tau_\xi}\left[\frac{\tau_v}{\gamma+\frac{\gamma(\tau_p+\tau_v)}{\tau_\varepsilon}+T\left(\tau_p+\tau_v\right)}-\frac{1}{\frac{b\gamma}{\tau_\varepsilon}+T}\right]<0, \tag{A.23}$$

and

$$\text{Contracting effect} = \frac{2a_\xi^2\left(\frac{b\gamma}{\tau_\varepsilon}+T\right)}{\tau_\xi}\left[\frac{1}{\left(\frac{b\gamma}{\tau_\varepsilon}+T\right)^2}\frac{\gamma}{\tau_\varepsilon}\left.\frac{\partial b}{\partial\lambda}\right|_{\lambda=1}\right]>0. \tag{A.24}$$

Thus,

$$\left.\frac{dVar(\tilde{f}-\tilde{p})}{d\lambda}\right|_{\lambda=1} = \frac{2a_\xi\left(\frac{b\gamma}{\tau_\varepsilon}+T\right)^2}{\tau_\xi}\left[\frac{\tau_v}{\gamma+\frac{\gamma(\tau_p+\tau_v)}{\tau_\varepsilon}+T\left(\tau_p+\tau_v\right)}-\frac{1}{\frac{b\gamma}{\tau_\varepsilon}+T}+\frac{\frac{\gamma}{\tau_\varepsilon}\left.\frac{\partial b}{\partial\lambda}\right|_{\lambda=1}}{\left(\frac{b\gamma}{\tau_\varepsilon}+T\right)^2}\right]. \tag{A.25}$$

Sufficient Condition for the Contracting Effect to Dominate:
By (A.25), a sufficient condition for the contracting effect to dominate is

$$\frac{\tau_v}{\gamma+\frac{\gamma(\tau_p+\tau_v)}{\tau_\varepsilon}+T\left(\tau_p+\tau_v\right)}+\frac{\frac{\gamma}{\tau_\varepsilon}\left.\frac{\partial b}{\partial\lambda}\right|_{\lambda=1}}{\left(\frac{b\gamma}{\tau_\varepsilon}+T\right)^2}-\frac{1}{\frac{b\gamma}{\tau_\varepsilon}+T}>0,$$

which is equivalent to

$$\frac{\gamma}{\tau_\varepsilon}\frac{\partial b}{\partial \lambda}\bigg|_{\lambda=1} > \left(\frac{b\gamma}{\tau_\varepsilon}+T\right)\frac{\gamma+T\tau_p+\frac{\gamma\tau_p}{\tau_\varepsilon}+\frac{\gamma\tau_v}{\tau_\varepsilon}(1-b)}{\gamma+\frac{\gamma(\tau_p+\tau_v)}{\tau_\varepsilon}+T(\tau_p+\tau_v)}. \tag{A.26}$$

Given the expression for b, we compute

$$\frac{\partial b}{\partial \lambda}\bigg|_{\lambda=1} = \frac{2\lambda\tau_\varepsilon\tau_\xi\left(e^{2\gamma c}-1\right)}{\gamma\sqrt{4\lambda^2\tau_\xi\tau_\varepsilon\left(e^{2\gamma c}-1\right)-4\lambda^2\tau_\xi\tau_v\left(e^{2\gamma c}-1\right)^2+T^2\tau_\varepsilon^2}}, \tag{A.27}$$

which is inserted into condition (A.26), yielding

$$\frac{2\lambda\tau_\xi\left(e^{2\gamma c}-1\right)}{\sqrt{4\lambda^2\tau_\xi\tau_\varepsilon\left(e^{2\gamma c}-1\right)-4\lambda^2\tau_\xi\tau_v\left(e^{2\gamma c}-1\right)^2+T^2\tau_\varepsilon^2}} > \left(\frac{b\gamma}{\tau_\varepsilon}+T\right)\frac{\gamma+T\tau_p+\frac{\gamma\tau_p}{\tau_\varepsilon}+\frac{\gamma\tau_v}{\tau_\varepsilon}(1-b)}{\gamma+\frac{\gamma(\tau_p+\tau_v)}{\tau_\varepsilon}+T(\tau_p+\tau_v)}. \tag{A.28}$$

Note that the RHS of (A.28) is smaller than $\frac{\gamma}{\tau_\varepsilon}+T$, because $b<1$ and $\gamma+T\tau_p+\frac{\gamma\tau_p}{\tau_\varepsilon}+\frac{\gamma\tau_v}{\tau_\varepsilon}(1-b)<\gamma+\frac{\gamma(\tau_p+\tau_v)}{\tau_\varepsilon}+T(\tau_p+\tau_v)$. Thus, a stronger sufficient condition is

$$\frac{2\lambda\tau_\xi\left(e^{2\gamma c}-1\right)}{\sqrt{4\lambda^2\tau_\xi\tau_\varepsilon\left(e^{2\gamma c}-1\right)-4\lambda^2\tau_\xi\tau_v\left(e^{2\gamma c}-1\right)^2+T^2\tau_\varepsilon^2}} > \frac{\gamma}{\tau_\varepsilon}+T. \tag{A.29}$$

The LHS of (A.29) increases with τ_ξ and approaches ∞ as τ_ξ approaches ∞. Hence, for sufficiently high values of τ_ξ, the contracting effect dominates.

Sufficient Condition for the Informed Capital Effect to Dominate:

By (A.25), a sufficient condition for the informed capital effect to dominate is

$$\frac{\tau_v}{\gamma+\frac{\gamma(\tau_p+\tau_v)}{\tau_\varepsilon}+T(\tau_p+\tau_v)}+\frac{\frac{\gamma}{\tau_\varepsilon}\frac{\partial b}{\partial\lambda}\big|_{\lambda=1}}{\left(\frac{b\gamma}{\tau_\varepsilon}+T\right)^2}-\frac{1}{\frac{b\gamma}{\tau_\varepsilon}+T}<0,$$

which is equivalent to

$$\frac{\gamma}{\tau_\varepsilon}\frac{\partial b}{\partial \lambda}\bigg|_{\lambda=1} < \left(\frac{b\gamma}{\tau_\varepsilon}+T\right)\frac{\gamma+T\tau_p+\frac{\gamma\tau_p}{\tau_\varepsilon}+\frac{\gamma\tau_v}{\tau_\varepsilon}(1-b)}{\gamma+\frac{\gamma(\tau_p+\tau_v)}{\tau_\varepsilon}+T(\tau_p+\tau_v)}. \tag{A.30}$$

Using (A.27), condition (A.30) becomes

$$\frac{2\lambda\tau_\xi\left(e^{2\gamma c}-1\right)}{\sqrt{4\lambda^2\tau_\xi\tau_\varepsilon\left(e^{2\gamma c}-1\right)-4\lambda^2\tau_\xi\tau_v\left(e^{2\gamma c}-1\right)^2+T^2\tau_\varepsilon^2}} < \left(\frac{b\gamma}{\tau_\varepsilon}+T\right)\frac{\gamma+T\tau_p+\frac{\gamma\tau_p}{\tau_\varepsilon}+\frac{\gamma\tau_v}{\tau_\varepsilon}(1-b)}{\gamma+\frac{\gamma(\tau_p+\tau_v)}{\tau_\varepsilon}+T(\tau_p+\tau_v)}.$$

Because the RHS of the above condition is larger than $\frac{\gamma T}{\gamma+\frac{\gamma(\tau_p+\tau_v)}{\tau_\varepsilon}+T(\tau_p+\tau_v)}$, which in turn is larger than $\frac{\gamma T}{\gamma+\frac{\gamma\left(\frac{\tau_\xi}{T^2}+\tau_v\right)}{\tau_\varepsilon}+T\left(\frac{\tau_\xi}{T^2}+\tau_v\right)}$ (by $\tau_p<\frac{\tau_\xi}{T^2}$), a stronger sufficient condition is

$$\frac{2\tau_\xi\left(e^{2\gamma c}-1\right)}{\sqrt{4\lambda^2\tau_\xi\tau_\varepsilon\left(e^{2\gamma c}-1\right)-4\lambda^2\tau_\xi\tau_v\left(e^{2\gamma c}-1\right)^2+T^2\tau_\varepsilon^2}}<\frac{\gamma T}{\gamma+\frac{\gamma\left(\frac{\tau_\xi}{T^2}+\tau_v\right)}{\tau_\varepsilon}+T\left(\frac{\tau_\xi}{T^2}+\tau_v\right)}.$$

When $\tau_\xi=0$, the LHS of the above condition is 0, while the RHS is positive. Thus, for sufficiently low τ_ξ, the above condition is satisfied, meaning that the informed capital effect dominates.

A.8. *Proof of Proposition 5*

We can compute the cost of capital

$$CC=\frac{Q}{F(\lambda,\tau_p,b)},$$

where

$$F(\lambda,\tau_p,b)\equiv\frac{\lambda}{\frac{b\gamma}{\tau_\varepsilon}+T}+\frac{(1-\lambda)\left(\tau_v+\tau_p\right)}{\gamma+T(\tau_v+\tau_p)+\frac{\gamma(\tau_v+\tau_p)}{\tau_\varepsilon}}.$$

Taking derivatives, we have

$$\frac{dCC}{d\lambda}=-\frac{Q}{F^2}\left[\frac{\partial F}{\partial\lambda}+\frac{\partial F}{\partial\tau_p}\frac{\partial\tau_p}{\partial\lambda}+\frac{\partial F}{\partial b}\frac{\partial b}{\partial\lambda}+\frac{\partial F}{\partial\tau_p}\frac{\partial\tau_p}{\partial b}\frac{\partial\tau_p}{\partial b}\right] \tag{A.31}$$

$$=\underbrace{\underbrace{\frac{\partial CC}{\partial\lambda}}_{\leqslant 0}+\underbrace{\frac{\partial CC}{\partial\tau_p}}_{\leqslant 0}\underbrace{\frac{\partial\tau_p}{\partial\lambda}}_{\geqslant 0}}_{\text{informed capital effect}\leqslant 0}+\underbrace{\underbrace{\frac{\partial CC}{\partial b}}_{\geqslant}\underbrace{\frac{\partial b}{\partial\lambda}}_{\geqslant 0}+\underbrace{\underbrace{\frac{\partial CC}{\partial\tau_p}}_{\leqslant 0}\underbrace{\frac{\partial\tau_p}{\partial b}}\underbrace{\frac{\partial b}{\partial\lambda}}_{\geqslant 0}}_{\leqslant 0}}_{\text{contracting effect}\geqslant 0}. \tag{A.32}$$

This proves the signs of the informed capital effect and the contracting effect in both parts. Next, we prove which effect dominates.

Proof of Part 1. Suppose that $\lambda=0$. We find that

$$\left.\frac{\partial CC}{\partial\tau_p}\frac{\partial\tau_p}{\partial\lambda}\right|_{\lambda=0}=0,$$

$$\left.\frac{\partial CC}{\partial b}\frac{\partial b}{\partial\lambda}\right|_{\lambda=0}=0,\ \left.\frac{\partial CC}{\partial\tau_p}\frac{\partial\tau_p}{\partial b}\frac{\partial b}{\partial\lambda}\right|_{\lambda=0}=-\frac{\lambda^2\tau_\xi}{\left(\frac{b\gamma 1}{\tau_\varepsilon}+T\right)^3}\frac{\gamma}{\tau_\varepsilon}\left.\frac{\partial CC}{\partial\tau_p}\frac{\partial b}{\partial\lambda}\right|_{\lambda=0}=0.$$

Hence, only the first component of (A.32) prevails at $\lambda=0$. Direct computation reveals that

$$\left.\frac{dCC}{d\lambda}\right|_{\lambda=0}=\frac{Q\left[\gamma_A\left(\tau_v+\tau_\epsilon\right)+T\tau_v\tau_\epsilon\right]\begin{pmatrix}T\gamma_A\tau_v\tau_\epsilon\left[2\tau_v\left(e^{2c\gamma_A}-1\right)-\tau_\epsilon\right]+\tau_v\sqrt{T^2\gamma_A^2\tau_\epsilon^4}\\+2\gamma_A^2\left(\tau_v+\tau_\epsilon\right)\left[\tau_v\left(e^{2c\gamma_A}-1\right)-\tau_\epsilon\right]\end{pmatrix}}{\tau_v^2\tau_\epsilon\left(\sqrt{T^2\gamma_A^2\tau_\epsilon^4}+T\gamma_A\tau_\epsilon^2\right)}. \tag{A.33}$$

Proof of Part 2. Suppose that $\lambda = 1$. We find

$$\frac{\partial F}{\partial \tau_p}\frac{\partial \tau_p}{\partial \lambda}\bigg|_{\lambda=1} = 0, \quad \frac{\partial F}{\partial \tau_p}\frac{\partial \tau_p}{\partial b}\frac{\partial \tau_p}{\partial b}\bigg|_{\lambda=1} = 0.$$

By (A.31), we know that only $\frac{\partial F}{\partial \lambda}$ and $\frac{\partial F}{\partial b}\frac{\partial b}{\partial \lambda}$ prevail in determining the sign of $\frac{dCC}{d\lambda}\big|_{\lambda=1}$.

We further compute

$$F|_{\lambda=1} = \frac{1}{\frac{b\gamma}{\tau_\varepsilon} + T},$$

$$\frac{\partial F}{\partial \lambda}\bigg|_{\lambda=1} = \frac{1}{\frac{b\gamma}{\tau_\varepsilon} + T} - \frac{\tau_v + \tau_p}{\gamma + T(\tau_v + \tau_p) + \frac{\gamma(\tau_v+\tau_p)}{\tau_\varepsilon}},$$

$$\frac{\partial F}{\partial b}\frac{\partial b}{\partial \lambda}\bigg|_{\lambda=1} = -\frac{1}{\left(\frac{b\gamma}{\tau_\varepsilon} + T\right)^2}\frac{\gamma}{\tau_\varepsilon}\frac{\partial b}{\partial \lambda}\bigg|_{\lambda=1}.$$

Hence,

$$\frac{dCC}{d\lambda}\bigg|_{\lambda=1} = \left(\frac{b\gamma}{\tau_\varepsilon} + T\right)^2\left[\frac{\tau_v + \tau_p}{\gamma + \frac{\gamma(\tau_p+\tau_v)}{\tau_\varepsilon} + T\left(\tau_p + \tau_v\right)} + \frac{\frac{\gamma}{\tau_\varepsilon}\frac{\partial b}{\partial \lambda}\big|_{\lambda=1}}{\left(\frac{b\gamma}{\tau_\varepsilon} + T\right)^2} - \frac{1}{\frac{b\gamma}{\tau_\varepsilon} + T}\right]. \tag{A.34}$$

The construction of the conditions under which the contracting effect or the informed capital effect dominates is very similar to that of Proposition 4. This can be seen from a comparison of equations (A.25) and (A.34). Thus, the proof is omitted.

A.9. *Proof of Proposition 6*

The price variance is

$$Var(\tilde{p}) = \frac{a_v^2}{\tau_v} + a_v^2\frac{\left(\frac{b\gamma}{\tau_\varepsilon} + T\right)^2}{\lambda^2\tau_\xi}.$$

Taking derivatives, we have

$$\frac{dVar(\tilde{p})}{d\lambda} = \underbrace{\frac{2a_v}{\tau_v}\frac{\partial a_v}{\partial \lambda} + 2a_v\frac{\left(\frac{b\gamma}{\tau_\varepsilon} + T\right)^2}{\lambda^2\tau_\xi}\frac{\partial a_v}{\partial \lambda} - a_v^2\frac{2\left(\frac{b\gamma}{\tau_\varepsilon} + T\right)^2}{\lambda^3\tau_\xi}}_{\text{informed capital effect}}$$

$$+\underbrace{\left[\frac{2a_v}{\tau_v}\frac{\partial a_v}{\partial b} + 2a_v\frac{\left(\frac{b\gamma}{\tau_\varepsilon} + T\right)^2}{\lambda^2\tau_\xi}\frac{\partial a_v}{\partial b} + a_v^2\frac{2\left(\frac{b\gamma}{\tau_\varepsilon} + T\right)}{\lambda^2\tau_\xi}\frac{\gamma}{\tau_\varepsilon}\right]\frac{\partial b}{\partial \lambda}}_{\text{contracting effect}}. \tag{A.35}$$

Proof of Part 1. Suppose that $\lambda = 0$. It is easy to show that the first components of both the informed capital effect ($\frac{2a_v}{\tau_v}\frac{\partial a_v}{\partial \lambda}$) and contracting effect ($\frac{2a_v}{\tau_v}\frac{\partial a_v}{\partial b}\frac{\partial b}{\partial \lambda}$) vanish because $a_v|_{\lambda=0} = 0$ and $\left.\frac{\partial a_v}{\partial \lambda}\right|_{\lambda=0}$ is finite. We can compute

$$\left.\frac{dVar(\tilde{p})}{d\lambda}\right|_{\lambda=0} = -2\frac{1}{Liquidity^3}\frac{1}{\tau_\xi}\frac{dLiquidity}{d\lambda}.$$

Hence, the result directly inherits from Part 1 of Proposition 7. As shown in Part 1 of Proposition 7, the contracting effect vanishes and only the informed capital effect prevails.

Proof of Part 2. Suppose that $\lambda = 1$. We can compute

$$a_v|_{\lambda=1} = 1,\ \tau_p\big|_{\lambda=1} = \frac{\tau_\xi}{\left(\frac{b\gamma}{\tau_\varepsilon}+T\right)^2},\ a_\xi\big|_{\lambda=1} = a_v|_{\lambda=1}\frac{\frac{b\gamma}{\tau_\varepsilon}+T}{\lambda},$$

$$\left.\frac{\partial a_v}{\partial \lambda}\right|_{\lambda=1} = \frac{\tau_v(\frac{b\gamma}{\tau_\varepsilon}+T)}{\gamma + T(\tau_v+\tau_p\big|_{\lambda=1}) + \frac{\gamma(\tau_v+\tau_p)}{\tau_\epsilon}},\ \left.\frac{\partial a_v}{\partial b}\right|_{\lambda=1} = 0.$$

Inserting these expressions into (A.35), we have

$$\begin{aligned}
&\text{Informed capital effect}\\
&= \frac{2a_v}{\tau_v}\left.\frac{\partial a_v}{\partial \lambda}\right|_{\lambda=1} + 2\frac{\left(\frac{b\gamma}{\tau_\varepsilon}+T\right)^2}{\lambda^2\tau_\xi}a_v\left.\frac{\partial a_v}{\partial \lambda}\right|_{\lambda=1} - \frac{2\left(\frac{b\gamma}{\tau_\varepsilon}+T\right)^2}{\lambda^3\tau_\xi}a_v^2\Big|_{\lambda=1}\\
&= \frac{2\left(\frac{b\gamma}{\tau_\varepsilon}+T\right)}{\gamma+T(\tau_v+\tau_p)+\frac{\gamma(\tau_v+\tau_p)}{\tau_\varepsilon}} - \frac{2\left(\frac{b\gamma}{\tau_\varepsilon}+T\right)^2}{\tau_\xi}\frac{\gamma+T\tau_p+\gamma\frac{(1-b)\tau_v+\tau_p}{\tau_\varepsilon}}{\gamma+T(\tau_v+\tau_p)+\gamma\frac{\tau_v+\tau_p}{\tau_\epsilon}}\\
&< 0,\\
&\text{Contracting effect}\\
&= \frac{2\left(\frac{b\gamma}{\tau_\varepsilon}+T\right)}{\tau_\xi}\frac{\gamma}{\tau_\varepsilon}\left.\frac{\partial b}{\partial \lambda}\right|_{\lambda=1}\\
&= \frac{2\left(\frac{b\gamma}{\tau_\varepsilon}+T\right)}{\tau_\xi}\frac{2\tau_\xi\left(e^{2\gamma c}-1\right)}{\sqrt{4\tau_\xi\tau_\varepsilon\left(e^{2\gamma c}-1\right)-4\tau_\xi\tau_v\left(e^{2\gamma c}-1\right)^2+T^2\tau_\varepsilon^2}}\ \text{(by (A.27))}\\
&> 0
\end{aligned}$$

Sufficient Condition for the Contracting Effect to Dominate:

By the above expressions for the informed capital effect and the contracting effect, a sufficient condition for the contracting effect to dominate is

$$\frac{2\tau_\xi\left(e^{2\gamma c}-1\right)}{\sqrt{4\tau_\xi\tau_\varepsilon\left(e^{2\gamma c}-1\right)-4\tau_\xi\tau_v\left(e^{2\gamma c}-1\right)^2+T^2\tau_\varepsilon^2}} > \frac{b\gamma}{\tau_\varepsilon}+T.$$

Since $b<1$, a stronger sufficient condition is

$$\frac{2\tau_\xi\left(e^{2\gamma c}-1\right)}{\sqrt{4\tau_\xi\tau_\varepsilon\left(e^{2\gamma c}-1\right)-4\tau_\xi\tau_v\left(e^{2\gamma c}-1\right)^2+T^2\tau_\varepsilon^2}}>\frac{\gamma}{\tau_\varepsilon}+T.$$

Because the LHS is increasing in τ_ξ and approaches ∞ as τ_ξ approaches ∞, the above condition is satisfied for sufficiently high τ_ξ.

Sufficient Condition for the Informed Capital Effect to Dominate:

By the expressions for the informed capital effect and the contracting effect, a sufficient condition for the informed capital effect to dominate is

$$\frac{\frac{b\gamma}{\tau_\varepsilon}+T}{\tau_\xi}\frac{\gamma+T\tau_p+\gamma\frac{(1-b)\tau_v+\tau_p}{\tau_\varepsilon}}{\gamma+T(\tau_v+\tau_p)+\gamma\frac{\tau_v+\tau_p}{\tau_\varepsilon}}-\frac{1}{\gamma+T(\tau_v+\tau_p)+\frac{\gamma(\tau_v+\tau_p)}{\tau_\varepsilon}}$$
$$>\frac{2\left(e^{2\gamma c}-1\right)}{\sqrt{4\tau_\xi\tau_\varepsilon\left(e^{2\gamma c}-1\right)-4\tau_\xi\tau_v\left(e^{2\gamma c}-1\right)^2+T^2\tau_\varepsilon^2}}.$$

The LHS of the above condition is larger than $\frac{\left(\frac{b\gamma}{\tau_\varepsilon}+T\right)}{\tau_\xi}\frac{\gamma+T\tau_p+\gamma\frac{\tau_p}{\tau_\varepsilon}}{\gamma+T(\tau_v+\tau_p)+\gamma\frac{\tau_v+\tau_p}{\tau_\varepsilon}}-\frac{1}{\gamma+T(\tau_v+\tau_p)+\gamma\frac{\tau_v+\tau_p}{\tau_\varepsilon}}$, which is in turn larger than $\frac{1}{\tau_\xi}\frac{\gamma T}{\gamma+T(\tau_v+\tau_p)+\gamma\frac{\tau_v+\tau_p}{\tau_\varepsilon}}$. Moreover, given $\tau_p=\frac{\tau_\xi}{\left(\frac{b\gamma}{\tau_\varepsilon}+T\right)^2}<\frac{\tau_\xi}{T^2}$, $\frac{1}{\tau_\xi}\frac{\gamma T}{\gamma+T(\tau_v+\tau_p)+\gamma\frac{\tau_v+\tau_p}{\tau_\varepsilon}}$ is larger than $\frac{1}{\tau_\xi}\frac{\gamma T}{\gamma+T\left(\tau_v+\frac{\tau_\xi}{T^2}\right)+\gamma\frac{\tau_v+\frac{\tau_\xi}{T^2}}{\tau_\varepsilon}}$. Hence, a stronger sufficient condition is

$$\frac{\gamma T}{\gamma+T\left(\tau_v+\frac{\tau_\xi}{T^2}\right)+\gamma\frac{\tau_v+\frac{\tau_\xi}{T^2}}{\tau_\epsilon}}-\frac{2\left(e^{2\gamma c}-1\right)\tau_\xi}{\sqrt{4\tau_\xi\tau_\varepsilon\left(e^{2\gamma c}-1\right)-4\tau_\xi\tau_v\left(e^{2\gamma c}-1\right)^2+T^2\tau_\varepsilon^2}}>0.$$

The LHS of the above condition is decreasing in τ_ξ, and is still positive at $\tau_\xi=0$. Hence, the above condition holds for sufficiently small τ_ξ.

A.10. Proof of Proposition 7

We can compute

$$Liquidity=\frac{1}{a_\xi}=\frac{\lambda}{\frac{b\gamma}{\tau_\varepsilon}+T}+\frac{(1-\lambda)\tau_v}{K},$$

where

$$K=\gamma+T(\tau_v+\tau_p)+\frac{\gamma\left(\tau_v+\tau_p\right)}{\tau_\varepsilon}+\frac{\lambda(1-\lambda)\tau_\xi}{\frac{b\gamma}{\tau_\varepsilon}+T}.$$

Thus,

$$\frac{dLiquidity}{d\lambda} = \underbrace{\frac{1}{\frac{b\gamma}{\tau_\varepsilon}+T} - \frac{\tau_v}{K} - \frac{(1-\lambda)\tau_v}{K^2}\left[\left(T+\frac{\gamma}{\tau_\varepsilon}\right)\frac{\partial \tau_p}{\partial \lambda} + \frac{(1-2\lambda)\tau_\xi}{\frac{b\gamma}{\tau_\varepsilon}+T}\right]}_{\text{informed capital effect}}$$
$$\underbrace{-\left\{\frac{\lambda}{\left(\frac{b\gamma}{\tau_\varepsilon}+T\right)^2}\frac{\gamma}{\tau_\varepsilon} + \frac{(1-\lambda)\tau_v}{K^2}\left[\left(T+\frac{\gamma}{\tau_\varepsilon}\right)\frac{\partial \tau_p}{\partial b} - \frac{\lambda(1-\lambda)\tau_\xi}{\left(\frac{b\gamma}{\tau_\varepsilon}+T\right)^2}\frac{\gamma}{\tau_\varepsilon}\right]\right\}\frac{\partial b}{\partial \lambda}}_{\text{contracting effect}}. \tag{A.36}$$

Proof of Part 1. Suppose that $\lambda = 0$. It is easy to show that the contracting effect vanishes. In addition, we can compute

$$\left.\frac{dLiquidity}{d\lambda}\right|_{\lambda=0} = \frac{\left[\gamma+(1-b)\frac{\gamma\tau_v}{\tau_\varepsilon}\right]\left(\gamma+T\tau_v+\frac{\gamma\tau_v}{\tau_\varepsilon}\right)-\tau_v\tau_\xi}{\frac{b\gamma}{\tau_\varepsilon}+T}\frac{1}{\left(\gamma+T\tau_v+\frac{\gamma\tau_v}{\tau_\varepsilon}\right)^2}.$$

Thus,

$$\tau_v\tau_\xi > \left(\gamma+\frac{\gamma\tau_v}{\tau_\varepsilon}\right)\left(\gamma+T\tau_v+\frac{\gamma\tau_v}{\tau_\varepsilon}\right) \Rightarrow \left.\frac{dLiquidity}{d\lambda}\right|_{\lambda=0} < 0,$$
$$\tau_v\tau_\xi < \gamma\left(\gamma+T\tau_v+\frac{\gamma\tau_v}{\tau_\varepsilon}\right) \Rightarrow \left.\frac{dLiquidity}{d\lambda}\right|_{\lambda=0} > 0.$$

Proof of Part 2. Suppose that $\lambda = 1$. We can compute

$$\left.\frac{dLiquidity}{d\lambda}\right|_{\lambda=1} = \underbrace{\frac{1}{\frac{b\gamma}{\tau_\varepsilon}+T} - \frac{\tau_v}{\gamma+T(\tau_v+\tau_p)+\gamma\frac{\tau_v+\tau_p}{\tau_\varepsilon}}}_{\text{informed capital effect}>0} + \underbrace{\frac{-1}{\left(\frac{b\gamma}{\tau_\varepsilon}+T\right)^2}\frac{\gamma}{\tau_\varepsilon}\left.\frac{\partial b}{\partial \lambda}\right|_{\lambda=1}}_{\text{contracting effect}<0}.$$

The proof of which effect dominates is very similar to the proof of Proposition 6 and is thus omitted.

Appendix B. Supplementary material

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jet.2019.104977.

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