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# Have financial markets become more informative?☆

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ABSTRACT

The finance industry has grown, financial markets have become more liquid, information technology has been revolutionized. But have financial market prices become more informative? We derive a welfare-based measure of price informativeness: the predicted variation of future cash flows from current market prices. Since 1960, price informativeness has increased at longer horizons (three to five years). The increase is concentrated among firms with greater institutional ownership and share turnover, firms with options trading, and growth firms. Prices have also become a stronger predictor of investment, and investment a stronger predictor of cash flows. These findings suggest increased revelatory price efficiency.



## 1. Introduction

Fama (1970, p. 383) writes, “The primary role of the capital market is allocation of ownership of the economy's capital stock. In general terms, the ideal is a market in which prices provide accurate signals for resource allocation: that is, a market in which firms can make production-investment decisions ... under the assumption that security prices at any time ‘fully reflect’ all available information.” Since these words were written, financial markets have been transformed. Information processing costs have plummeted and information availability has vastly expanded. Trading costs have fallen, and liquidity has increased by orders of magnitude. Institutional investing has become dominant, and spending on price discovery has increased.[1] The financial sector's share of output has doubled. To assess whether these changes have brought Fama's ideal closer, in this paper we ask: Have financial market prices become more informative?

To answer this question, we derive a welfare-based measure of price informativeness and then analyze its evolution over time. Using US stock market data from 1960

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[1] Using numbers from French (2008), spending on price discovery has risen from 0.3% to 1% of gross domestic product since 1980.

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to 2014, we find that among comparable firms price informativeness has increased substantially at medium and long horizons (three to five years) while remaining relatively stable at short horizons (one year). Results from a variety of tests support the interpretation that the rise in price informativeness is due to greater information production in financial markets. Under this interpretation, rising price informativeness has contributed to an increase in the efficiency of capital allocation in the economy.

We use a simple framework to derive a welfare-based measure of informativeness and generate testable predictions. Standard q-theory (Tobin, 1969) implies that investment is proportional to the conditional expectation of future cash flows, making firm value convex in this expectation. Intuitively, investment is an option on information, and firm value embeds the value of this option. It follows that aggregate efficiency is increasing in information (Hayek, 1945), which can be quantified by the predicted variance of future cash flows (i.e., the variance of their conditional expectation). We are particularly interested in the information content of prices, which is given by the predicted variance of cash flows using market prices as the conditioning variable. Our price informativeness measure is its square root.

We construct time series of price informativeness from yearly cross-sectional regressions of future earnings on current stock market valuation ratios (we also include current earnings and sector controls). We focus on the one-, three-, and five-year forecasting horizons and on Standard & Poor's (S&P) 500 firms whose stable characteristics allow for a fairly clean comparison over time.

Price informativeness is increasing with horizon, consistent with prices capturing differences in growth rates between firms. Moreover, current earnings are already a good predictor of next year's earnings, making prices more useful at longer horizon. From a capital allocation perspective, the longer horizons are particularly important, as the time-to-build literature suggests that investment plans take over a year to implement, with the cash flows materializing farther down the road.

Our key result is that price informativeness has increased substantially at the three- and five-year horizons. The upward trend is steady throughout the 50-year sample, and its cumulative impact is economically significant: price informativeness is 60% higher in 2010 than 1960 at the three-year horizon and 80% higher at the five-year horizon. The increase is also highly statistically significant. Price informativeness at the one-year horizon, which is smaller to begin with, shows only a modest increase.[2]

The increase in price informativeness is not explained by changes in return predictability. Because valuations are driven by either cash flows or expected returns (Campbell and Shiller, 1988), a decrease in cross-sectional return predictability (e.g., a drop in the value premium) could make price informativeness rise even if information production does not. We find that this is not the case by putting returns on the left side of our forecasting regressions, which shows that the predictable component of returns remains stable.

Theory suggests that the information contained in market prices for future earnings should also be reflected in investment decisions. We therefore look at the predicted variance of investment based on market prices. We find that market prices have become stronger predictors of investment as measured by research and development (R&D) spending though not capital expenditure (CAPX). Thus, when it comes to real decisions like R&D for which market information is arguably particularly useful, the information content of prices has also increased.

More informative prices do not necessarily imply that financial markets have generated an improvement in welfare. Market prices contain information produced independently by investors, as well as information disclosed by firms. It is the independent, market-based component of price informativeness that contributes to the efficiency of capital allocation. Bond, Edmans, and Goldstein (2012) call this component revelatory price efficiency (RPE), in contrast to forecasting price efficiency (FPE), which also includes information already known to decision makers inside the firm.

Although separating FPE and RPE is challenging, we can use our theoretical framework to guide our analysis. In our framework, managers have access to internal information, some of which they disclose to the market. Investors combine this disclosure with their own independent information to trade, and this causes prices to incorporate both types of information (FPE). Managers then filter out as much of the independent information contained in prices as they can (RPE) and combine it with their own internal information to set investment optimally (aggregate efficiency). The rich two-way feedback between firms and markets in our framework ensures that the predictions we formulate and test are robust to a wide range of models proposed in the literature.

Our framework shows that an increase in market-based information (RPE) can be distinguished from a pure increase in firm disclosure by looking at aggregate efficiency, the predicted variation of future cash flows based on the manager's full information set. All else equal, an increase in disclosure causes aggregate efficiency to remain the same even as price informativeness (FPE) rises. Although the manager's information set is not observed, it gets reflected in her investment decisions. We show that we can bound aggregate efficiency from below by the predicted variation of future cash flows from investment and from above by the cross-sectional dispersion of investment, both of which are increasing in the amount of information the manager has. Measuring investment as either R&D alone or R&D and CAPX together, we find evidence that the predicted variation of earnings from investment has

[2] For completeness, we also calculate price informativeness for firms beyond the S&P 500. We stress, however, that the composition of this sample has changed dramatically over the years (see Fama and French, 2004), making the comparison potentially misleading. This is readily apparent from trends in observable characteristics such as idiosyncratic volatility and earnings dispersion (measures of uncertainty), which have risen drastically. By contrast, these characteristics are remarkably stable for S&P 500 firms. Likely as a result of the compositional shift, price informativeness for firms beyond the S&P 500 appears to decline. Interestingly, the decline is concentrated at the short horizon, so again there is relative improvement at the long end. Above all, we view these results as motivating our focus on S&P 500 firms.

increased. We also find that the cross-sectional dispersion of R&D has increased. This suggests that aggregate efficiency has increased. Combined with the observed rise in price informativeness (FPE), the increase in aggregate efficiency supports the interpretation that market-based information production (RPE), and not just disclosure, has increased.

While we are thus able to rule out a pure rise in disclosure as the explanation for the rise in price informativeness, a more subtle explanation remains. It could be that information production inside firms and disclosure have both increased. The former would explain the rise in aggregate efficiency, and the latter would explain the rise in price informativeness. Teasing out this more complicated explanation is challenging, and it requires additional predictions that we can test. We construct and test four such predictions that exploit cross-sectional differences between firms. While none of our tests is perfect, we find that the overall evidence supports the interpretation that market-based information production (RPE) has increased.

Our first cross-sectional prediction is that market-based information production should be higher for firms with high institutional ownership. Institutional investors have come to dominate financial markets, their stake in the average firm rising from 20% in 1980 to 60% in 2014. Given their professional expertise, we expect them to have a large impact on market-based information production. In our test, we compare firms with institutional ownership above and below the median, going beyond the S&P 500 to obtain greater cross-sectional variation. Dispersion has increased so that the gap in institutional ownership between the two groups has widened. We find that price informativeness is both higher and has increased more for the group with high and increasing institutional ownership. This result is consistent with the RPE view that information production in markets has increased.

In our second cross-sectional test, we compare the price informativeness of stocks with and without option listings and stocks with high and low levels of options trading. The Chicago Board Option Exchange (CBOE) began listing options in 1973 and has been adding new listings in a staggered manner. Our test is based on the idea that options provide traders with leverage, the ability to hedge, and a low-cost way to sell short, all of which increase the incentive and scope for market-based information production. We find that price informativeness has increased more for CBOE-listed firms than for non-listed firms and that price informativeness is higher for firms with higher levels of option turnover. These findings are also consistent with the RPE view.

In our third test, we compare firms with high and low levels of liquidity as proxied by share turnover. The idea is that greater liquidity facilitates the incorporation of private information into prices. It also increases the incentives of market participants to produce such information. Consistent with this idea, we find that stocks with higher turnover have higher price informativeness. Because liquidity has increased strongly over the past five decades, this finding helps to explain the observed rise in overall price informativeness and supports the view that RPE has increased.

For our final cross-sectional test, we enrich our model with cross-sectional differences between firms. We incorporate the natural feature that a firm's cash flows from growth options may not be perfectly correlated with its cash flows from assets in place. Firm insiders have an advantage in producing information about assets in place; after all they are the ones who put them there. Valuing growth options, meanwhile, requires making comparisons with other firms and analyzing market trends, and here the market can have the advantage or at least less of a disadvantage. Based on this reasoning, if market-based information has increased we would expect price informativeness to increase more for firms with substantial growth options (growth firms), and if internal information and disclosure have increased, we would expect greater improvement among firms with fewer growth options (i.e., value firms). Consistent with the market-based RPE view, we find that price informativeness has risen much more for growth firms than for value firms. This result is interesting from a broader perspective as it indicates that the increase in price informativeness is concentrated among hard-to-value firms where it is most needed.

The rest of this paper proceeds as follows. Section 2 reviews the literature, Section 3 derives our informativeness measure, Section 4 describes the data, Section 5 presents results, and Section 6 concludes.

## 2. Related literature

Levine (2005) categorizes the economic role of the financial sector into five channels: (1) information production about investment opportunities and allocation of capital, (2) mobilization and pooling of household savings, (3) monitoring of investments and performance, (4) financing of trade and consumption, and (5) provision of liquidity, facilitation of secondary market trading, diversification, and risk management. Our focus is on examining (1) empirically.

The information production role of financial markets is part of a classic literature in economics going back at least to Schumpeter (1912) and Hayek (1945). Greenwood and Jovanovic (1990) and King and Levine (1993b) provide endogenous growth models in which information production in financial markets enables efficient investment. We derive a welfare-based measure of price informativeness that is in the spirit of this literature, one that can be easily calculated from readily available data.

The empirical literature on finance and growth relies mainly on cross-country comparisons (Bekaert, Campbell, and Lundblad, 2001; King and Levine, 1993a; Morck, Yeung, and Yu, 2000; Rajan and Zingales, 1998). Our novel methodology exploits firm-level variation, which allows us to examine the information production channel within a single country, in our case the US, over time.

The US time series represents a particularly important setting because over the last few decades the US financial sector has grown six times faster than gross domestic product (GDP) (Philippon, 2015). At its peak in 2006, it contributed 8.3% to U.S. GDP compared with 2.8% in 1950 [see Philippon (2015) and Greenwood and Scharfstein (2013) for in-depth discussions]. Finance has also drawn in a large share of human capital (Philippon and Reshef, 2012). The question arises whether these changes have led to an increase in economic efficiency. While it is difficult to discern such a relation in aggregate US data, we provide a partial answer to this question by using cross-sectional data to examine the informativeness of financial market prices.

The answer is by no means clear a priori. The dot-com bust of 2000 and the financial crisis of 2008 have called the benefits of financial development into question (e.g., Zingales, 2015). Prices can be distorted due to behavioral biases (e.g., Hong and Stein, 1999; Shiller, 2000), or incentives (e.g., Rajan, 2005). Gennaioli, Shleifer, and Vishny (2012) argue that financial innovation can increase fragility. Bolton, Santos, and Scheinkman (2016) provide a model in which rents in the financial sector attract an excessive share of the economy's human capital. Philippon and Reshef (2012) find a potentially distorting wage premium in the financial sector, and Philippon (2015) finds that the unit cost of financial intermediation has remained relatively high in recent decades. Quantifying information production as we do in this paper contributes to the important effort of measuring value added in the financial sector.

A large theoretical literature with seminal papers by Glosten and Milgrom (1985); Grossman and Stiglitz (1980); Kyle (1985), and Holmström and Tirole (1993) studies the incentives of traders to produce information. As financial technology develops and the cost of producing information shrinks, the information content of prices increases. The information revolution and the growth of financial markets suggest that the premise of this proposition is in place. Our contribution is to assess its implication.

Bond, Edmans, and Goldstein (2012) survey the literature on information production in financial markets, emphasizing the challenge of separating the genuinely new information produced in markets (revelatory price efficiency) from what is already known and merely reflected in prices (forecasting price efficiency). This distinction can be traced back to Hirshleifer (1971) and Tobin (1984). We follow this conceptual framework and seek to disentangle RPE and FPE by measuring the efficiency of investment and by comparing groups of firms where RPE or FPE is expected to prevail.

Recent theoretical work on asset prices and real efficiency includes Bond, Goldstein, and Prescott (2010); Dow and Gorton (1997); Goldstein and Guembel (2008); Goldstein, Ozdenoren, and Yuan (2013); Kurlat and Veldkamp (2015); Ozdenoren and Yuan (2008); Subrahmanyam and Titman (1999), and Edmans, Goldstein, and Jiang (2015). While these papers share the basic feedback from market prices to investment that is the subject of our paper, each focuses on a particular form of more advanced feedback such as that from investment to market prices. In Section 3, we use our theoretical framework to discuss these papers in some detail, and we derive the predictions we test based on their common features.

On the empirical side, Chen, Goldstein, and Jiang (2007) and Bakke and Whited (2010) find that the relationship between stock prices and investment is stronger for firms with more informative stock prices, whereas Baker, Stein, and Wurgler (2003) find that it is stronger for firms that issue equity more often. Turley (2012) exploits a regulatory change to show that lower transaction costs increase short-term (one to three month) stock price informativeness. Our contribution here is to examine the evolution of price informativeness over a long period of time characterized by unprecedented growth in the financial sector.

The most common measure of informativeness is price nonsynchronicity (Roll, 1988), which is based on the correlation between a firm's return and a market or industry benchmark (a high correlation is interpreted as low informativeness). Papers that adopt this measure include Morck, Yeung, and Yu (2000), Durnev, Morck, Yeung, and Zarowin (2003), and Chen, Goldstein, and Jiang (2007). Durnev, Morck, Yeung, and Zarowin (2003) show that price nonsynchronicity is positively related to the correlation between returns and future earnings at the industry level, which helps to validate it as a measure of informativeness. A second popular measure comes from the microstructure literature: the probability of informed trading or PIN (Easley, Kiefer, ara, and Paperman, 1996), which is based on order flow. Our contribution here is to derive a welfare-based measure to quantify the information contained in prices that is relevant for real outcomes.

Our paper is also related to the accounting literature on disclosure [see surveys by Healy and Palepu (2001) and Beyer, Cohen, Lys, and Walther (2010)]. Our sample includes some significant changes in disclosure requirements, most prominently Regulation Fair Disclosure (Reg FD) in 2000 and the Sarbanes-Oxley Act in 2002. Considerable debate remains regarding the effects of these reforms, even their sign is unsettled.[3] We find no evidence of structural breaks in informativeness around their passage. In addition, our result that aggregate efficiency has increased makes it unlikely that changes in disclosure alone can explain the observed rise in price informativeness.

A second related strand of the accounting literature studies value relevance, the impact of accounting metrics on market values [see, e.g., Holthausen and Watts (2001) and Dechow, Sloan, and Zha (2014)]. This literature establishes both that earnings information drives returns and that returns do not always fully incorporate earnings information. This is one reason that we include current earnings as a control in our forecasting regressions. There is also evidence that the value relevance of earnings has declined over our sample (Collins, Maydew, and Weiss, 1997), which would bias our results downward. We show that our main result holds under a variety of accounting metrics, including different measures of earnings and operating cash flows. The broader difference between this literature and our paper is that we measure the extent to which market values predict—as opposed to react to—accounting metrics, specifically earnings and investment.

[3] Heflin, Subramanyam, and Zhang (2003) find no evidence of increased earnings surprises in returns after Reg FD, suggesting that the information available to market participants was not reduced. On the other hand, Wang (2007) reports that firms cut back on issuing earnings guidance reports after Reg FD. Yet Bushee, Matsumoto, and Miller (2004) provide evidence that disclosure remained constant or even increased after Reg FD.

In sum, our paper lies at the intersection of the finance-and-growth literature and the literature on information production in financial markets. Its underlying premise is that measuring price informativeness over time helps to assess the economic value of a growing financial sector.

## 3. Theoretical framework and discussion

We present a theoretical framework with two goals in mind. The first is to derive a welfare-based measure of price informativeness that we can take to the data. The second is to formulate testable predictions that we can use to interpret our results. We also discuss these predictions in the context of the existing literature.

Our framework has two essential components: a q-theory and aggregate efficiency block and an information environment block.

### 3.1. Q-theory and aggregate efficiency

Consider a firm with ex post fundamental value as in standard q-theory following Hayashi (1982):

$$v(z,k) = (1+z)\left(\bar{k}+k\right) - k - \frac{\gamma}{2\bar{k}}k^2, \tag{1}$$

where $\bar{k}$ represents assets in place, $k$ is investment in new capital, $z$ is a productivity shock, and $\gamma$ is an adjustment cost parameter.

Investment is chosen to maximize firm value under the manager's (more generally, the decision maker's) information set $\mathcal{I}_m$: $k^\star = \text{argmax}_k \mathbb{E}[v(z,k)|\mathcal{I}_m]$. We have normalized the discount rate to zero for simplicity (we address discount rates in Section 5.5). This leads to the well-known q-theory investment equation

$$\gamma \frac{k^\star}{\bar{k}} = \mathbb{E}[z \mid \mathcal{I}_m]. \tag{2}$$

The investment rate $k^\star/\bar{k}$ is proportional to the conditional expectation of net productivity $z$ given the manager's information set. The maximized ex post firm value is then

$$\frac{v(z,k^\star)}{\bar{k}} = 1 + z + \frac{z}{\gamma}\mathbb{E}[z|\mathcal{I}_m] - \frac{1}{2\gamma}\mathbb{E}[z|\mathcal{I}_m]^2. \tag{3}$$

We can also write the expected firm value conditional on investment and the information available to the manager as

$$\mathbb{E}\left[\frac{v(z,k^\star)}{\bar{k}}\middle|\mathcal{I}_m\right] = 1 + \mathbb{E}[z|\mathcal{I}_m] + \frac{1}{2\gamma}\left(\mathbb{E}[z \mid \mathcal{I}_m]\right)^2. \tag{4}$$

We are interested in the efficiency of capital allocation across firms, so we consider a large number of ex ante identical firms (same $\bar{k}$) that draw different signals about $z$. We normalize $z$ to have mean of zero across these firms. Aggregate efficiency is then defined by the ex ante (or cross-sectional average) firm value

$$\mathbb{E}[v(z,k^\star)] = \bar{k} + \frac{\bar{k}}{2\gamma}\mathbb{V}\mathrm{ar}(\mathbb{E}[z|\mathcal{I}_m]). \tag{5}$$

Aggregate efficiency is a function of the variance of the forecastable component of net productivity $z$. This is the first key theoretical point that we use in our empirical analysis. The next step is to think about how $\mathcal{I}_m$ is determined in equilibrium.

### 3.2. Information environment

In practice, managers have access to information produced inside the firm, as well as to outside information contained in market prices. We summarize the internal information with the signal

$$\eta = z + \epsilon_\eta, \tag{6}$$

where $\epsilon_\eta \sim N\left(0, \sigma_\eta^2\right)$. The price-based information is contained in the price $p$ of a security linked to the firm's payoff. This information is itself derived from the private information of informed traders in the market for this security. We summarize the information of these informed traders with the signal

$$s = z + \epsilon_s, \tag{7}$$

where $\epsilon_s \sim N\left(0, \sigma_s^2\right)$. We assume that $\epsilon_\eta$ and $\epsilon_s$ are independent, so we can think of $\eta$ and $s$ as the two fundamental sources of information that society can use to improve efficiency.

In practice, market participants and managers also share common sources of information other than prices, most prominently through disclosure. To take this into account, we assume that traders observe an additional signal coming from the manager:

$$\eta' = \eta + \epsilon_{\eta'}, \tag{8}$$

where $\epsilon_{\eta'} \sim N(0, \sigma_{\eta'}^2)$ is orthogonal to $\epsilon_\eta$ and $\epsilon_s$. The disclosure signal $\eta'$ captures the flow of information from the firm to the market, which runs in the opposite direction of the flow of information from the market to the firm in the form of the price $p$. To summarize, the information set of the manager is $\mathcal{I}_m = \{\eta, \eta', p\}$ and the information set of informed traders is $\mathcal{I}_\tau = \{\eta', s\}$.

### 3.3. Feedback and equilibrium

A full-fledged model needs to specify the objectives of the traders (e.g., CARA or mean variance preferences, constraints, etc.) as well as a trading protocol (e.g., competitive or strategic, with or without market makers, etc.). We present one such model in Appendix A. For the purpose of this discussion, it is more important to focus on the key features shared by nearly all models.

We must first specify exactly which security (claim on $v$) is traded in financial markets. In practice, it can be the case that equity is publicly traded but debt is not or that the traded security is an option or a credit derivative. So, define $\mathcal{F}(z,k)$ as the payoff of the claim that is traded in financial markets. One important particular case is $\mathcal{F}(z,k) = v(z,k)$ with $v$ as in Eq. (3). Because the informed traders' information set consists of $\eta'$ and $s$, the equilibrium price typically takes the form

$$p = \alpha\mathbb{E}\left[\mathcal{F}(z,k^\star)|\eta', s\right] + \beta u, \tag{9}$$

where $u$ is noise trading demand and $\alpha$ and $\beta$ are endogenous coefficients that are part of the rational expectations equilibrium. Exactly how to solve for these coefficients, and whether we obtain a linear price function depends on the details of the model. The more tractable models, including our Appendix model, result in pricing functions of the form in Eq. (9). To summarize, most models in the literature boil down to two equations:

$$k^\star = \frac{\bar{k}}{\gamma}\mathbb{E}\left[z|\eta, \eta', p\right] \tag{10}$$

and

$$p = \alpha\mathbb{E}\left[\mathcal{F}(z, k^\star)|\eta', s\right] + \beta u. \tag{11}$$

The basic feedback is that managers learn from prices, and so $k^\star$ depends on $p$. It implies that the informativeness of prices matters for firm value, aggregate efficiency, and welfare. This feature, which is the most important one for our analysis, is common to all models we discuss, even though they differ in the complexity of the other interactions between value and prices.

The more advanced feedback channels depend on the nature of the traded claim and on the trading protocol. For instance, Subrahmanyam and Titman (1999) make the simplifying assumption $\mathcal{F}(z, k^\star) = z$ to ensure linearity of the conditional expectations. In that case, the pricing equation, Eq. (11), does not depend on the mapping $k^\star$ in Eq. (10) and the model remains linear and tractable. Our model in Appendix A adopts this approach and discusses its implications. It can be interpreted as a linear approximation to a more complex model when $k^\star/\bar{k}$ is not too large as is the case in the data.

Other papers (e.g., Goldstein, Ozdenoren, and Yuan, 2013) use the more complex but also richer case $\mathcal{F} = v$. In that case, $p$ can be interpreted as the market value of the firm. Firm value is a nonlinear function of $z$ and $k^\star$, so finding $p$ involves solving a complex fixed-point problem. The traders need to form beliefs about the function $k^\star$, i.e., about how the manager uses prices to decide on investment. Traders then use these beliefs to forecast total firm value, which determines the equilibrium price. Dow and Gorton (1997) show that this can lead to multiple equilibria.[4] In one equilibrium, managers invest based on prices, which gives traders an incentive to gather information. In the other equilibrium, prices are not informative and managers do not invest.

Goldstein and Guembel (2008) show that the basic feedback can give incentives to a large uninformed speculator to manipulate the stock price by short selling the stock, inducing inefficient disinvestment, reducing firm value, and thereby making the short-selling strategy profitable. Conversely, Edmans, Goldstein, and Jiang (2015) emphasize the strategic behavior of a large informed trader who knows that whatever information she reveals will be used to increase firm value. This leads to asymmetric revelation of good and bad news. These effects rely on the basic feedback and on the strategic behavior of large traders who influence prices.

[4] In their model, managers are clueless, $\sigma_\eta^2 = \infty$, and returns on assets in place are independent of $z$, which is precisely the opposite assumption from Subrahmanyam and Titman (1999). Ozdenoren and Yuan (2008) work with another tractable alternative, $\mathcal{F} = k^\star + z$, similarly assuming $\sigma_\eta^2 = \infty$. In Bond, Goldstein, and Prescott (2010), $\sigma_\eta^2 < \infty$ but $\sigma_s^2 = 0$, so traders have perfect information.

### 3.4. Empirical predictions

The framework outlined above offers a precise overview of the existing literature. Our next task is to formulate specific predictions that we can test empirically.

We begin by quantifying price informativeness, i.e., the forecasting power of prices for future cash flows, which Bond, Edmans, and Goldstein (2012) call forecasting price efficiency (FPE). We scale by $\bar{k}$ to allow for meaningful comparisons across firms, and we define a firm's market-to-book ratio $q = p/\bar{k}$. FPE is given by the variance of the predictable component of firm value $v/\bar{k}$ given $q$. From Eq. (3), $v/\bar{k}$ has some nonlinear terms in $z$ but, to a first-order approximation, $v/\bar{k} \approx 1 + z$, so we focus on

$$\mathcal{V}_{FPE} \equiv \mathbb{V}\mathrm{ar}(\mathbb{E}[z|q]). \tag{12}$$

FPE measures the total amount of information about future cash flows contained in market prices. At the same time, it is only a forecasting concept. Aggregate efficiency depends on the information of the manager:

$$\mathcal{V}_M \equiv \mathbb{V}\mathrm{ar}\left(\mathbb{E}\left[z|\eta, \eta', q\right]\right). \tag{13}$$

We are interested in the part of $\mathcal{V}_M$ that comes from market prices, which Bond, Edmans, and Goldstein (2012) call revelatory price efficiency (RPE). It is given by

$$\mathcal{V}_{RPE} \equiv \mathbb{V}\mathrm{ar}\left(\mathbb{E}\left[z|\eta, \eta', q\right]\right) - \mathbb{V}\mathrm{ar}\left(\mathbb{E}\left[z|\eta, \eta'\right]\right). \tag{14}$$

RPE measures the extent to which prices improve real allocations. When prices are uninformative or when managers already know the information they contain, RPE is low. And when prices provide managers with information that is useful for improving the efficiency of investment, RPE is high. This is the core idea of Hayek (1945).

Each of the theoretical models discussed above gives an explicit mapping from the fundamental information structure $(\sigma_s^2,\ \sigma_\eta^2,\ \sigma_{\eta'}^2)$ into the objects of interest, $\mathcal{V}_{FPE}$ and $\mathcal{V}_{RPE}$. We cannot do justice to all the subtle predictions based on advanced feedback, but we can focus on the predictions that are robust across models.

*Prediction 1.* All else equal,

(i) a decrease in $\sigma_s^2$ (traders produce more information) increases $\mathcal{V}_{FPE}$, $\mathcal{V}_{RPE}$, and $\mathcal{V}_M$;
(ii) a decrease in $\sigma_\eta^2$ (firms produce more information) increases $\mathcal{V}_{FPE}$ and $\mathcal{V}_M$ but not $\mathcal{V}_{RPE}$; and
(iii) a decrease in $\sigma_{\eta'}^2$ (firms disclose more information) increases $\mathcal{V}_{FPE}$ but neither $\mathcal{V}_M$ nor $\mathcal{V}_{RPE}$.

When traders produce more information (their signal $s$ becomes less noisy), prices become more informative and so FPE goes up. RPE also goes up because the additional information in prices is new to managers. As managers use this information, aggregate efficiency increases. Aggregate efficiency also increases when managers produce more information ($\eta$ becomes less noisy), and this again causes FPE to go up through disclosure. However, in this case prices are merely reflecting information already available managers and so RPE does not rise. Finally, an improvement in disclosure ($\eta'$ becomes less noisy) leaves aggregate efficiency and RPE unchanged because it does not affect the amount of information available to managers. It, does, however, raise FPE because the additional disclosure gets reflected in prices.

Prediction 1 allows us to interpret an observed trend in FPE as coming from internal information, from market participants, or from disclosure by looking for parallel trends in aggregate efficiency. For instance, an increase in $\mathcal{V}_{FPE}$ and $\mathcal{V}_M$ rules out a pure disclosure explanation [part (iii)]. Separating parts (i) and (ii) then requires additional testable predictions. We construct such predictions by enriching the model with cross-sectional differences across firms after we have established the basic trends in FPE.

Our empirical analysis centers on Prediction 1. As we noted, this prediction is common to models throughout the literature. To motivate it further, we derive Prediction 1 formally in the model we present in Appendix A.

## 4. Data and summary statistics

We now describe our data and how we construct the variables we use.

### 4.1. Sample and variables

Our main sample is annual from 1960 to 2014. We obtain stock prices from the Center for Research in Security Prices (CRSP). All accounting variables are from Compustat. Institutional ownership is from 13-F filings provided by Thomson Reuters. The test on option listings uses listing dates from the CBOE (available after 1973 when single-name option trading began), and the test on option turnover uses option volume data from OptionMetrics (available after 1996). The GDP deflator used to adjust for inflation is from the Bureau of Economic Analysis.

We take stock prices as of the end of March and accounting variables as of the end of the previous fiscal year, typically December. This timing convention ensures that market participants have access to the accounting variables that we use as controls.

For most of the paper, we limit attention to S&P 500 nonfinancial firms, which represent the bulk of the value of the US corporate sector. As we show, their characteristics have remained remarkably stable, which makes them comparable over time. This is in contrast to the broader universe of firms, whose characteristics have changed drastically.

Our main equity valuation measure is the log-ratio of market capitalization $M$ to total assets $A$, $\log M/A$.[5] Our main cash flow variable is earnings measured as EBIT (earnings before interest and taxes). We also show that our main results are robust to using alternative measures such as EBITDA (earnings before interest, taxes, depreciation and amortization), net income, and cash flows from operations (CFO). We focus on EBIT because it is most widely available in Compustat and because it is the focus of analyst research. For investment, we use both research and development (R&D) and capital expenditure (CAPX). We scale both current and future cash flows and investment by current total assets. For instance, in a forecasting regression for earnings with horizon $h$ years, the left-side variable is $E_{t+h}/A_t$. This specification is implied by our framework (see Section 3; we are predicting $v/\bar{k} \approx 1+z$). In particular, it incorporates growth between $t$ and $t+h$. Unlike prices, we do not take logs because it is the level of cash flows that matters for aggregate efficiency. We winsorize all ratios at the 1% level.

We must account for firm delistings to ensure that our forecasting regressions are free of survivorship bias.[6] When a firm is delisted, we invest the delisting proceeds (calculated using the delisting price and dividend) in a portfolio of firms in the same industry (by two-digit SIC code). We use the earnings accruing to this portfolio to fill in the earnings of the delisted firm. We do the same for investment.

We adjust for inflation with the GDP deflator. This is necessary because it is real price informativeness that matters for welfare. Because inflation is multiplicative, differences in future nominal cash flows between firms are larger than differences in real cash flows. This biases the forecasting coefficient up during high inflation periods such as the 1970s and early 1980s.[7]

### 4.2. Summary statistics

Table 1 presents summary statistics for our main sample of S&P 500 firms, separately covering the full period 1960–2014 and the subperiods 1960–1985 and 1986–2014. Firms have become larger and their profits have grown with the size of the economy. Yet profitability (earnings over assets) is stable both in terms of levels and cross-sectional dispersion. This is true of both current and future profitability (measured against current assets), our key left-side variables. Market valuations, our key right-side variable, have risen with the overall market and their cross-sectional dispersion is slightly higher. Investment has shifted a bit from CAPX to R&D and R&D has become more right-skewed, but overall investment rates are stable.

Fig. 1 depicts the cross-sectional distribution of several characteristics over time by plotting their median (red line) and their 10th–90th percentile range (gray shading) in a

[5] The correct functional form is whichever one managers use to extract information from prices. With identical firms and normal shocks, one could use $q$, the ratio of the market price to existing assets (see Section 3). In practice, we find that taking logs works slightly better because it mitigates skewness in the data.

[6] Survivorship bias would arise if the relation between market valuations and future earnings is different among firms that are delisted (their future earnings and investment appear as missing in our sample) than among firms that are not delisted. Because our focus is on trends, it is changes in delisting rates that are of concern. In our sample of S&P 500 firms, the delisting rate is slightly higher (3.2% per year) in the second half of the sample than in the first half (2.3%). This is because most delistings occur when a firm is acquired, so the delisting rate tracks the merger waves of the 1980s and 1990s.

[7] In the first circulated draft of the paper (dated December 2013), we incorrectly inferred that price informativeness had remained stable. This was due to the combined effect of three differences in methodology. First, we did not adjust for inflation. This led price informativeness to be overstated in the high-inflation 1970s and early 1980s. Second, we did not correct for delistings, which have increased somewhat in the latter part of our sample. Third, we did not consider the long five-year horizon.

**Table 1**

Summary statistics. This table presents means, medians, and standard deviations of key variables for firms in the Standard & Poor's (S&P) 500 index. Market capitalization is from the Center for Research in Security Prices (CRSP) in millions of dollars as of the end of March. Total assets, research and development (R&D), capital expenditure (CAPX), and earnings before interest and taxes (EBIT) are from Compustat in millions of dollars as of the end of the previous fiscal year. All quantities are adjusted for inflation using the gross domestic product (GDP) deflator (= 100 in 2010). Next, $\log(M/A)$ is the log-ratio of market cap to assets, $R\&D/A$ is R&D over assets, $CAPX/A$ is CAPX over assets, $E/A$ is EBIT over assets, and $E(t+h)/A$, $h = 1, 3, 5$, is earnings in year $t+h$ over assets in year $t$. All ratios are winsorized at the 1% level. Idiosyncratic volatility is the standard deviation over the last 12 months of returns net of the market return. Share turnover is volume divided by shares outstanding. Institutional share is the fraction of shares held by institutional investors (from 13-F filings). Option listings is an indicator variable for whether a firm has options trading on the Chicago Board Option Exchange (CBOE), available after 1973. Option turnover is one hundred times annual option volume divided by equity shares outstanding (from OptionMetrics, 1996 to 2014). The sample contains all S&P 500 non-financial firms from 1960 to 2014.

| | Full sample | | | 1960–1985 | | | 1986–2014 | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | Mean | Median | St. Dev. | Mean | Median | St. Dev. | Mean | Median | St. Dev. |
| Market capitalization | 10,420 | 3,213 | 28,027 | 3,793 | 1,481 | 10,562 | 17,043 | 6,796 | 37,032 |
| Total assets | 11,113 | 3,931 | 30,449 | 5,304 | 2,194 | 13,434 | 16,384 | 6,426 | 39,324 |
| R&D | 390 | 90 | 996 | 164 | 54 | 403 | 529 | 133 | 1,205 |
| CAPX | 744 | 224 | 1,978 | 512 | 145 | 1,656 | 943 | 315 | 2,198 |
| Earnings | 1,101 | 402 | 2,750 | 597 | 233 | 1,713 | 1,544 | 646 | 3,348 |
| $\log(M/A)$ | −0.166 | −0.197 | 0.879 | −0.383 | −0.410 | 0.824 | 0.032 | 0.037 | 0.881 |
| $R\&D/A$ | 0.038 | 0.024 | 0.044 | 0.029 | 0.020 | 0.028 | 0.044 | 0.026 | 0.050 |
| $CAPX/A$ | 0.071 | 0.060 | 0.050 | 0.080 | 0.070 | 0.051 | 0.063 | 0.052 | 0.047 |
| $E/A$ | 0.116 | 0.107 | 0.075 | 0.120 | 0.110 | 0.073 | 0.113 | 0.104 | 0.077 |
| $E(t+1)/A$ | 0.124 | 0.111 | 0.087 | 0.127 | 0.113 | 0.083 | 0.122 | 0.108 | 0.090 |
| $E(t+3)/A$ | 0.139 | 0.117 | 0.115 | 0.140 | 0.119 | 0.106 | 0.139 | 0.114 | 0.123 |
| $E(t+5)/A$ | 0.155 | 0.123 | 0.145 | 0.155 | 0.126 | 0.131 | 0.155 | 0.118 | 0.159 |
| Idiosyncratic volatility | 0.075 | 0.066 | 0.040 | 0.071 | 0.064 | 0.033 | 0.079 | 0.068 | 0.045 |
| Share turnover | 0.098 | 0.049 | 0.146 | 0.031 | 0.020 | 0.038 | 0.164 | 0.109 | 0.180 |
| Institutional share | 0.635 | 0.651 | 0.207 | 0.429 | 0.446 | 0.172 | 0.668 | 0.685 | 0.193 |
| Option listings | 0.635 | 1.000 | 0.481 | 0.259 | 0.000 | 0.438 | 0.895 | 1.000 | 0.307 |
| Option turnover | 0.351 | 0.122 | 1.100 | | | | 0.351 | 0.122 | 1.100 |
| Number of observations | | 24,701 | | | 12,350 | | | 12,351 | |

given year. Panels A and B confirm that the distributions of the valuation ratio $\log M/A$ and profitability $E/A$ have remained stable, and Panels C and D confirm that R&D has become more right-skewed and CAPX has declined in importance.

While the underlying characteristics of these firms have changed little, their trading environment has changed drastically. As Table 1 shows, share turnover has increased fivefold, institutional ownership has risen by about half, and a large majority of firms now have their options trading on the CBOE in significant volume. These changes reflect the broader transformation in financial markets that serves as the backdrop for our investigation of price informativeness. We return to them in Sections 5.7–5.9.

The stability among S&P 500 firms stands in sharp contrast to the broader sample of all firms, whose characteristics are presented in Table C.1 and discussed in Appendix C. Among all firms profitability has both fallen and become much more disperse. Consistent with Campbell, Lettau, Malkiel, and Xu (2001), median idiosyncratic volatility has increased from 9.8% to 12.3% per month (for S&P 500 firms the change is negligible, from 6.4% to 6.8%). Fama and French (2004) show that these changes are related to the listing of smaller and younger firms and to the emergence of Nasdaq. Besides being more uncertain, these firms are also arguably harder to value since many lack a consistent earnings record. These compositional changes imply that the universe of firms is not comparable over time, which is why we focus on the S&P 500 throughout the paper.

## 5. Empirical results

In this section, we present the results of our empirical analysis.

### 5.1. Estimation methodology

We construct our measure of price informativeness (FPE) by running cross-sectional regressions of future earnings on current market prices. We include current earnings and industry sector as controls to avoid crediting markets with obvious public information. In each year $t = 1960, \ldots, 2014$ and at every horizon $h = 1, \ldots, 5$, we run

$$\frac{E_{i,t+h}}{A_{i,t}} = a_{t,h} + b_{t,h} \log\left(\frac{M_{i,t}}{A_{i,t}}\right) + c_{t,h}\left(\frac{E_{i,t}}{A_{i,t}}\right) + d^s_{t,h}\mathbf{1}^s_{i,t} + \epsilon_{i,t,h}, \tag{15}$$

where $i$ is a firm index and $\mathbf{1}^s$ is a sector (one-digit SIC code) indicator. Table B.1, in Appendix B, provides an example from 2009. These regressions provide a set of coefficients indexed by year $t$ and horizon $h$.

From Section 3, price informativeness $\mathcal{V}_{FPE}$ is the predicted variance of future cash flows from market prices [see Eq. (12)]. We compute it here with the minor modification of taking a square root, which gives meaningful units (dollars of future cash flows per dollar of current total assets). From regression (15), price informativeness in year $t$ at horizon $h$ is the forecasting coefficient $b_{t,h}$

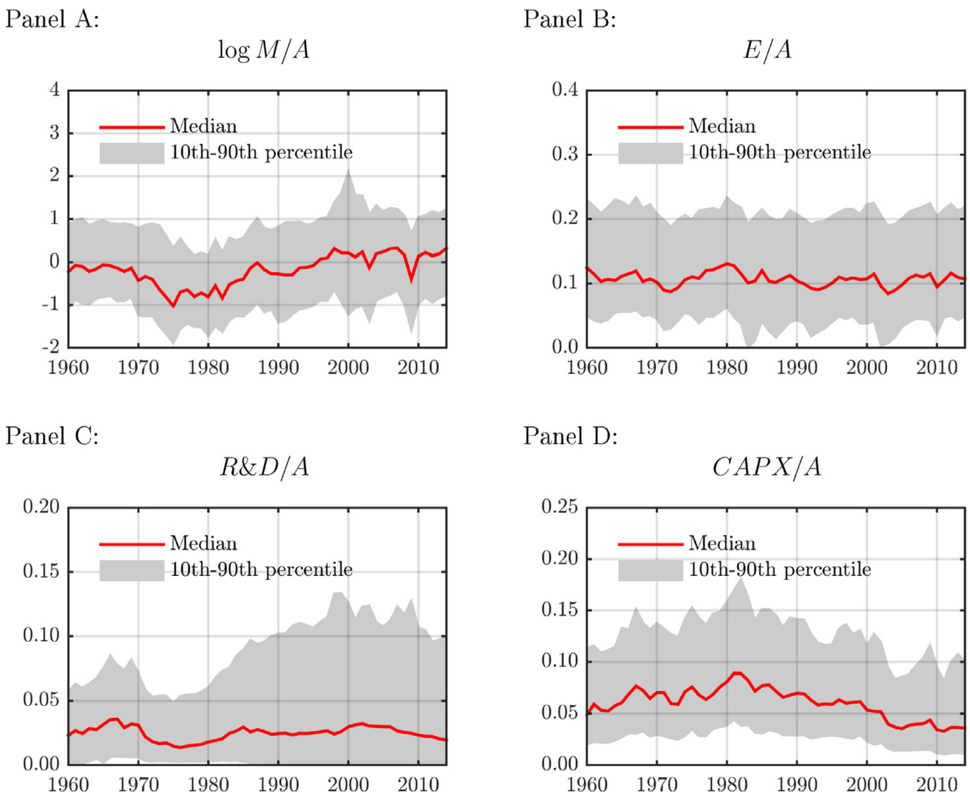


**Fig. 1.** Summary statistics over time. The sample consists of nonfinancial firms in the S&P 500 index from 1960 to 2014. Each panel shows medians (solid red line) and the 10th–90th percentile range (gray shading). $\log M/A$ is the log ratio of market capitalization to total assets. $E/A$ is earnings before interest and taxes (EBIT) over assets. $R\&D/A$ and $CAPX/A$ are research and development and capital expenditure over assets, respectively. All quantities are adjusted for inflation.

multiplied by $\sigma_t(\log(M/A))$, the cross-sectional standard deviation of the forecasting variable $\log M/A$ in year $t$:

$$\left(\sqrt{\mathcal{V}_{FPE}}\right)_{t,h} = b_{t,h} \times \sigma_t(\log(M/A)). \tag{16}$$

We are interested in how this measure has evolved over time.

### 5.2. Price informativeness by horizon

Fig. 2 gives a first look by plotting average price informativeness by horizon and sub-period. We cap the horizon at five years to ensure that we have enough data to produce reliable estimates. The range between one and five years also covers the time span over which information can plausibly affect investment and investment can produce cash flows. For instance, the time-to-build literature finds that investment plans take about two years to implement with cash flows following in the years after that (Koeva, 2000). From a capital allocation perspective, the medium and long horizons are especially important.

The red line in Fig. 2 plots price informativeness at each horizon averaged over the full length of the sample. As expected, informativeness is positive; market prices are positive predictors of future earnings. Informativeness is also increasing with horizon. The reason is that while current earnings are already a good predictor of earnings one year later, prices are useful for predicting earnings further out.[8] This adds to the motivation for focusing on the longer horizons of three to five years.

The dashed black and dash-dotted blue lines in Fig. 2 plot average price informativeness for the first and second halves of our sample. Informativeness is higher in the second half at every horizon. The increase is itself increasing with horizon. One-year informativeness is only slightly higher, and three- and five-year informativeness show a much larger increase. From here on, for conciseness we focus on horizons of one, three, and five years ($h = 1, 3, 5$).

### 5.3. Price informativeness over time

Fig. 3 plots the time series of our estimates. Each panel holds horizon fixed and looks across time, ending in 2010 because the last years for which we have three- and five-year estimates are 2009 and 2011, respectively (our sample ends in 2014). Panels A and B show the forecasting coefficients $b_{t,h}$ from regressions (15), Panels C

[8] Formally, Fig. B1 in Appendix B shows that while the forecasting coefficient on prices $b_{t,h}$ is increasing with horizon, the forecasting coefficient on current earnings $c_{t,h}$ is decreasing with horizon. Thus, current earnings are relatively more informative at short horizons and prices are relatively more informative at long horizons.

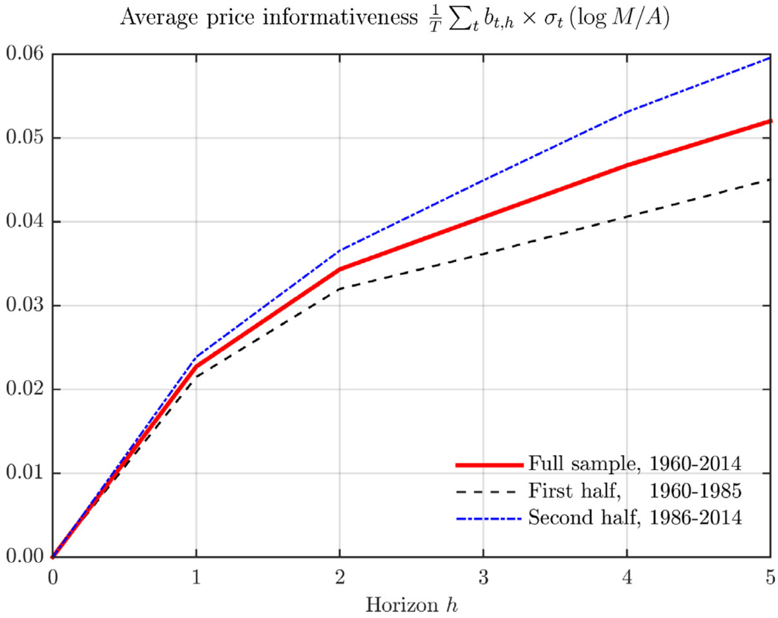


**Fig. 2.** Average price informativeness by horizon and subsample. This figure shows average price informativeness calculated from the cross-sectional forecasting regression (15): $E_{i,t+h}/A_{i,t} = a_{t,h} + b_{t,h}\log(M_{i,t}/A_{i,t}) + c_{t,h}(E_{i,t}/A_{i,t}) + d^s_{t,h}\mathbf{1}^s_{i,t} + \epsilon_{i,t,h}$, where $M$ is market cap, $A$ is total assets, $E$ is earnings before interest and taxes (EBIT), and $\mathbf{1}^s$ is a sector (one-digit SIC code) indicator variable. We run a separate regression for each year $t = 1960, \ldots, 2014$ and horizon $h = 1, \ldots, 5$. Price informativeness for year $t$ and horizon $h$ is $b_{t,h} \times \sigma_t(\log M/A)$, where $\sigma_t(\log M/A)$ is the cross-sectional standard deviation of $\log M/A$ in year $t$. The horizontal axis represents horizon $h$. The solid red line shows price informativeness at horizon $h$ averaged over the full sample, i.e., $\frac{1}{55}\sum_{t=1960}^{2014} b_{t,h} \times \sigma_t(\log M/A)$. The dashed black line is for the first half, 1960 to 1985, and the dash-dotted blue line is for the second half, 1986 to 2014. The sample contains S&P 500 nonfinancial firms from 1960 to 2014.

and D show price informativeness $b_{t,h} \times \sigma_t(\log M/A)$ from Eq. (16), and Panels E and F show the marginal contribution of market prices to the regression $R^2$, which measures the fraction of the ex post variation in future earnings that market prices capture. Noted are the fitted equations for linear time trends for the three- and five-year horizon estimates. The time trends are normalized so that the intercept measures the level in 1960 and the slope measures its cumulative change over the full sample period. Adjacent are $p$-values for the trend coefficients based on Newey–West standard errors with five lags to account for potential autocorrelation.[9]

The coefficients, informativeness, and marginal $R^2$ series are always positive, indicating that market prices are consistently positive predictors of future earnings. All series are typically higher at the longer horizons, consistent with the discussion in Section 5.2. A drop is evident in the three-year series at the end of the Nasdaq boom in 2000, when many high-valuation firms turned out to have low earnings ex post, but this drop is short-lived and does not influence the long-run trend.

Our key result is that the coefficients, marginal $R^2$, and, most important, the price informativeness series in Fig. 3 all show clear upward trends at the three- and five-year horizons. In terms of magnitudes, three-year price informativeness is about 60% higher in 2010 than in 1960, and the increase is highly statistically significant. Five-year informativeness is about 80% higher, and also highly significant. Because our measure is welfare-based, these numbers represent a substantial increase. By contrast, the one-year series show only a mild increase. Although the estimates can be noisy from year to year, the upward trend is steady throughout the five decades of our sample.[10] These results show that the extent to which market prices can be used to distinguish firms that will deliver high earnings in the future from those that will not has increased over the past five decades.

For a more detailed look, we run regressions of price informativeness at each horizon on a set of indicator variables, one for each decade in our sample:

$$\left(\widehat{\sqrt{\mathcal{V}_{FPE}}}\right)_{t,h} = a_h + \sum_d b_{d,h} \times \mathbf{1}^d_t + \epsilon_{t,h},$$
$$d = 1970\text{–}1979, \ldots, 2010\text{–}2014. \quad (17)$$

The baseline decade 1960–1969 is absorbed by the constant $a_h$. Each coefficient $b_{d,h}$ thus measures the difference

[9] Our choice of lag is based on two considerations. The first is that our estimates come from overlapping regressions, which can induce autocorrelation (for instance our five-year estimate for 1960 uses data from 1960 to 1965, that for 1961 uses data from 1961 to 1966, and so on). The longest overlap is from the five-year horizon, and this is why we use a lag of five years (for consistency, we apply the same lag at all horizons). The second consideration is that the optimal lag selection procedure of Newey and West (1994) implies an optimal lag of between four and five years. Our results are robust to alternative choices.

[10] There is no evidence of structural breaks anywhere in our sample, including the years 2000, 2001, and 2002, when Reg FD, decimalization, and the Sarbanes-Oxley Act were implemented, respectively. We report the results of structural break tests in Table 3 in Appendix B.

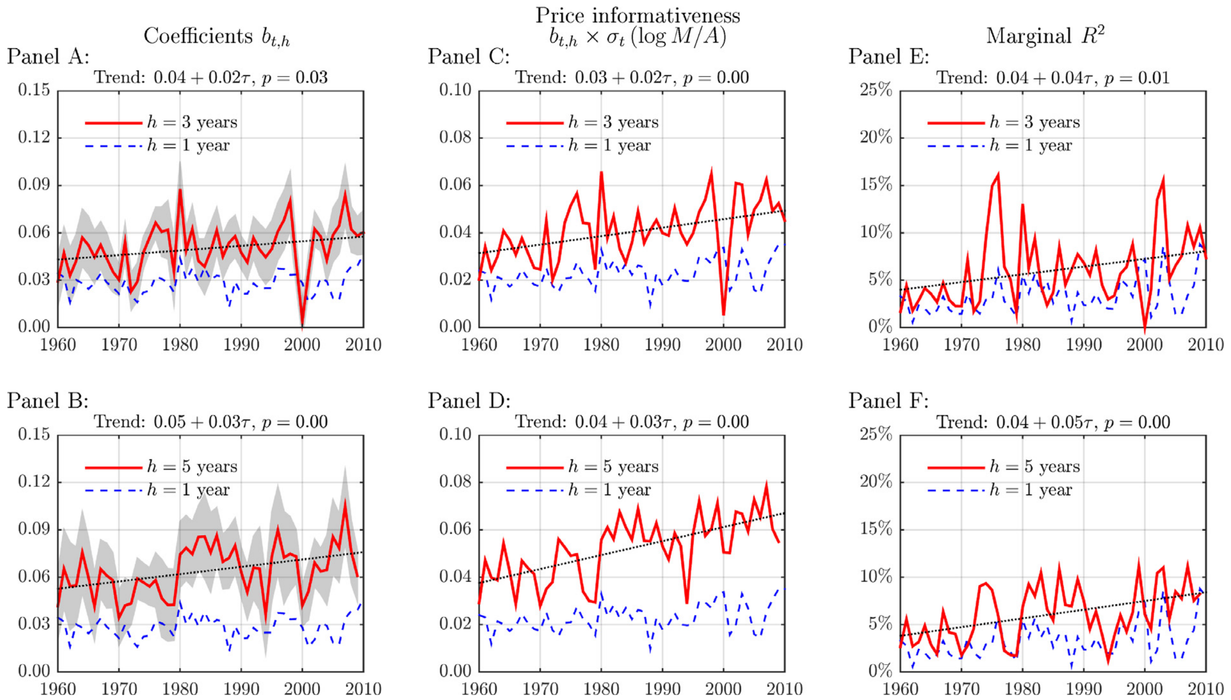


**Fig. 3.** Price informativeness over time. Results from the cross-sectional forecasting regression (15): $E_{i,t+h}/A_{i,t} = a_{t,h} + b_{t,h} \log(M_{i,t}/A_{i,t}) + c_{t,h}(E_{i,t}/A_{i,t}) + d^s_{t,h}\mathbf{1}^s_{i,t} + \epsilon_{i,t,h}$, where $M$ is market cap, $A$ is total assets, $E$ is earnings before interest and taxes (EBIT), and $\mathbf{1}^s$ is a sector (one-digit SIC code) indicator. We run a separate regression for each year $t = 1960, \ldots, 2014$ and horizon $h = 1, 3, 5$ (for $h = 5$ the last available estimate is for 2009). The coefficients $b_{t,\,h}$ are plotted inside a 95% confidence interval. Price informativeness is $b_{t,\,h} \times \sigma_t(\log M/A)$, where $\sigma_t(\log M/A)$ is the cross-sectional standard deviation of $\log M/A$ in year $t$. Above each plot is a linear time trend $\tau$ normalized to zero and one at the beginning and end of the sample (plotted in black dots) with $p$-value based on Newey–West standard errors with five lags. The marginal $R^2$ is the difference between the full-regression $R^2$ and the $R^2$ from a regression that omits $\log M/A$. The sample contains S&P 500 nonfinancial firms from 1960 to 2014.

in means between decade $d$ and the 1960s. As before, we compute Newey–West standard errors with five lags.

The first three columns of Table 2 present the results. Overall, they confirm the pattern in Fig. 3. The intercepts are positive, significant, and increasing with horizon. At the one-year horizon ($h = 1$), the coefficients on the decade dummy variables tend to be small, never larger than a quarter of the intercept, and often insignificant. Thus, one-year informativeness has increased only mildly over the course of our sample. Looking at three- and five-year informativeness ($h = 3$ and 5), on the other hand, the coefficients are much larger, highly significant, and, in some cases, over half the size of the intercept, especially in the later decades of the sample. For instance, five-year price informativeness is about 50% higher in the 2000s than in the 1960s. Table 2 thus confirms that the increase in medium- and longer-term price informativeness is both statistically and economically significant.

#### 5.3.1. Robustness

Columns 4–6 of Table 2 run regression (17) but with 1980–1989 as the baseline decade. This allows us to gauge whether changes in price informativeness have accelerated or decelerated in the latter half of the sample. Most, though not all, of the increase takes place before 1990. From Fig. 3, this is likely due to the dip in informativeness around 2000. The trend is otherwise steady and close to linear.[11]

Fig. 4 shows that the increase in price informativeness is robust to a number of variations. In the first variation, we replace the market value of equity with the sum of the market value of equity and the book value of long-term debt in calculating the valuation ratio in the forecasting regression (15). This ensures that our measure is not picking up changes in the relation between firm leverage and future earnings. As Panels A and B of Fig. 4 show, price informativeness continues to increase at the three- and five-year horizons even when we adjust for debt. The cumulative growth is 50% at three years and 70% at five years, which is very close to our baseline specification and highly significant. We do not adopt this as our main specification because debt is measured at book value and not market value.

Panels C–H of Fig. 4 show robustness to alternative measures of firm cash flows. Our main results use EBIT because it is most widely available and because it is the focus of market analysts. Here we consider EBITDA, net income, and cash flows from operations (CFO) as

[11] Table 2in Appendix B shows the full set of differences in means between each pair of decades in the sample. Nearly all differences between two subsequent decades are positive and those between decades that are farther apart are typically significant.

**Table 2**
Price informativeness over time. This table presents time series regressions of price informativeness by horizon. Price informativeness is calculated as in Eq. (16) using estimates from the cross-sectional forecasting regression (15). The price informativeness series are shown in Fig. 3. For this table, we regress the time series of price informativeness at a given horizon $h = 1, 3, 5$ years on a set of indicator variables corresponding to each decade in our sample. The baseline decade, 1960–1969 in Columns 1–3 and 1980–1989 in Columns 4–6, is absorbed by the constant. There are no five-year price informativeness estimates for 2010–2014 because our sample ends in 2014. Newey–West standard errors with five lags are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. The sample contains all S&P 500 non-financial firms from 1960 to 2014.

| | Price informativeness ($\times$ 100) | | | | | |
|---|---|---|---|---|---|---|
| | 1960–1969 baseline | | | 1980–1989 baseline | | |
| Decade | $h = 1$ (1) | $h = 3$ (2) | $h = 5$ (3) | $h = 1$ (4) | $h = 3$ (5) | $h = 5$ (6) |
| Constant (1960–1969 level) | 2.001*** | 3.111*** | 4.123*** | | | |
| | (0.059) | (0.184) | (0.111) | | | |
| Constant (1980–1989 level) | | | | 2.406*** | 4.186*** | 5.997*** |
| | | | | (0.188) | (0.276) | (0.075) |
| 1960–1969 | | | | −0.405** | −1.075*** | −1.874*** |
| | | | | (0.197) | (0.332) | (0.134) |
| 1970–1979 | 0.020 | 0.707* | −0.106 | −0.385* | −0.367 | −1.980*** |
| | (0.092) | (0.417) | (0.378) | (0.209) | (0.441) | (0.352) |
| 1980–1989 | 0.405** | 1.075*** | 1.874*** | | | |
| | (0.197) | (0.332) | (0.134) | | | |
| 1990–1999 | 0.413* | 1.406*** | 1.489*** | 0.008 | 0.331 | −0.385 |
| | (0.240) | (0.331) | (0.397) | (0.259) | (0.396) | (0.391) |
| 2000–2009 | 0.503*** | 1.561** | 2.143*** | 0.098 | 0.487 | 0.269 |
| | (0.185) | (0.583) | (0.311) | (0.257) | (0.618) | (0.300) |
| 2010–2014 | 0.314 | 0.840*** | | −0.091 | −0.235 | |
| | (0.288) | (0.253) | | (0.339) | (0.327) | |
| $R^2$ | 12.2% | 19.5% | 53.3% | 12.2% | 19.5% | 53.3% |
| Number of observations | 54 | 52 | 50 | 54 | 52 | 50 |

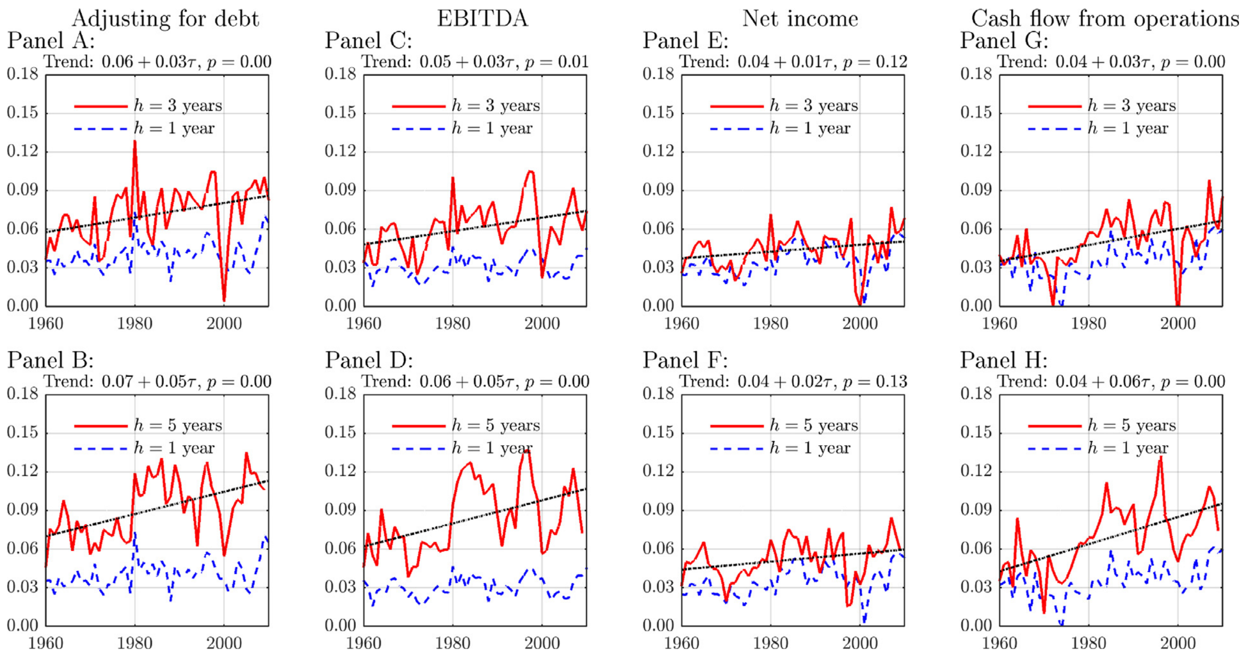


**Fig. 4.** Price informativeness over time, robustness. We report price informativeness under several variations. Price informativeness is calculated by running the forecasting regression (15) and taking the product of the forecasting coefficient and the cross-sectional standard deviation of market prices in year $t$, $b_{t,h} \times \sigma_t(\log M/A)$. Panels A and B add the book value of debt in calculating the valuation ratio (i.e., use $M + D$ instead of $M$). Panels C and D use earnings before interest, taxes, depreciation and amortization (EBITDA) to measure earnings. Panels E and F use net income and Panels F and G use cash flow from operations (CFO). Above each plot is a linear time trend $\tau$ normalized to zero and one at the beginning and end of the sample (plotted in black dots) with $p$-value based on Newey–West standard errors with five lags. The sample contains S&P 500 nonfinancial firms from 1960 to 2014.

alternatives.[12] Fig. 4 shows that price informativeness is increasing at three- and five-year horizons using any of these alternative measures. The increase is smallest using net income, 25% at the three-year horizon and 50% at the five-year horizon, and largest with CFO, 75% at the three-year horizon and 150% at the five-year horizon. All are highly significant except net income, which has $p$-values of 0.12 and 0.13. Overall, the robustness of the increase in price informativeness to a variety of measures suggests that it is not driven by issues related to accounting such as the extent to which firms smooth earnings.

### 5.3.2. Beyond the S&P 500

Fig. C.1 and Table C.2 in Appendix C replicate the analysis of this subsection for the universe of all firms. As in Table C.1, the composition of these firms has changed dramatically. Likely as a result of these changes, price informativeness beyond the S&P 500 appears to decline. The decline occurs precisely in the years in which observable characteristics change the most, which is consistent with a composition effect. This is best seen around the rise of Nasdaq in the 1980s, and, as Fama and French (2004) show, the observable changes are to a significant degree driven by the growing numbers of Nasdaq stocks. Short-horizon informativeness drops much more than long-horizon informativeness, so again there is relative improvement at the long end. We return to this sample in Section 5.7, where we look at institutional ownership. For now, the important point is that these observations motivate our focus on the S&P 500.

## 5.4. Market prices and investment

Having established that price informativeness has increased for comparable firms, a natural follow-up question is whether the greater informativeness extends to real firm decisions. Our framework predicts that as prices become more informative, they should predict investment more strongly. To test this prediction, we calculate the predicted variation of investment from prices. Following the procedure for calculating price informativeness (the predicted variation of earnings from prices), we run our forecasting regression (15) but with investment on the left instead of earnings. We also add current investment as an additional control. We look at both R&D and CAPX. To be precise, in the case of R&D, we run

$$\frac{R\&D_{i,t+h}}{A_{i,t}} = a_{t,h} + b_{t,h}\log\left(\frac{M_{i,t}}{A_{i,t}}\right) + c_{t,h}\left(\frac{E_{i,t}}{A_{i,t}}\right) + d_{t,h}\left(\frac{R\&D_{i,t}}{A_{i,t}}\right) + e^{s}_{t,h}\mathbf{1}^{s}_{i,t} + \epsilon_{i,t,h}. \tag{18}$$

Mandatory disclosure of R&D began in 1972, and so we restrict the sample for the R&D regression accordingly (prior to 1972, only about 50 S&P 500 firms report R&D). The predicted variation of investment from prices is then $b_{t,h} \times \sigma_t(\log(M/A))$. The results of this estimation are presented in Fig. 5 and Table 3.

Fig. 5 confirms that prices are positively related to future investment measured as either R&D or CAPX. For CAPX (Panels C and D), there is no trend in the predicted variation. Table 3 shows this formally. As in Table 1 and Fig. 1, CAPX has been trending down while R&D has been trending up. Thus, structural forces appear to be leading the importance of CAPX to diminish.

The key result of Fig. 5 is that the predicted variation of R&D from prices has increased substantially over our sample (Panels A and B). It is about four times higher in 2010 than in 1960, and the trend is highly significant. Table 3 confirms this result by computing differences in means relative to the baseline years 1972–1979. The differences are large, significant, and increasing over time. The upward trend can be seen even at the short one-year horizon. This is predicted by our theory because investment precedes earnings.

Market prices have thus become more informative about real firm decisions such as R&D. This finding is of particular interest because intangible capital is by nature harder to value, making any additional information particularly useful.

## 5.5. Market prices and returns

Our results so far show that price informativeness has risen. Our next task is to investigate the source of this result. As a first possibility, the increase could be due to a decrease in the cross-sectional predictability of returns. Asset prices are a combination of expected cash flows and expected returns (Campbell and Shiller, 1988). A drop in the cross-sectional variation of expected returns could cause the predicted variation of cash flows to rise. In other words, prices could become more informative about cash flows if they become less informative about returns. The cross-sectional variation of expected returns could decline for several reasons: risk prices could fall, the distribution of risk loadings (betas) could become more compressed, or there could be less "noise trading" in the language of models in the literature. The question for us is whether such a decline has occurred in the first place.

We can test for it by measuring the predicted variation of returns from prices and examining whether it has declined over time. We do so by running our usual forecasting regression (15) but with returns on the left instead of earnings:

$$\log R_{i,t\to t+h} = a_{t,h} + b_{t,h}\log\left(\frac{M_{i,t}}{A_{i,t}}\right) + c_{t,h}\left(\frac{E_{i,t}}{A_{i,t}}\right) + d^{s}_{t,h}\mathbf{1}^{s}_{i,t} + \epsilon_{i,t,h}, \tag{19}$$

where $\log R_{i,t\to t+h}$ is firm $i$'s log return at horizon $h$ starting in year $t$. The predicted variation of returns from

[12] CFO is calculated following Dechow, Sloan, and Sweeney (1995). This method relies on the balance sheet rather than the cash flow statement. We use it because cash flow statements are not available prior to the promulgation of FASB rule 95 in 1987. The two ways of measuring CFO have 92% correlation where they overlap. As in Dechow, Sloan, and Sweeney (1995) and Dechow, Kothari, and Watts (1998), we take the balance sheet-based measure for the whole sample to ensure our results are comparable over time.

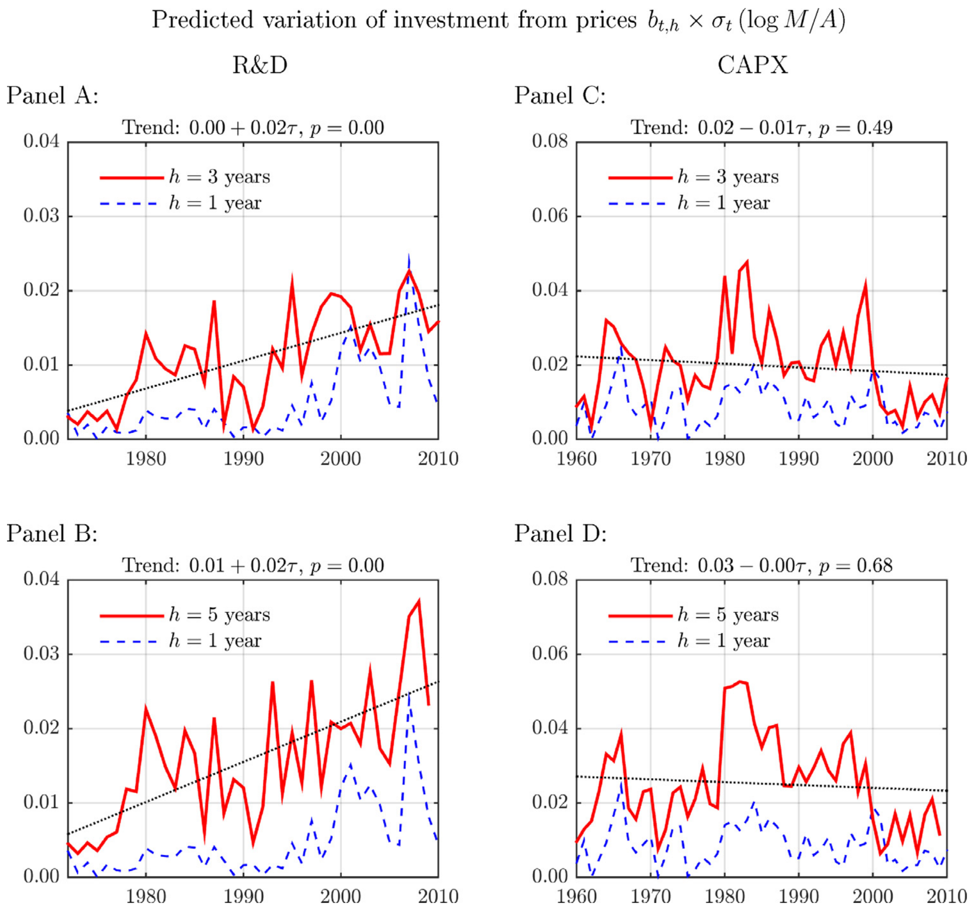


**Fig. 5.** Market prices and investment. The predicted variation of investment from prices calculated from the cross-sectional forecasting regression (18): $\frac{R\&D_{i,t+h}}{A_{i,t}} = a_{t,h} + b_{t,h} \log\left(\frac{M_{i,t}}{A_{i,t}}\right) + c_{t,h}\left(\frac{R\&D_{i,t}}{A_{i,t}}\right) + d_{t,h}\left(\frac{E_{i,t}}{A_{i,t}}\right) + e^{s}_{t,h}\mathbf{1}^{s}_{i,t} + \epsilon_{i,t,h}$, where $M$ is market cap, $A$ is total assets, $R\&D$ is research and development, $E$ is earnings before interest and taxes (EBIT), and $\mathbf{1}^s$ is a sector (one-digit SIC code) indicator. We run the same regressions for CAPX (capital expenditure). We run a separate regression for each year $t = 1960, \ldots, 2014$ and horizon $h = 1, 3, 5$ (for $h = 5$ the last available estimate is for 2009). Informativeness of prices for investment is $b_{t,h} \times \sigma_t(\log M/A)$, where $\sigma_t(\log M/A)$ is the cross-sectional standard deviation of $\log M/A$ in year $t$. Above each plot is a linear time trend $\tau$ normalized to zero and one at the beginning and end of the sample (plotted in black dots) with $p$-value based on Newey–West standard errors with five lags. The sample contains S&P 500 nonfinancial firms from 1960 to 2014 (data on R&D start in 1972).

prices in year $t$ at horizon $h$ is $b_{t,h} \times \sigma_t(\log M/A)$. The results from this estimation are presented in Fig. 6 and Table 4.

As Fig. 6 shows, market prices predict returns with a negative sign. This is the well-known value effect. Firms with high valuations, i.e. growth firms, tend to have lower average returns (e.g., Fama and French, 1992). Many theories, both rational and behavioral, have been proposed to explain the value effect. What matters for us is whether the value effect has become weaker over time in a way that could explain the observed increase in price informativeness.

The key result in Fig. 6 is that the predicted variation of returns from prices (solid red lines) does not exhibit a trend at any horizon. While the year-to-year estimates are noisy (reflecting the volatility of returns), the series are essentially flat at all horizons and the trend estimates are insignificant. For comparison, we also plot our price informativeness series (dashed black lines), which climb steadily throughout the sample as in Fig. 3.

Table 4 looks at the differences in means by decade relative to the 1960s. A couple of decade-indicator coefficients are significant, but their signs alternate between positive and negative. Thus, we find no evidence of a change in the relation between prices and expected returns that can account for the observed increase of price informativeness.

### 5.6. Aggregate efficiency

Our results so far indicate that price informativeness has risen and that this is driven by greater information about cash flows, not lower cross-sectional return predictability. The next question we ask is where the added information is coming from. As a first step, we want to know whether it is coming from greater information production or simply improved disclosure. Total information could have remained unchanged, but the amount of information firms disclose could have increased, perhaps due to more accurate financial reporting. This would make prices

**Table 3**
Market prices and investment. This table presents time series regressions of the predicted variation of investment from prices by horizon. The predicted variation of investment from prices is calculated as $b_{t,h} \times \sigma_t(\log M/A)$, where $b_{t,h}$ is the forecasting coefficient of prices ($\log M/A$) in regression (18) and $\sigma_t(\log M/A)$ is the cross-sectional standard deviation of $\log M/A$ in year $t$. The predicted variation of investment from prices series are shown in Fig. 5. For this table we regress the predicted variation series at a given horizon $h = 1, 3, 5$ years on a set of indicator variables corresponding to each decade in our sample [the baseline decade, 1960–1969 for capital expenditure (CAPX) and 1972–1979 for research and development (R&D), is absorbed by the constant]. There are no five-year predicted variation estimates for 2010–2014 because our sample ends in 2014. Newey–West standard errors with five lags are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. The sample contains all S&P 500 non-financial firms from 1960 to 2014 (R&D data start in 1972).

| | Predicted variation of investment from prices (×100) | | | | | |
|---|---|---|---|---|---|---|
| | R&D | | | CAPX | | |
| | $h=1$ | $h=3$ | $h=5$ | $h=1$ | $h=3$ | $h=5$ |
| Decade | (1) | (2) | (3) | (4) | (5) | (6) |
| Constant (1960–1969 level) | | | | 0.942*** | 1.867*** | 2.206*** |
| | | | | (0.212) | (0.357) | (0.325) |
| Constant (1972–1979 level) | 0.134*** | 0.379*** | 0.636*** | | | |
| | (0.027) | (0.076) | (0.153) | | | |
| 1970–1979 | | | | −0.325 | −0.238 | −0.244 |
| | | | | (0.232) | (0.396) | (0.353) |
| 1980–1989 | 0.153*** | 0.669*** | 0.908*** | 0.411 | 1.209** | 1.930*** |
| | (0.048) | (0.091) | (0.160) | (0.250) | (0.541) | (0.610) |
| 1990–1999 | 0.147 | 0.779** | 0.920*** | −0.166 | 0.630 | 0.813** |
| | (0.088) | (0.287) | (0.249) | (0.216) | (0.470) | (0.337) |
| 2000–2009 | 1.028*** | 1.264*** | 1.761*** | −0.266 | −0.911** | −0.903** |
| | (0.097) | (0.127) | (0.298) | (0.302) | (0.370) | (0.344) |
| 2010–2014 | 0.401*** | 1.166*** | | −0.453* | −0.455 | |
| | (0.040) | (0.077) | | (0.226) | (0.365) | |
| $R^2$ | 63.7% | 50.6% | 51.0% | 24.9% | 46.8% | 64.3% |
| Number of observations | 42 | 40 | 38 | 54 | 52 | 50 |

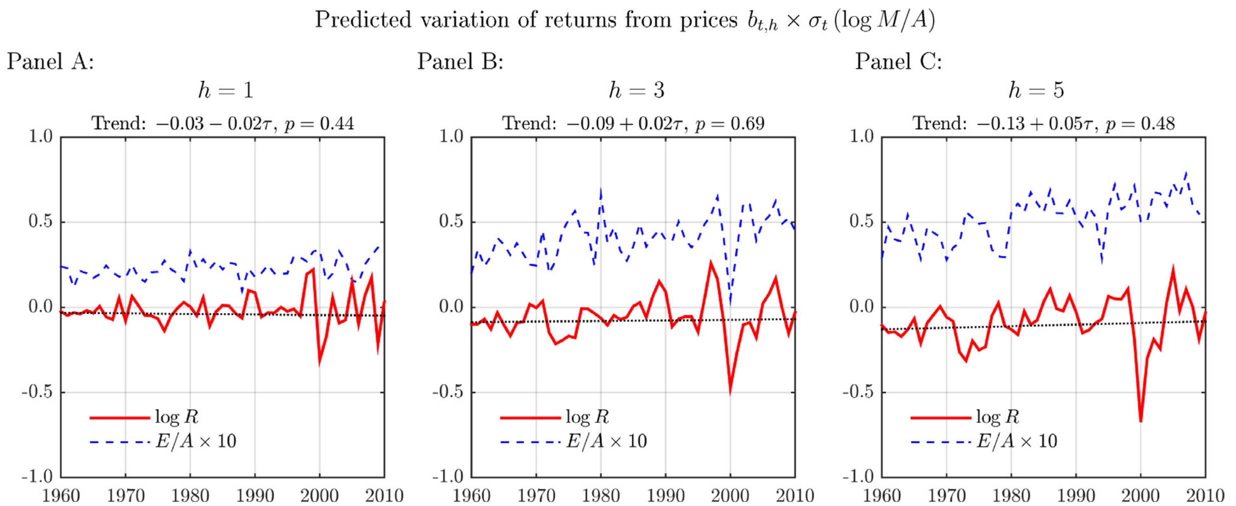


**Fig. 6.** Market prices and returns. The predicted variation of returns from prices calculated from the cross-sectional return predictability regression (19): $\log R_{i,t\to t+h} = a_{t,h} + b_{t,h}\log(M_{i,t}/A_{i,t}) + c_{t,h}(R\&D_{i,t}/A_{i,t}) + d_{t,h}(E_{i,t}/A_{i,t}) + e^s_{t,h}\mathbf{1}^s_{i,t} + \epsilon_{i,t,h}$, where $\log R_{t\to t+h}$ is the log return from $t$ to $t+h$, $M$ is market cap, $A$ is total assets,$E$ is earnings before interest and taxes (EBIT), and $\mathbf{1}^s$ is a sector (one-digit SIC code) indicator variable. We run a separate regression for each year $t = 1960, \ldots, 2014$ and horizon $h = 1, 3, 5$ (for $h = 5$ the last available estimate is for 2009). The predicted variation of returns from prices (solid red lines) is $b_{t,h} \times \sigma_t(\log M/A)$, where $\sigma_t(\log M/A)$ is the cross-sectional standard deviation of $\log M/A$ in year $t$. Above each plot is a linear time trend $\tau$ normalized to zero and one at the beginning and end of the sample (plotted in black dots) with $p$-value based on Newey–West standard errors with five lags. We also plot price informativeness (the predicted variation of earnings from prices) for comparison (dashed black lines). The sample contains S&P 500 nonfinancial firms from 1960 to 2014.

more informative (FPE would go up) but it would not significantly improve real allocations (RPE would remain the same).

We can test the disclosure hypothesis using Prediction 1 in Section 3, which says that while an increase in disclosure increases price informativeness (FPE), it leaves aggregate efficiency unchanged. This is because aggregate efficiency depends on the information available to the firm's manager, which is unaffected by disclosure. Thus, to test the disclosure hypothesis, we need

**Table 4**
Market prices and returns. This table presents time series regressions of the predicted variation of returns from prices by horizon. The predicted variation of returns from prices is calculated as $b_{t,h} \times \sigma_t(\log M/A)$, where $b_{t,h}$ is the forecasting coefficient of prices ($\log M/A$) in regression (19) and $\sigma_t(\log M/A)$ is the cross-sectional standard deviation of $\log M/A$ in year $t$. The resulting series are shown in Fig. 6. For this table, we regress the predicted variation series at a given horizon $h = 1, 3, 5$ years on a set of indicator variables corresponding to each decade in our sample (the baseline decade, 1960–1969, is absorbed by the constant). There are no five-year estimate for 2010–2014 because our sample ends in 2014. Newey-West standard errors with five lags are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. The sample contains all S&P 500 non-financial firms from 1960 to 2014.

| | Predicted variation of returns from prices ($\times 100$) | | |
|---|---|---|---|
| Decade | $h = 1$ (1) | $h = 3$ (2) | $h = 5$ (3) |
| Constant (1960–1969 level) | −3.214*** | −8.712*** | −11.101*** |
| | (0.274) | (0.907) | (2.162) |
| 1970–1979 | −1.197 | −0.884 | −4.449 |
| | (0.983) | (3.054) | (4.081) |
| 1980–1989 | 0.395 | 4.686** | 5.894* |
| | (0.607) | (1.787) | (3.416) |
| 1990–1999 | 1.172** | 3.416** | 4.592 |
| | (0.502) | (1.371) | (2.888) |
| 2000–2009 | −6.421* | −3.947 | −4.987 |
| | (3.196) | (6.322) | (9.293) |
| 2010–2014 | 2.491*** | 5.189*** | |
| | (0.371) | (0.934) | |
| $R^2$ | 23.2% | 13.6% | 14.4% |
| Number of observations | 54 | 52 | 50 |

to see if aggregate efficiency has increased with price informativeness. This exercise is of interest more broadly as aggregate efficiency is a key factor in economic growth.

Although aggregate efficiency is not observed, we can use our theoretical framework to bound it between two measurable quantities.

*Claim 1. Aggregate efficiency $\mathcal{V}_M$ is bounded by the predicted variance of cash flows from investment, $\mathbb{V}\mathrm{ar}\left(\mathbb{E}\left[v/\bar{k} \middle| k^\star\right]\right)$, and the cross-sectional variance of scaled investment, $\mathbb{V}\mathrm{ar}\left(\gamma k^\star/\bar{k}\right)$:*

$$\mathbb{V}\mathrm{ar}\left(\mathbb{E}\left[\frac{v}{\bar{k}}\middle|k^\star\right]\right) \;\le\; \mathcal{V}_M \;\le\; \mathbb{V}\mathrm{ar}\left(\gamma\frac{k^\star}{\bar{k}}\right). \tag{20}$$

The inequality on the right comes from the first-order condition (2). In our framework, because $\gamma k^\star/\bar{k} = \mathbb{E}\left[z \mid \eta, \eta', p\right]$, investment perfectly reveals the information of the manager, resulting in an equality. In practice, investment is noisy and lumpy, increasing the measured variance and resulting in a strict inequality.

The inequality on the left simply reflects the fact that investment is chosen by the manager, hence it is included in the manager's information set. When cash flows from assets in place and growth options are perfectly correlated as in Eq. (1), investment is an optimal forecast of total cash flows, resulting in an equality. When this is not the case, investment is an optimal forecast only of cash flows from growth options, and not overall cash flows, resulting in a strict inequality (we explore this case in Section 5.10).

From Fig. 1 and Table 1, the cross-sectional dispersion in investment rates has risen in the case of R&D but not CAPX. Yet the average rate of CAPX has fallen (so the dispersion has risen relative to the mean). This again highlights the general decline in importance of CAPX.

By contrast, for R&D there is a dramatic increase in dispersion. The cross-sectional standard deviation of R&D over assets has nearly doubled from 2.8% in the first half of our sample to 5.0% in the second half. From Fig. 1, R&D has also become much more skewed. Firms in the 90th percentile now spend 10% of assets on R&D each year compared with 5% in the 1960s (the 10th percentile remains close to zero). The increased cross-sectional variation in investment as measured by R&D is consistent with managers having more information and allocating investment accordingly.

From Claim 1, the variation in investment rates represents an upper bound on aggregate efficiency. To calculate a lower bound, we need to measure the predicted variation of earnings from investment. We do so by replacing market prices with investment in our main forecasting regression (15):

$$\frac{E_{i,t+h}}{A_{i,t}} = a_{t,h} + b_{t,h}\log\left(\frac{R\&D_{i,t}}{A_{i,t}}\right) + c_{t,h}\log\left(\frac{CAPX_{i,t}}{A_{i,t}}\right) + d_{t,h}\left(\frac{E_{i,t}}{A_{i,t}}\right) + e^s_{t,h}\mathbf{1}^s_{i,t} + \epsilon_{i,t,h}. \tag{21}$$

We include R&D and CAPX side by side to extract as much information from investment as possible.[13] The predicted variation of earnings from investment is the standard deviation of the fitted value based on investment:

$$\sigma_t\left(b_{t,h}\log\left(\frac{R\&D_{i,t}}{A_{i,t}}\right) + c_{t,h}\log\left(\frac{CAPX_{i,t}}{A_{i,t}}\right)\right). \tag{22}$$

The results are presented inFig. 7 and Table 5. We include a specifications with R&D as the sole predictor (equivalent to imposing $c_{t,h} = 0$ above) and one with both R&D and CAPX.

Fig. 7 shows a modest and insignificant increase in the predicted variation of earnings from investment at the three-year horizon. The increase at the five-year horizon is larger and significant at the 10% level. The marginal significance is due to the high level of noisiness in the estimates, perhaps as a result of measurement error and the lumpiness of investment. The magnitudes are comparable to the increase in price informativeness: about 50% at the five-year horizon over a somewhat shorter period (1972–2010 versus 1960–2010). Table 5 looks at differences in means by decade. The increase in five-year investment informativeness between 1972–1979 and 2000–2009 is statistically significant at the 10% level with R&D only and at the 5% level with both R&D and CAPX. In the case of R&D and CAPX, there is also significance for the earlier decades.

Our results thus show that the variation in investment and the predicted variation of earnings from investment

[13] We did not take logs of investment rates in Section 5.4 because investment there served as a real outcome variable and not an information signal. We take logs here as we did with market prices because doing so mitigates skewness and thus improves forecastability.

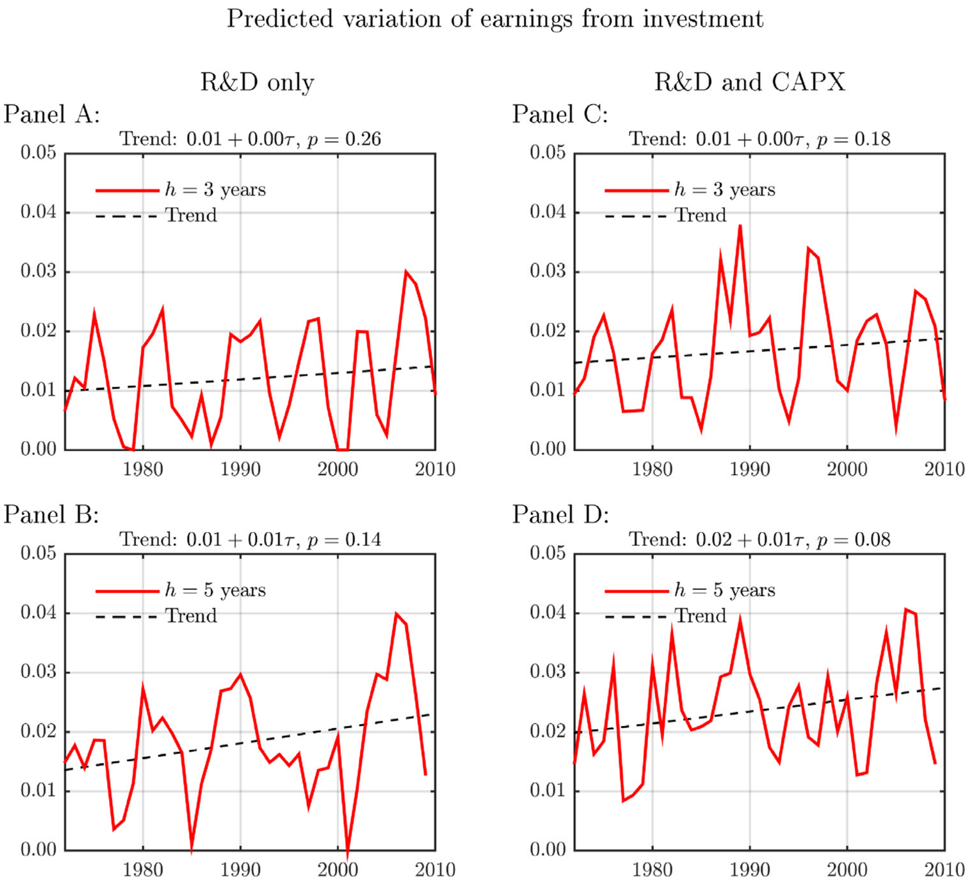


**Fig. 7.** Aggregate efficiency. The predicted variation of earnings from investment calculated from the forecasting regression (21): $\frac{E_{i,t+h}}{A_{i,t}} = a_{t,h} + b_{t,h} \log\left(\frac{R\&D_{i,t}}{A_{i,t}}\right) + c_{t,h} \log\left(\frac{CAPX_{i,t}}{A_{i,t}}\right) + d_{t,h}\left(\frac{E_{i,t}}{A_{i,t}}\right) + e^{s}_{t,h}\mathbf{1}^{s}_{i,t} + \epsilon_{i,t,h}$, where *R&D* is research and development, *CAPX* is capital expenditure, *M* is market cap, *A* is total assets, *E* is earnings before interest and taxes (EBIT), and $\mathbf{1}^s$ is a sector (one-digit SIC code) indicator variable. We run a separate regression for each year $t = 1972, \ldots, 2014$ and horizon $h = 1, 3, 5$ (for $h = 5$ the last available estimate is for 2009). The predicted variation of earnings from investment (solid red lines) is $\sigma_t\left(b_{t,h} \log R\&D/A + c_{t,h} \log CAPX/A\right)$, the cross-sectional standard deviation of the fitted linear combination of *R&D/A* and *CAPX/A* in year *t*. Above each plot is a linear time trend $\tau$ normalized to zero and one at the beginning and end of the sample (plotted in black dashes) with *p*-value based on Newey–West standard errors with five lags. The sample contains S&P 500 nonfinancial firms from 1972 to 2014 (R&D data start in 1972).

have both increased, at least when it comes to R&D.[14] Based on the logic of Claim 1, these findings suggest that aggregate efficiency has increased. This evidence favors the view that information production has increased over the view that the increased price informativeness is due to improved firm disclosure.

### 5.7. Institutional ownership and price informativeness

The key remaining question is whether the increased information production has taken place in markets or inside firms. In the framing of Section 3, we want to distinguish between parts (i) and (ii) of Prediction 1. Under part (i), as market participants produce more information, FPE, aggregate efficiency, and RPE all increase. Under part (ii), as firms produce more information, FPE and aggregate efficiency increase but RPE does not.

Pinpointing exactly where information is produced is a challenging task. The ideal experiment would randomize firms' exposure to market-based information production or their capacity to produce information internally and determine which source of variation results in the biggest increase in price informativeness. This ideal experiment is not available to us because our analysis takes place at a high level of aggregation over a long period of time. Our best alternative is to cut the data in ways that proxy for one type of variation or the other. Here and in Sections 5.8–5.10, we do this in four different ways.

Our first test cuts the data by institutional ownership. Among the most salient trends in financial markets in recent decades is the rise of institutional ownership. The median institutional share has increased from 12% in 1980 to 69% in 2014 among all firms and from 39% to 80% among S&P 500 firms. The difference between the two groups comes from the low end of the distribution. The 10th

[14] Looking at both measures is especially useful because the results are unlikely to be driven by changes in measurement error. The reason is that measurement error tends to push the two measures in opposite directions, whereas we see them moving in the same direction.

**Table 5**

Aggregate efficiency. This table presents time series regressions of the predicted variation of earnings from investment by horizon. The predicted variation of earnings from investment is calculated as $\sigma_t\left(b_{t,h}\log R\&D/A + c_{t,h}\log CAPX/A\right)$, the cross-sectional standard deviation of the fitted linear combination of $R\&D/A$ and $CAPX/A$ (R&D is research and development and CAPX is capital expenditure) in year $t$ from regression (21). We also show results for R&D only, obtained by imposing $c_{t,h} = 0$ in regression (21) and in the calculation of the predicted variation above. The resulting predicted variation series are shown in Fig. 7. For this table, we regress the predicted variation series at a given horizon $h = 1, 3, 5$ years on a set of indicator variables corresponding to each decade in our sample (the baseline decade, 1972–1979, is absorbed by the constant). There are no five-year estimate for 2010–2014 because our sample ends in 2014. Newey-West standard errors with five lags are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. The sample contains all S&P 500 non-financial firms from 1960 to 2014 (R&D data start in 1972).

| | Predicted variation of earnings from investment ($\times$100) | | | | | |
|---|---|---|---|---|---|---|
| | R&D only | | | R&D and CAPX | | |
| Decade | $h = 1$ (1) | $h = 3$ (2) | $h = 5$ (3) | $h = 1$ (4) | $h = 3$ (5) | $h = 5$ (6) |
| Constant (1972–1979 level) | 0.438*** | 0.911*** | 1.299*** | 0.678*** | 1.243*** | 1.700*** |
| | (0.111) | (0.260) | (0.207) | (0.057) | (0.205) | (0.225) |
| 1980–1989 | −0.018 | 0.192 | 0.596 | 0.283** | 0.600 | 1.018*** |
| | (0.189) | (0.473) | (0.361) | (0.124) | (0.409) | (0.299) |
| 1990–1999 | 0.227* | 0.533* | 0.396 | 0.287* | 0.646** | 0.559** |
| | (0.121) | (0.299) | (0.344) | (0.159) | (0.290) | (0.245) |
| 2000–2009 | 0.146 | 0.540 | 0.992* | 0.386 | 0.587** | 0.907** |
| | (0.149) | (0.495) | (0.520) | (0.270) | (0.252) | (0.389) |
| 2010–2014 | −0.032 | −0.431 | | −0.014 | −0.421 | |
| | (0.235) | (0.299) | | (0.202) | (0.265) | |
| $R^2$ | 5.2% | 10.0% | 15.0% | 7.3% | 13.2% | 20.2% |
| Number of observations | 42 | 40 | 38 | 42 | 40 | 38 |

and 90th percentiles among all firms in 2014 are 12% and 94%, whereas among S&P 500 firms they are 61% and 94%. Hence, while both groups have seen a large increase in average institutional share, the set of all firms offers much more cross-sectional variation. For this reason, in this test we use the sample of all firms.

Our test is predicated on the idea that institutional investors are more likely than retail investors to produce independent information due to their greater scale, expertise, and professional resources. Based on this idea, if higher institutional ownership is associated with higher price informativeness, it would provide evidence consistent with the hypothesis that the rise in institutional ownership has contributed to the rise in price informativeness. This would then suggest that RPE has increased.

For this test, we split firms into groups with high and low institutional share with the median institutional share in each year as the cutoff. We then run the forecasting regression (15) separately for each group and calculate price informativeness as in Eq. (16).

Fig. 8 presents the results. While the average institutional share for both the high and low groups has been trending up over time, the high group has seen a somewhat larger increase (solid red line) so that the gap between them has grown.

In Section 5.3 we saw that price informativeness outside the S&P 500 appears decline, likely due to compositional changes. Fig. 8 shows that this decline is entirely contained among firms with low institutional ownership (dashed black lines). The high group has much higher price informativeness and shows no sign of a decrease. The differences are very large. Three-year price informativeness is three times larger for the high group than the low group. At the five-year horizon, it is 50% larger. The two groups are far enough apart that their price informativeness series never cross.

**Table 6**

Institutional ownership and price informativeness. This table presents time series regressions of the difference in price informativeness between firms with high and low institutional ownership, using the median institutional share in each year as the cutoff. Price informativeness is obtained separately for each group by running the forecasting regression (15) and calculating the product of the forecasting coefficient and the cross-sectional standard deviation of market prices in year $t$, $b_{t,h} \times \sigma_t(\log M/A)$. The price informativeness series are shown in Fig. 8. For this table, we regress the difference in price informativeness between the high and low institutional share groups at a given horizon $h = 1, 3, 5$ years on a set of indicator variables corresponding to each decade in our sample (the baseline decade, 1980–1989, is absorbed by the constant). There are no five-year price informativeness estimates for 2010–2014 because our sample ends in 2014. Newey–West standard errors with five lags are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. The sample contains all non-financial firms from 1980 to 2014, the period over which institutional ownership data are available.

| | Price informativeness ($\times$100) high − low institutional ownership | | |
|---|---|---|---|
| Decade | $h = 1$ (1) | $h = 3$ (2) | $h = 5$ (3) |
| Constant (1980–1989 level) | 2.526*** | 2.842*** | 2.376*** |
| | (0.304) | (0.123) | (0.255) |
| 1990–1999 | 0.805** | 1.996*** | 2.981*** |
| | (0.387) | (0.309) | (0.452) |
| 2000–2009 | 0.700 | 1.401*** | 1.623** |
| | (0.522) | (0.331) | (0.650) |
| 2010–2014 | −0.249 | 2.040*** | |
| | (0.312) | (0.129) | |
| $R^2$ | 22.6% | 49.6% | 56.3% |
| Number of observations | 33 | 31 | 29 |

Table 6 provides a formal test. We regress the difference in price informativeness between the high and low groups on decade dummies. The large and highly significant constants indicate that informativeness is much larger for firms with high institutional ownership at all

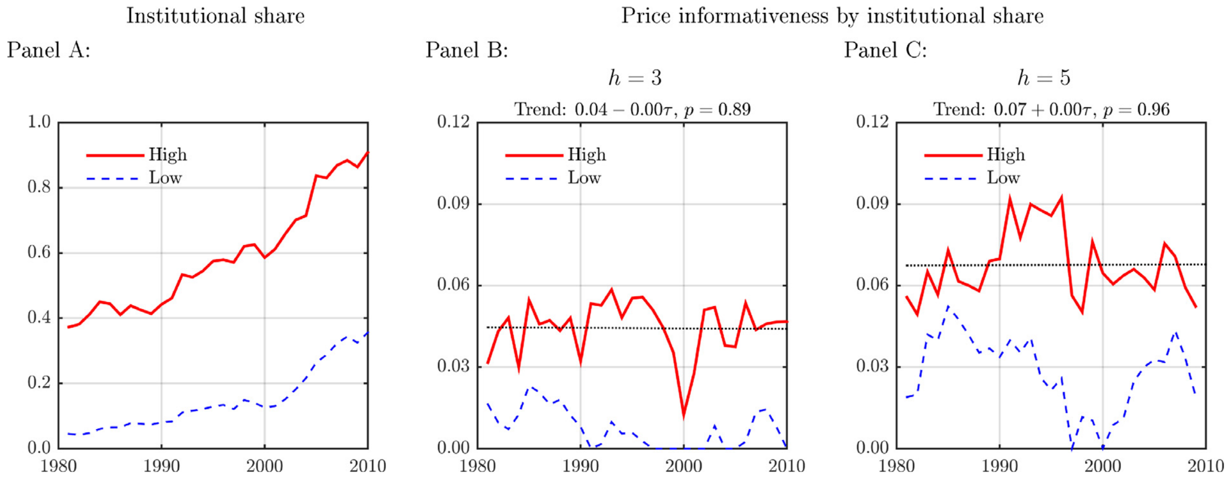


**Fig. 8.** Institutional ownership and price informativeness. We compare price informativeness for firms with high and low levels of institutional ownership, using the median institutional share in each year as the cutoff. Panel A plots the average institutional share for firms in each group. Price informativeness is obtained separately for each group by running the forecasting regression (15) and calculating the product of the forecasting coefficient and the cross-sectional standard deviation of market prices in year $t$, $b_{t,h} \times \sigma_t(\log M/A)$, $h = 3, 5$. Above each price informativeness plot is a linear time trend $\tau$ normalized to zero and one at the beginning and end of the sample (plotted in black dots) with $p$-value based on Newey–West standard errors with five lags. The sample contains all nonfinancial firms from 1980 to 2014 (institutional ownership data begin in 1980).

horizons. Because institutional ownership data are available only after 1980, testing for trends here is harder, yet, from the three- and five-year horizons, the gap in informativeness has expanded just as the gap in institutional share in Fig. 8 has grown.

The results of this subsection demonstrate a strong relation between institutional ownership and price informativeness. This is consistent with the view that institutional investors engage in information production and by doing so contribute to a rise in revelatory price efficiency.

### *5.8. Option trading and price informativeness*

In the second cross-sectional test, we examine the relation between price informativeness and option trading. The CBOE has been listing options of firms in a staggered manner since 1973. Our test is predicated on the idea that options facilitate the incorporation of market-based information into prices by providing liquidity, opportunities to hedge, embedded leverage, and a low-cost way to short sell. Based on this idea, a positive relation between price informativeness and option trading would suggest an increase in RPE.

Panels A and B of Fig. 9 compare price informativeness for S&P 500 firms with and without option listings. While the two groups have similar levels of price informativeness, the upward trend is visible only for the listed firms, for which it is large and highly significant. The flatness of the series for the unlisted group could be due to its declining membership, from 461 in 1973 to just 78 at the end of our sample (the series becomes noisy in later years). We are thus mainly interested in the difference between the two groups, and here the upward trend can be seen more clearly. In Panel A of Table 7, we again regress the difference in price informativeness between the two groups on decade dummies. The negative intercept implies that listed firms had lower price informativeness in the 1970s when options began trading. The coefficients for the later decades, however, are positive and significant, indicating that the rise in price informativeness is stronger among firms with traded options.

In part to control for the changing composition of the listed and unlisted groups, we look at the intensive margin by comparing price informativeness for firms with high and low levels of option turnover. We calculate option turnover as annual option volume divided by equity shares outstanding. Intuitively, the impact of option trading on price informativeness should depend on the size of the option market relative to the equity market. Because option volume data (from OptionMetrics) are available only after 1996, we cannot evaluate trends. It is nevertheless useful to look at the level of price informativeness for the two groups and consider it with the upward trend in option trading in mind.

The results are shown in Panels C and D of Fig. 9. Price informativeness tends to be higher for firms with high levels of option turnover. Panel B of Table 7 confirms that the difference is highly statistically significant. Thus, option trading is positively related to price informativeness.

Based on the idea that options facilitate market-based information production, these results are also consistent with the view that the observed increase in price informativeness is associated with greater revelatory price efficiency.

### *5.9. Liquidity and price informativeness*

In our third cross-sectional test, we examine the relation between liquidity and price informativeness. The past five decades have witnessed an enormous expansion of liquidity in financial markets. As one metric, the typical S&P 500 firm had monthly share turnover of just 1.6% in 1960 versus 20% in 2014 (turnover peaked at 42% in 2009). The increase in liquidity motivates us to ask whether financial market prices have become more informative. After all, private information enters the market through trading. The

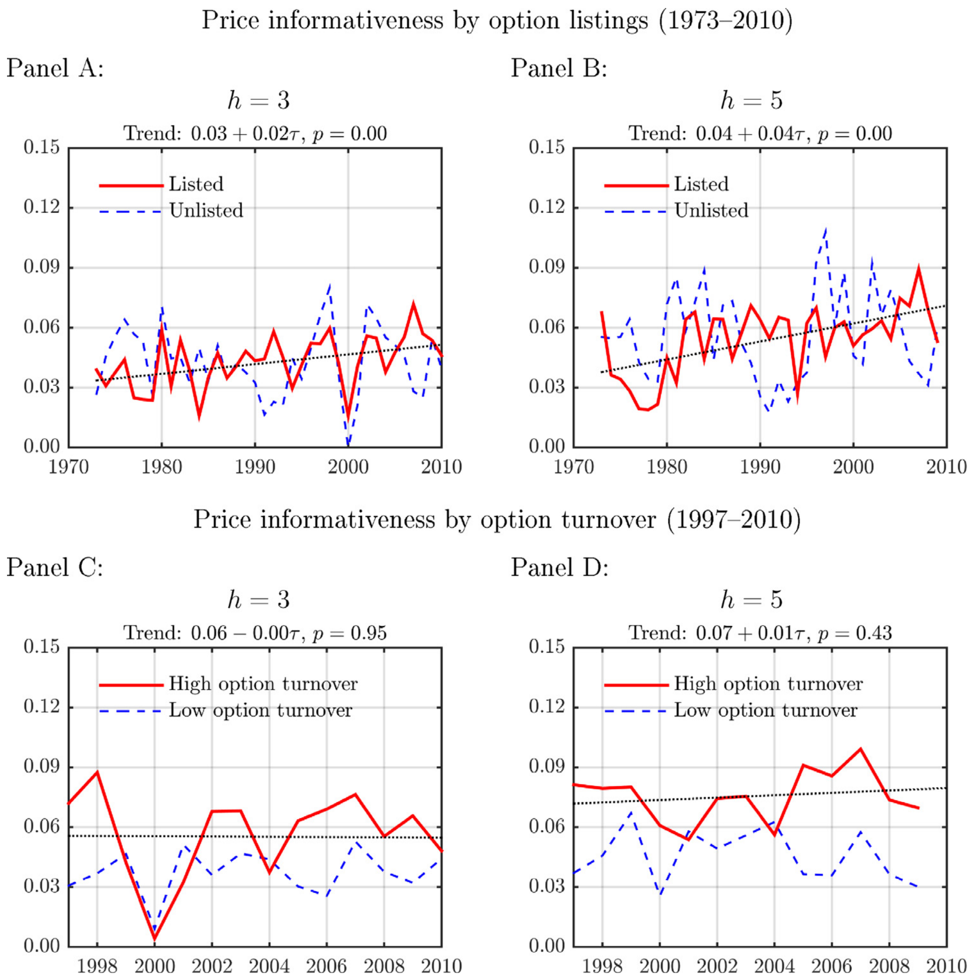


**Fig. 9.** Option trading and price informativeness. We compare price informativeness for firms with and without option listings and for firms with high and low option turnover, using median option turnover in each year as the cutoff. Option turnover is one hundred times option volume over a year divided by equity shares outstanding. Price informativeness is obtained separately for each group by running the forecasting regression (15) and calculating the product of the forecasting coefficient and the cross-sectional standard deviation of market prices in year $t$, $b_{t,h} \times \sigma_t(\log M/A)$. Above each plot is a linear time trend $\tau$ normalized to zero and one at the beginning and end of the sample (plotted in black dots) with $p$-value based on Newey–West standard errors with five lags. The sample contains S&P 500 nonfinancial firms from 1973 to 2014 for the option listing test (option listing begins in 1973), and 1997 to 2014 for the option turnover test (option volume is from OptionMetrics, which begins coverage in 1996).

opportunity to trade in a liquid market also increases the incentive to produce information in the first place.

In this section we split our sample into high and low turnover groups using the median turnover rate in each year as the cutoff. Under the view that liquidity facilitates information production, price informativeness should be higher for the high turnover group.

Fig. 10 shows the results. Average log turnover has increased strongly for both groups. There is also some convergence as the gap has narrowed over time.

The main result in Fig. 10 is that price informativeness is on average higher for the high-turnover group. This is true at both the three- and five-year horizons. Price informativeness also rises for both groups over time, consistent with the rise in their turnover rates.

Columns 4–6 of Table 8 run a formal test. We are mainly interested in the constant, which measures the difference in price informativeness between the high- and low-turnover groups. This constant is positive and highly statistically significant. In terms of magnitudes, five-year informativeness is two points or 50% higher for the high-turnover group than the low-turnover group. Most of the decade dummies are negative (though few are significant), indicating that the two groups have seen their price informativeness converge in line with their turnover rates.

These results show that higher liquidity is associated with higher price informativeness. As liquidity has risen significantly over time, this finding supports the view that rising liquidity has contributed to the observed rise in price informativeness and an increase in RPE.

### 5.10. Growth options and price informativeness

In disentangling RPE and FPE, we have so far exploited variation in information production in markets. In this subsection, we exploit variation in information production

**Table 7**
Option trading and price informativeness. This table presents time series regressions of the difference in price informativeness between firms with and without option listings (Panel A) and difference in means test of price informativeness of firms with high and low option turnover (Panel B). Option turnover is one hundred times annual option volume divided by equity shares outstanding. Price informativeness is obtained separately for each group by running the forecasting regression (15) and calculating the product of the forecasting coefficient and the cross-sectional standard deviation of market prices in year $t$, $b_{t,h} \times \sigma_t(\log M/A)$. The price informativeness series are shown in Fig. 9. In Panel A, we regress the difference in price informativeness between the listed and unlisted groups at a given horizon $h = 1, 3, 5$ years on a set of indicator variables corresponding to each decade in our sample (the baseline decade, 1973–79, is absorbed by the constant). There are no five-year price informativeness estimates for 2010–2014 because our sample ends in 2014. In Panel B, we run a difference in means test for the price informativeness of high and low option turnover firms. Newey–West standard errors with five lags are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. The sample contains all S&P 500 non-financial firms from 1973 to 2014 for Panel A (option listings begin in 1973) and 1997 to 2014 for Panel B (OptionMetrics begins in 1996).

| *Panel A: option listing* | Price informativeness ($\times$100) listed − unlisted firms | | |
|---|---|---|---|
| Decade | $h = 1$ (1) | $h = 3$ (2) | $h = 5$ (3) |
| Constant (1973–79 level) | −0.873*** | −1.491*** | −1.623*** |
| | (0.162) | (0.446) | (0.390) |
| 1980–1989 | 0.682** | 1.111** | 0.573 |
| | (0.285) | (0.498) | (0.780) |
| 1990–1999 | 1.335*** | 2.136** | 2.188 |
| | (0.294) | (0.906) | (1.601) |
| 2000–2009 | 1.077*** | 2.455*** | 2.445** |
| | (0.376) | (0.759) | (0.961) |
| 2010–2014 | 1.217*** | 1.810*** | |
| | (0.199) | (0.457) | |
| $R^2$ | 22.0% | 21.7% | 13.0% |
| Number of observations | 41 | 39 | 37 |
| *Panel B: option turnover* | Price informativeness ($\times$100) high − low option turnover firms | | |
| | $h = 1$ (1) | $h = 3$ (2) | $h = 5$ (5) |
| Difference in means | 1.151*** | 1.800*** | 2.949*** |
| | (0.212) | (0.443) | (0.564) |
| Number of observations | 17 | 15 | 13 |

inside firms. To do this, we first extend our framework from Section 3 by incorporating firm heterogeneity. A particularly relevant source of heterogeneity empirically are differences in growth options versus assets in place. To capture such differences, we relax the assumption that growth options and assets in place are perfectly correlated by replacing Eq. (1) with

$$v(z, \tilde{z}, k) = (1 + \tilde{z})\bar{k} + zk - \frac{\gamma}{2\bar{k}}k^2, \tag{23}$$

where $z$ and $\tilde{z}$ are not perfectly correlated. We call firms with low assets in place ($\bar{k}$) growth firms and those with high $\bar{k}$ value firms as is customary. To derive a specific testable prediction, we make the following assumption.

*Assumption 1*. Managers know relatively more about assets in place, and traders know relatively more about about growth options. Formally, $s = z + \epsilon_s$ and $\eta = \tilde{z} + \epsilon_\eta$.

The assumption that managers (firm insiders) possess an information advantage with respect to assets in place is widely used in the literature. For instance, a large literature on asymmetric information in corporate finance is based on this assumption, (e.g., Myers and Majluf, 1984). In practice, firms have detailed internal reports on costs and sales of existing products that outsiders simply do not have. This type of advantage is likely smaller for future products. For firms that depend on future growth, the relevant information valuation methods rely on comparisons with other firms and analysis of market trends. Here market participants could have an advantage or at least less of a disadvantage. We can then state Prediction 2.

*Prediction 2*. Under Assumption 1, all else equal,

(i) a decrease in $\sigma_s^2$ (traders produce more information) increases $\mathcal{V}_{FPE}$ more for growth firms (low $\bar{k}$) than value firms (high $\bar{k}$); and
(ii) a decrease in $\sigma_\eta^2$ (firms produce more information) increases $\mathcal{V}_{FPE}$ more for value firms (high $\bar{k}$) than value firms (low $\bar{k}$).

Under Assumption 1, traders focus on valuing growth options. As their information increases, the FPE of growth firms rises more than value firms. Managers focus on assets in place, so an increase in their information has the opposite effect. Hence, Prediction 2 allows us to distinguish RPE and FPE by comparing the trends in FPE of growth and value firms. This is not a perfect test, but we think it contributes to the overall picture that emerges from all of our tests.[15]

To implement it, we split S&P 500 firms into high- and low-valuation groups, using the median value of the valuation ratio $\log M/A$ in each year as the cutoff. The high-valuation group contains growth stocks and the low-valuation group contains value stocks. We then calculate price informativeness separately for each group.

The results are presented in Fig. 11 and Table 8. From Fig. 11, value stocks have relatively low and flat price informativeness over the whole sample. In contrast, for growth firms, price informativeness has increased steadily, roughly doubling over the sample. Consistent with Fig. 11, Table 8 (columns 1–3) shows that the difference in informativeness between growth and value firms is generally higher in the latter decades of the sample, especially at the five-year horizon (the drop in the 2000s is due to the year 2000). Thus, the increase in price informativeness is concentrated among growth firms.

Under Assumption 1, these results support the interpretation that RPE has increased. They are also of interest more broadly as the prospects of growth firms are inherently harder to assess so any additional information is likely of high value.

[15] For instance, growth firms are more uncertain and potentially less transparent. However, our test is not about the overall difficulty of valuing growth firms versus value firms. Instead, Prediction 2 says that when market-based information production changes, the change in price informativeness should be bigger for growth firms than for value firms.

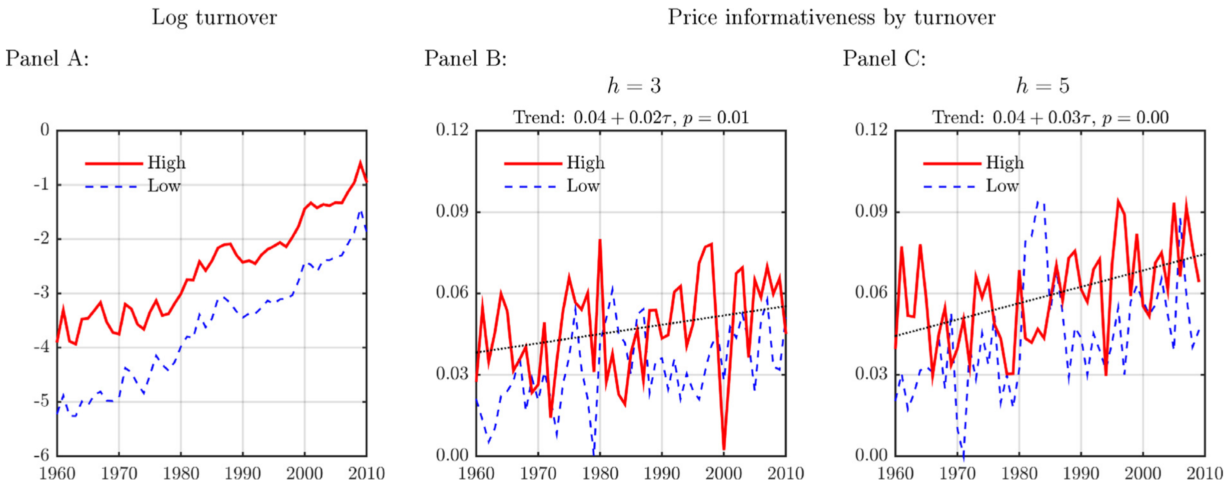


**Fig. 10.** Liquidity and price informativeness. We compare price informativeness for firms with high and low levels of share turnover, using the median turnover in each year as the cutoff. Panel A plots the average log turnover for firms in each group. Price informativeness is obtained separately for each group by running the forecasting regression (16) and calculating the product of the forecasting coefficient and the cross-sectional standard deviation of market prices in year $t$, $b_{t,h} \times \sigma_t(\log M/A)$. Above each price informativeness plot is a linear time trend $\tau$ normalized to zero and one at the beginning and end of the sample (plotted in black dots) with $p$-value based on Newey–West standard errors with five lags. The sample contains S&P 500 nonfinancial firms from 1960 to 2014.

**Table 8**

Liquidity, growth options, and price informativeness. This table presents time series regressions of the difference in price informativeness between high turnover and low turnover firms (Columns 1–3) and between value and growth firms (Columns 4–6). High (low) turnover firms are defined as those with a high (low) monthly share turnover using the median share turnover in each year as the cutoff. Growth (value) firms are defined as those with a high (low) valuation ratio ($\log M/A$) using the median valuation ratio in each year as the cutoff. Price informativeness is obtained separately for each group by running the forecasting regression (15) and calculating the product of the forecasting coefficient and the cross-sectional standard deviation of market prices in year $t$, $b_{t,h} \times \sigma_t(\log M/A)$. The price informativeness series are shown in Figs. 10 and 11. For this table, we regress the difference in price informativeness between high and low turnover firms and between growth and value firms at a given horizon $h = 1, 3, 5$ years on a set of indicator variables corresponding to each decade in our sample (the baseline decade, 1960–1969, is absorbed by the constant). There are no five-year price informativeness estimates for 2010–2014 because our sample ends in 2014. Newey-West standard errors with five lags are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. The sample contains all S&P 500 non-financial firms from 1960 to 2014.

| | Price informativeness (×100) | | | | | |
|---|---|---|---|---|---|---|
| | High − low turnover firms | | | Growth − value firms | | |
| Decade | $h = 1$ (1) | $h = 3$ (2) | $h = 5$ (3) | $h = 1$ (4) | $h = 3$ (5) | $h = 5$ (6) |
| Constant (1960–1969 level) | 1.298*** | 2.012*** | 2.109** | 0.847** | 2.591*** | 3.813*** |
| | (0.464) | (0.634) | (0.802) | (0.403) | (0.393) | (0.315) |
| 1970–1979 | −0.683 | −0.057 | −0.186 | 0.031 | −0.521 | −1.574*** |
| | (0.475) | (0.648) | (1.068) | (0.395) | (0.535) | (0.437) |
| 1980–1989 | −0.614 | −2.294** | −2.646* | 0.862* | 0.837 | 1.599* |
| | (0.500) | (0.920) | (1.568) | (0.442) | (0.584) | (0.800) |
| 1990–1999 | 0.227 | 0.560 | 0.375 | 1.588*** | 2.987*** | 3.029*** |
| | (0.561) | (0.776) | (0.849) | (0.450) | (0.586) | (0.497) |
| 2000–2009 | −0.199 | −0.832 | −0.584 | 0.759* | 0.867 | 1.465** |
| | (0.506) | (0.960) | (0.942) | (0.449) | (0.730) | (0.676) |
| 2010–2014 | −0.593 | −2.064*** | | 0.136 | 0.484 | |
| | (0.599) | (0.651) | | (0.457) | (0.474) | |
| $R^2$ | 13.1% | 23.6% | 17.9% | 40.5% | 36.4% | 49.3% |
| Number of observations | 54 | 52 | 50 | 54 | 52 | 50 |

## 6. Conclusion

The past few decades have seen enormous changes in financial markets. Information costs have plummeted, liquidity has deepened, spending on price discovery has increased, and institutional investing has become dominant. Against this backdrop, we ask a basic question: Have financial market prices become more informative? This question is important for economic efficiency and for assessing the value of a growing financial sector.

To answer it, we derive a welfare-based measure of price informativeness, the predicted variation of future cash flows from current market prices. This measure is easily calculated from firm-level data on stock prices and cash flows. Our measure quantifies the extent to which markets separate firms that will be profitable in the future from those that will not.

We find that financial market prices have become more informative, particularly at the important medium and long horizons. Price informativeness at the three- and

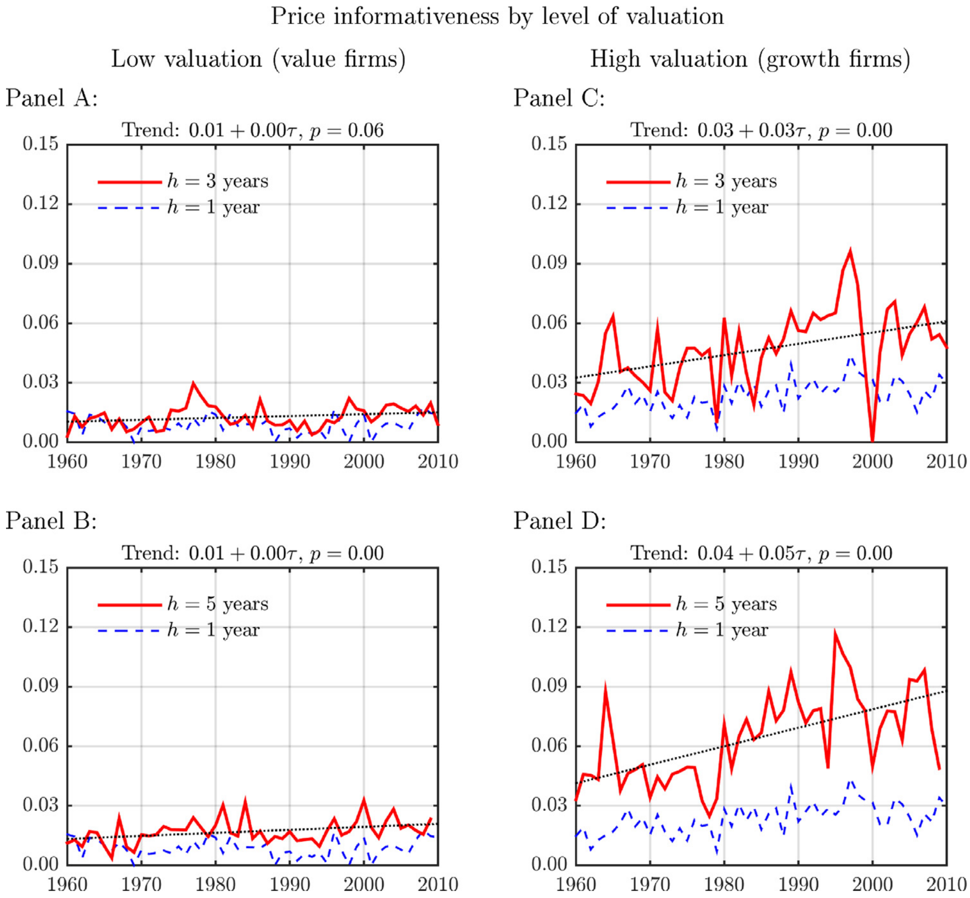


**Fig. 11.** Growth options and price informativeness. We compare price informativeness for firms with high and low valuation ratios, using the median value of the valuation ratio $\log M/A$ in each year as the cutoff. We refer to high valuation firms as growth firms and low valuation firms as value firms. Price informativeness is obtained separately for each group by running the forecasting regression (15) and calculating the product of the forecasting coefficient and the cross-sectional standard deviation of market prices in year $t$, $b_{t,h} \times \sigma_t(\log M/A)$. Above each plot is a linear time trend $\tau$ normalized to zero and one at the beginning and end of the sample (plotted in black dots) with $p$-value based on Newey–West standard errors with five lags. The sample contains S&P 500 nonfinancial firms from 1960 to 2014.

five-year horizons, respectively, is 60% and 80% higher in 2014 than in 1960. We present further evidence that supports the hypothesis that the increase in informativeness reflects greater revelatory price efficiency. Our results thus suggest that markets today generate more information. In doing so, they are contributing to the efficiency of capital allocation in the economy.

## Appendix A. Appendix model

In this Appendix, we provide a model of information production and trading as an example of the framework in Section 3. The model shares the basic setup of Eqs. (1)–(8). Following (Subrahmanyam and Titman, 1999), we assume the traded claim has payoff $z$.[16] There are $n$ informed traders who choose their demand $x$ to maximize a standard mean-variance objective:

$$\max_x \; x\mathbb{E}\left[z - p|\eta', s\right] - \frac{\rho}{2}x^2\mathbb{V}\mathrm{ar}\left[z|\eta', s\right], \tag{24}$$

which leads to the usual demand curve

$$x = \frac{\mathbb{E}\left[z|\eta', s\right] - p}{\rho\mathbb{V}\mathrm{ar}\left[z|\eta', s\right]}. \tag{25}$$

From Eqs. (7) and (8),

$$\mathbb{E}\left[z|\eta', s\right] = \frac{h_s s + h_{\eta'}\eta'}{h_z + h_s + h_{\eta'}}, \tag{26}$$

[16] Formally, Subrahmanyam and Titman (1999) assume a perfect correlation between growth options and assets in place, and they assume that the markets trade a claim on the existing assets $\mathcal{F} = z\bar{k}$. This is clearly equivalent to assuming that $z$ is traded directly. Subrahmanyam and Titman justify their assumption by the fact that there is a deterministic relation in the model between the cash flows of the assets in place and the cash flows of the entire firm. However, because this relation is nonlinear, the cash flow of the total firm is non-normal, which precludes a closed-form solution to the security market equilibrium in a model in which a claim on the total firm's cash flow is sold. But because a claim on existing assets provides the same information as would the price of the entire firm, they conclude that this is a sensible assumption.

where $h_z = \frac{1}{\sigma_z^2}$ and $h_s = \frac{1}{\sigma_{\epsilon_s}^2}$ and $h_{\eta'} = \frac{1}{\sigma_{\epsilon_\eta}^2 + \sigma_{\epsilon_{\eta'}}^2}$ are the precisions of $s$ and $\eta'$, respectively. We also get that

$$\mathbb{V}\mathrm{ar}\left[z|\eta', s\right] = \frac{1}{h_z + h_s + h_{\eta'}}. \tag{27}$$

Therefore, the demand of each trader is

$$x = \frac{1}{\rho}\left[h_s s + h_{\eta'}\eta' - p\left(h_z + h_s + h_{\eta'}\right)\right]. \tag{28}$$

We assume a random supply $u$ of shares (equivalently noise traders), so the equilibrium condition is

$$nx = u, \tag{29}$$

and we get the equilibrium price

$$\left(h_z + h_s + h_{\eta'}\right)p = h_s s + h_{\eta'}\eta' - \frac{\rho}{n}u. \tag{30}$$

Next, we want to understand what the manager learns. Because she knows $\eta'$, she can observe

$$s' = s - \frac{\rho}{nh_s}u \ = \ z + \epsilon_s - \frac{\rho}{nh_s}u. \tag{31}$$

Therefore, her information set is in fact $\{\eta,\ s'\}$, and she sets

$$\gamma\frac{k^\star}{\bar{k}} = \mathbb{E}[z|\mathcal{I}_m] \ = \ \frac{h_\eta \eta + h_{s'}s'}{h_z + h_\eta + h_{s'}}, \tag{32}$$

where

$$h_{s'} = \frac{1}{\sigma_{\epsilon_s}^2 + \left(\frac{\rho}{nh_s}\right)^2\sigma_u^2} \ = \ \frac{h_s}{1 + \left(\frac{\rho}{n}\right)^2\sigma_u^2}. \tag{33}$$

To compute aggregate efficiency as in Eq. (13), we substitute Eqs. (6) and(31) into Eq. (32) and obtain

$$\mathbb{E}[z|\mathcal{I}_m] = \frac{\left(h_\eta + h_{s'}\right)z + h_\eta\epsilon_\eta + h_{s'}\left(\epsilon_s - \frac{\rho}{nh_s}u\right)}{h_z + h_\eta + h_{s'}}, \tag{34}$$

and so aggregate efficiency is

$$\mathbb{V}\mathrm{ar}(\mathbb{E}[z|\mathcal{I}_m]) = \frac{\left(h_\eta + h_{s'}\right)^2\sigma_z^2 + h_\eta + h_{s'}}{\left(h_z + h_\eta + h_{s'}\right)^2} = \left(\frac{h_\eta + h_{s'}}{h_z + h_\eta + h_{s'}}\right)h_z^{-1}. \tag{35}$$

We can thus state Proposition A.1.

*Proposition A.1. Aggregate efficiency is increasing in internal information $h_\eta$, the information of traders $h_s$, and uncertainty $h_z^{-1}$.*

*Proof.* Recall from Eq. (13) that aggregate efficiency is $\mathbb{V}\mathrm{ar}(\mathbb{E}[z|\mathcal{I}_m])$. The proof follows by substituting Eq. (33) into Eq. (35) and taking derivatives. □

The informativeness of prices depends on all sources of noise. We have

$$\left(h_z + h_s + h'\right)p = h_s s + h'\eta' - \frac{\rho}{n}u \tag{36}$$

$$= \left(h_s + h'\right)z + h_s\epsilon_s + h'\left(\epsilon_\eta + \epsilon_{\eta'}\right) - \frac{\rho}{n}u, \tag{37}$$

so observing the price is equivalent to observing

$$\pi = \left(1 + \frac{h_z}{h_s + h'}\right)p \ = \ z + \frac{h_s}{h_s + h_{\eta'}}\epsilon_s + \frac{h_{\eta'}}{h_s + h_{\eta'}}\left(\epsilon_\eta + \epsilon_{\eta'}\right) - \frac{\rho}{\left(h_s + h_{\eta'}\right)n}u. \tag{38}$$

We have

$$\mathbb{E}[z|p] = \frac{h_\pi \pi}{h_\pi + h_z}, \tag{39}$$

where

$$h_\pi = \frac{1}{\mathbb{V}\mathrm{ar}\left(\frac{h_s}{h_s+h_{\eta'}}\epsilon_s + \frac{h_{\eta'}}{h_s+h_{\eta'}}\left(\epsilon_\eta + \epsilon_{\eta'}\right) - \frac{\rho}{\left(h_s+h_{\eta'}\right)n}u\right)} = \frac{\left(h_s + h_{\eta'}\right)^2}{h_s + h_{\eta'} + \frac{\rho^2}{n^2}\sigma_u^2}. \tag{40}$$

The predicted variance of cash flows ($z$) from prices (FPE) is

$$\mathbb{V}\mathrm{ar}(\mathbb{E}[z|p]) = \mathbb{V}\mathrm{ar}\left(\frac{h_\pi\left(z + \frac{h_s}{h_s+h_{\eta'}}\epsilon_s + \frac{h_{\eta'}}{h_s+h_{\eta'}}\left(\epsilon_\eta + \epsilon_{\eta'}\right) - \frac{\rho}{\left(h_s+h_{\eta'}\right)n}u\right)}{h_\pi + h_z}\right) \tag{41}$$

$$= \frac{h_\pi}{h_\pi + h_z}h_z^{-1}. \tag{42}$$

So FPE depends on internal information and disclosure via $h_{\eta'}$, on RPE via $h_s$, and on noise trading. As for RPE, we have

$$\mathbb{V}\mathrm{ar}\left(\mathbb{E}\left[z|\eta, \eta', s'\right]\right) - \mathbb{V}\mathrm{ar}\left(\mathbb{E}\left[z|\eta, \eta'\right]\right) = \left(\frac{h_\eta + h_{s'}}{h_z + h_\eta + h_{s'}} - \frac{h_\eta}{h_z + h_\eta}\right)h_z^{-1}. \tag{43}$$

We have the following comparative statics, summarized in Proposition A.2.

*Proposition A.2. All else equal,*

(i) *an increase in $h_s$ leads to an increase in aggregate efficiency, price informativeness (FPE), and revelatory price efficiency (RPE);*
(ii) *an increase in $h_\eta$ leads to an increase in aggregate efficiency, an increase in the predicted variance of cash flows from investment, and, if disclosure is positive, an increase in FPE but not RPE; and*
(iii) *an increase in $h_{\eta'}$, holding $h_\eta$ constant, leads only to an increase in FPE.*

*Proof.* The results follow by taking derivatives in the expressions for aggregate efficiency, Eq. (35), FPE, Eq. (42), and RPE, Eq. (43). For the predicted variance of cash flows from investment, in this model it is equal to aggregate efficiency because investment is proportional to the conditional expectation of cash flows based on the manager's information. □

Proposition A.2 formalizes Prediction 1 in Section 3.

Next, changes in information technology can be captured in several ways. We can simply assume that signals become more informative, as in Proposition A.2. Or we can solve for equilibrium learning and assume the cost of information decreases. We can do this for both managers and traders. In the case of traders, for instance, we can pin down $n$ with a free entry condition. The utility of the informed trader is

$$U = \frac{1}{2\rho}\frac{\left(\mathbb{E}\left[z-p|\eta',s\right]\right)^2}{\mathbb{V}\mathrm{ar}[z|\eta',s]} = \frac{1}{2\rho}\frac{\left(\frac{h_s s+h_{\eta'}\eta'}{h_z+h_s+h_{\eta'}}-p\right)^2}{\frac{1}{h_z+h_s+h_{\eta'}}}. \quad (44)$$

Substituting for the price from Eq. (36), we get

$$U = \frac{\left(\frac{\rho}{n}u\right)^2}{2\rho\left(h_z+h_s+h_{\eta'}\right)}. \quad (45)$$

So expected utility of becoming an informed trader is

$$\mathbb{E}[U] = \frac{\rho\sigma_u^2}{2\left(h_z+h_s+h_{\eta'}\right)}\frac{1}{n^2}. \quad (46)$$

Let $\psi$ be the cost of becoming informed. Then, in equilibrium, $\mathbb{E}[U]=\psi$ and we have

$$n = \sqrt{\frac{1}{\psi}\frac{\rho\sigma_u^2}{2\left(h_z+h_s+h_{\eta'}\right)}}. \quad (47)$$

The number of traders who enter depends on the cost of information, the amount of noise trading, and the signal precisions.[17] This shows how a lower cost of information increases RPE.

## Appendix B. Additional tests and robustness

In this Appendix we provide additional tests and robustness for the evolution of price informativeness over time.

Table B.1 shows the estimates of our cross-sectional regression (15) for 2009, the last year for which we have data at the five-year horizon. The coefficient of market prices is positive and statistically significant. It is also increasing with horizon from 0.039 at the one-year horizon to 0.061 at the five-year horizon. The coefficient on current earnings is also positive and significant. The year 2009 is somewhat unusual as it coincides with the trough of the Great Recession. This is why the one-year coefficient on current earnings is lower than in other years.

Fig. B.1 plots the average coefficients from our cross-sectional forecasting regression (15) by horizon. The format of the figure follows Fig. 2. Like the coefficients on prices, the coefficients on earnings are slightly higher in the second half of the sample, but, because the cross-sectional standard deviation of earnings is the same (see Fig. 1), the predicted variation of future earnings from current earnings is flat over our sample. Unlike the coefficients on prices, the coefficients on earnings are decreasing in horizon. The long-horizon earnings coefficient is about 0.6, indicating a semipermanent effect of a shock to current earnings. These results support the view that current earnings are relatively more informative at short horizons and prices are relatively more informative at long horizons. They thus provide further motivation for focusing on price informativeness at longer horizons.

**Table B1**
Example cross-sectional regression from 2009. This table reports estimates from the cross-sectional forecasting regression (15) for the year 2009, the last year for which we have data at the five-year forecasting horizon:
$\frac{E_{i,2009+h}}{A_{i,2009}} = a_{2009,h} + b_{2009,h}\log\left(\frac{M_{i,2009}}{A_{i,2009}}\right) + c_{2009,h}\left(\frac{E_{i,2009}}{A_{i,2009}}\right) + d^s_{2009,h}\mathbf{1}^s_{i,2009} + \epsilon_{i,2009,h}$,
where $E$ is earnings before interest and taxes (EBIT), $A$ is total assets, $M$ is market cap, and $\mathbf{1}^s$ is an indicator variable for sector $s$. Standard errors are clustered at the industry level (two-digit SIC code). [These standard errors are not used in other tests. Instead, the standard errors in other tests (Tables 2–8, B2–B3, and C2) are calculated from the time series variation in the cross-sectional estimates (this is equivalent to a Fama-Macbeth regression).] *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. The sample contains all S&P 500 non-financial firms for 2009.

| | $E_{2009+h}/A_{2009}$ | | |
|---|---|---|---|
| Decade | $h=1$ (1) | $h=3$ (2) | $h=5$ (3) |
| Constant | 0.044 | 0.134*** | 0.094** |
| | (0.032) | (0.036) | (0.037) |
| $\log M_{2009}/A_{2009}$ | 0.039*** | 0.058*** | 0.061*** |
| | (0.008) | (0.009) | (0.010) |
| $E_{2009}/A_{2009}$ | 0.454*** | 0.481*** | 0.461*** |
| | (0.100) | (0.127) | (0.163) |
| Sector fixed effects | Yes | Yes | Yes |
| $R^2$ | 62.9% | 50.4% | 37.9% |
| Number of observations | 424 | 423 | 420 |

Table B.2 presents pairwise differences in means for price informativeness at the three- and five-year horizons (the underlying series are presented in Fig. 3 and Table 2). In each column, we regress price informativeness on decade-based indicator variables using a different decade as the baseline. The coefficients therefore represent pairwise differences in means between a given decade along each row and the baseline decade along each column. Looking at three years, the sign of most differences is consistent with increasing informativeness throughout the sample. Differences relative to the 1960s are significant. This is because the upward trend takes several decades to accumulate. Looking at five years, the signs are again consistent with increasing informativeness. Differences relative to the 1960s and 1970s are significant.

Next, we examine the evidence for a structural break in price informativeness. The adoption of Reg FD in 2000 and the enactment of the Sarbanes-Oxley Act in 2002 are likely candidates. These reforms had a large impact on firms' disclosure environment. Another potentially important reform is decimalization which occurred in 2001. If the observed increase in price informativeness is due to changes in disclosure, then these reforms could produce detectable changes in our price informativeness series. More broadly, we check whether evidence exists of a structural break at any point in our sample.

[17] In this simple model, disclosure increases entry because it is assumed that disclosure is observed only by informed traders and not noise traders. We could make an alternative assumption that disclosure reduces noise trading so this is not a robust prediction.

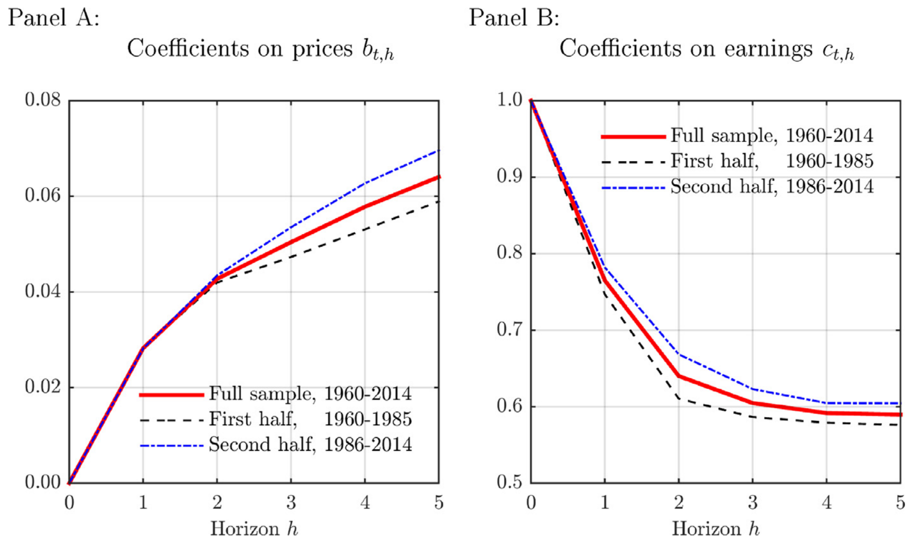


**Fig. B1.** Average cross-sectional coefficients by horizon and subsample. This figure shows average coefficients calculated from the cross-sectional forecasting regression (15): $E_{i,t+h}/A_{i,t} = a_{t,h} + b_{t,h}\log(M_{i,t}/A_{i,t}) + c_{t,h}(E_{i,t}/A_{i,t}) + d^s_{t,h}\mathbf{1}^s_{i,t} + \epsilon_{i,t,h}$, where $M$ is market cap, $A$ is total assets, $E$ is earnings before interest and taxes (EBIT), and $\mathbf{1}^s$ is a sector (one-digit SIC code) indicator variable. We run a separate regression for each year $t = 1960, \ldots, 2014$ and horizon $h = 1, \ldots, 5$. We report average of the coefficients $b_{t,h}$ for prices and $c_{t,h}$ for earnings. The horizontal axis represents horizon $h$. The solid red line shows coefficients at horizon $h$ averaged over the full sample, i.e. $\frac{1}{55}\sum_{t=1960}^{2014} b_{t,h}$ and $\frac{1}{55}\sum_{t=1960}^{2014} c_{t,h}$. The dashed black line is for the first half, 1960–1985, and the dash-dotted blue line is for the second half, 1986–2014. The sample contains S&P 500 nonfinancial firms, 1960 to 2014.

**Table B2**

Price informativeness, pairwise differences in means. This table presents differences in means of price informativeness at horizons of three and five years across decades. Price informativeness is calculated as in Eq. (16) using estimates from the cross-sectional forecasting regression (15). The price informativeness series are shown in Fig. 3. For this table, in each column we regress the time series of price informativeness at horizon $h = 3, 5$ years (Panels A and B, respectively) on a set of indicator variables corresponding to each decade in our sample. The baseline decade varies by column. There are no five-year price informativeness estimates for 2010–2014 because our sample ends in 2014. Newey–West standard errors with five lags are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. The sample contains all S&P 500 non-financial firms from 1960 to 2014.

| | 1960–1969<br>(1) | 1970–1979<br>(2) | 1980–1989<br>(3) | 1990–1999<br>(4) | 2000–2009<br>(5) | 2010–2014<br>(6) |
|---|---|---|---|---|---|---|
| *Panel A: horizon $h = 3$ years* | | | | | | |
| 1960–1969 | | −0.707 | −1.075** | −1.406*** | −1.561* | −0.840** |
| | | (0.417) | (0.332) | (0.331) | (0.583) | (0.253) |
| 1970–1979 | 0.707 | | −0.367 | −0.699 | −0.854 | −0.133 |
| | (0.417) | | (0.441) | (0.475) | (0.675) | (0.424) |
| 1980–1989 | 1.075** | 0.367 | | −0.331 | −0.487 | 0.235 |
| | (0.332) | (0.441) | | (0.396) | (0.618) | (0.327) |
| 1990–1999 | 1.406*** | 0.699 | 0.331 | | −0.155 | 0.566 |
| | (0.331) | (0.475) | (0.396) | | (0.716) | (0.326) |
| 2000–2009 | 1.561* | 0.854 | 0.487 | 0.155 | | 0.721 |
| | (0.583) | (0.675) | (0.618) | (0.716) | | (0.548) |
| 2010–2014 | 0.840** | 0.133 | −0.235 | −0.566 | −0.721 | |
| | (0.253) | (0.424) | (0.327) | (0.326) | (0.548) | |
| *Panel B: horizon $h = 5$ years* | | | | | | |
| 1960–1969 | | 0.106 | −1.874*** | −1.489*** | −2.143*** | |
| | | (0.378) | (0.134) | (0.397) | (0.311) | |
| 1970–1979 | −0.106 | | −1.980*** | −1.595** | −2.249*** | |
| | (0.378) | | (0.352) | (0.523) | (0.461) | |
| 1980–1989 | 1.874*** | 1.980*** | | 0.385 | −0.269 | |
| | (0.134) | (0.352) | | (0.391) | (0.300) | |
| 1990–1999 | 1.489*** | 1.595** | −0.385 | | −0.654 | |
| | (0.397) | (0.523) | (0.391) | | (0.563) | |
| 2000–2009 | 2.143*** | 2.249*** | 0.269 | 0.654 | | |
| | (0.311) | (0.461) | (0.300) | (0.563) | | |

To test for structural breaks, we first form the null hypothesis that price informativeness has increased linearly over our sample from 1960 to 2014. We run a regression of price informativeness at each horizon on a constant and a linear time trend as in Fig. 3. The results are in Table B.3. The coefficients on the time trend are positive and significant. The point estimate is that the one-year informativeness series is only about 30% higher in 2014 than in 1960, and the three- and five-year informativeness series are 60% and 80% higher, respectively.

**Table B3**

Tests for a structural break in price informativeness. This table presents results from tests for structural breaks in the time series of price informativeness. Price informativeness is calculated as in Eq. (16) using estimates from the cross-sectional forecasting regression (15). The price informativeness series are shown in Fig. 3. For this table, we regress each series on a constant and a linear time trend as in Fig. 3. The linear time trend is normalized to zero in 1960 and one in 2014. Newey-West standard errors with five lags are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. We then run a Supremum Wald test for a break in the estimated coefficients at an unknown break date and a Wald test for a break in the estimated coefficients in 2000, 2001, and 2002 (the respective adoption years of Reg FD, decimalization, and the Sarbanes-Oxley Act). For each test, we report the Wald statistic and associated $p$-value. For the test for an unknown break point we also report the year with the highest break point likelihood. The sample contains all S&P 500 non-financial firms from 1960 to 2014.

| | Price informativeness ($\times$100) | | |
|---|---|---|---|
| | $h=1$ (1) | $h=3$ (2) | $h=5$ (3) |
| Constant | 1.976*** | 3.140*** | 3.755*** |
| | (0.097) | (0.254) | (0.224) |
| Time trend | 0.605*** | 1.940*** | 3.190*** |
| | (0.224) | (0.451) | (0.343) |
| $R^2$ | 8.74% | 18.93% | 43.01% |
| Number of observations | 54 | 52 | 50 |
| | Test for an unknown break point | | |
| Highest likelihood break point | 1996 | 1974 | 1980 |
| Supremum Wald statistic ($\chi^2$) | 4.548 | 3.767 | 8.799 |
| $p$-value | 0.633 | 0.767 | 0.152 |
| | Test for a known break point in 2000 | | |
| Wald statistic ($\chi^2$) | 0.830 | 2.059 | 0.454 |
| $p$-value | 0.660 | 0.358 | 0.797 |
| | Test for a known break point in 2001 | | |
| Wald statistic ($\chi^2$) | 1.741 | 0.878 | 0.021 |
| $p$-value | 0.419 | 0.645 | 0.989 |
| | Test for a known break point in 2002 | | |
| Wald statistic ($\chi^2$) | 0.678 | 3.762 | 1.076 |
| $p$-value | 0.712 | 0.152 | 0.584 |

Next, we run a Supremum Wald test for an unknown break point in the coefficients from the regression on a linear time trend. This test calculates a Wald statistic for the hypothesis that the intercept and slope of this regression are different before and after each year in our sample. It then reports the year with the highest Wald statistic and a $p$-value that takes into account the search over all years. The results are below the trend estimates in Table B.3. The most likely break point years differ by horizon and none has a $p$-value below 10% (the lowest $p$-value is for the five-year series in 1980).

Because the test for an unknown break point has relatively low power, we also perform tests for known break points in 2000 (Reg FD), 2001 (decimalization), and 2002 (the Sarbanes–Oxley Act). The results are also reported in Table B.3. The $p$-values are again high. The lowest (0.15) is for the three-year price series in 2002. Overall, we find no evidence of a structural break point in our price informativeness series. Instead, informativeness has been increasing steadily throughout our 50-year sample. This makes it less likely that the increase is driven by changes in disclosure requirements, which are discrete in nature.

## Appendix C. Firms beyond the S&P 500

In this Appendix we present results for the universe of firms beyond the S&P 500.

Table C.1 presents summary statistics for the universe of firms. Compared with the S&P 500, these firms are smaller, are less profitable, and have lower market valuation ratios. They also exhibit much greater uncertainty as indicated by their idiosyncratic volatility and cross-sectional dispersion of profitability at all horizons. More important, this dispersion has increased between the first and second halves of our sample. For instance, the dispersion of current earnings to assets has nearly doubled. The average level of profitability has fallen from 9% to - 0.6%. The drop in the

**Table C1**

Summary statistics, all firms. The table presents means, medians, and standard deviations of key variables, all firms. Market capitalization is from the Center for Research in Security Prices in millions of dollars as of the end of March. Total assets, research and development (R&D), capital expenditure (CAPX), and earnings before interest and taxes (EBIT) are from Compustat in millions of dollars as of the end of the previous fiscal year. All quantities are adjusted for inflation using the gross domestic product (GDP) deflator (= 100 in 2010). Next, $\log(M/A)$ is the log-ratio of market cap to assets, $R\&D/A$ is R&D over assets, $CAPX/A$ is CAPX over assets, $E/A$ is EBIT over assets, and $E(t+h)/A$, $h=1,3,5$ is earnings in year $t+h$ over assets in year $t$. All ratios are winsorized at the 1% level. Idiosyncratic volatility is the standard deviation of returns over the last 12 months after subtracting the market return. Share turnover is volume divided by shares outstanding. Institutional share is the fraction of shares held by institutional investors (from 13-F filings). Option listings is an indicator variable for whether a firm has options trading on the Chicago Board Option Exchange (available after 1973). Option turnover is one hundred times annual option volume divided by equity shares outstanding (from OptionMetrics, 1996 to 2014). The sample contains all non-financial firms from 1960 to 2014.

| | Full sample | | | 1960–1985 | | | 1986–2014 | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | Mean | Median | Standard deviation | Mean | Median | Standard deviation | Mean | Median | Standard deviation |
| Market capitalization | 1,611 | 124 | 10,283 | 795 | 90 | 4,430 | 2,106 | 153 | 12,545 |
| Total assets | 1,893 | 165 | 11,499 | 1,297 | 172 | 6,114 | 2,200 | 161 | 13,452 |
| R&D | 59 | 4 | 371 | 33 | 2 | 178 | 69 | 4 | 421 |
| CAPX | 125 | 8 | 748 | 117 | 10 | 718 | 129 | 7 | 762 |
| Earnings | 170 | 10 | 1,041 | 134 | 16 | 753 | 188 | 8 | 1,159 |
| $\log(M/A)$ | −0.198 | −0.216 | 1.066 | −0.475 | −0.513 | 0.972 | −0.057 | −0.052 | 1.084 |
| $R\&D/A$ | 0.078 | 0.031 | 0.127 | 0.035 | 0.018 | 0.059 | 0.094 | 0.042 | 0.141 |
| $CAPX/A$ | 0.070 | 0.048 | 0.072 | 0.084 | 0.062 | 0.075 | 0.064 | 0.042 | 0.070 |
| $E/A$ | 0.027 | 0.076 | 0.217 | 0.092 | 0.102 | 0.137 | −0.006 | 0.061 | 0.242 |
| $E(t+1)/A$ | 0.052 | 0.080 | 0.197 | 0.106 | 0.106 | 0.137 | 0.025 | 0.065 | 0.217 |
| $E(t+3)/A$ | 0.088 | 0.084 | 0.218 | 0.129 | 0.110 | 0.170 | 0.066 | 0.068 | 0.237 |

(continued on next page)

**Table C1** (*continued*)

| Variable | Full sample Mean | Full sample Median | Full sample Standard deviation | 1960–1985 Mean | 1960–1985 Median | 1960–1985 Standard deviation | 1986–2014 Mean | 1986–2014 Median | 1986–2014 Standard deviation |
|---|---|---|---|---|---|---|---|---|---|
| $E(t+5)/A$ | 0.119 | 0.087 | 0.252 | 0.151 | 0.114 | 0.210 | 0.100 | 0.070 | 0.271 |
| Idiosyncratic volatility | 0.140 | 0.112 | 0.111 | 0.117 | 0.098 | 0.077 | 0.153 | 0.123 | 0.124 |
| Share turnover | 0.107 | 0.049 | 0.238 | 0.036 | 0.021 | 0.052 | 0.139 | 0.074 | 0.279 |
| Institutional share | 0.398 | 0.344 | 0.307 | 0.234 | 0.148 | 0.250 | 0.419 | 0.376 | 0.308 |
| Option listings | 0.529 | 1.000 | 0.499 | 0.131 | 0.000 | 0.337 | 0.664 | 1.000 | 0.472 |
| Option turnover | 0.245 | 0.063 | 0.785 | | | | 0.245 | 0.063 | 0.785 |
| Number of observations | | 211,984 | | | 80,561 | | | 131,423 | |

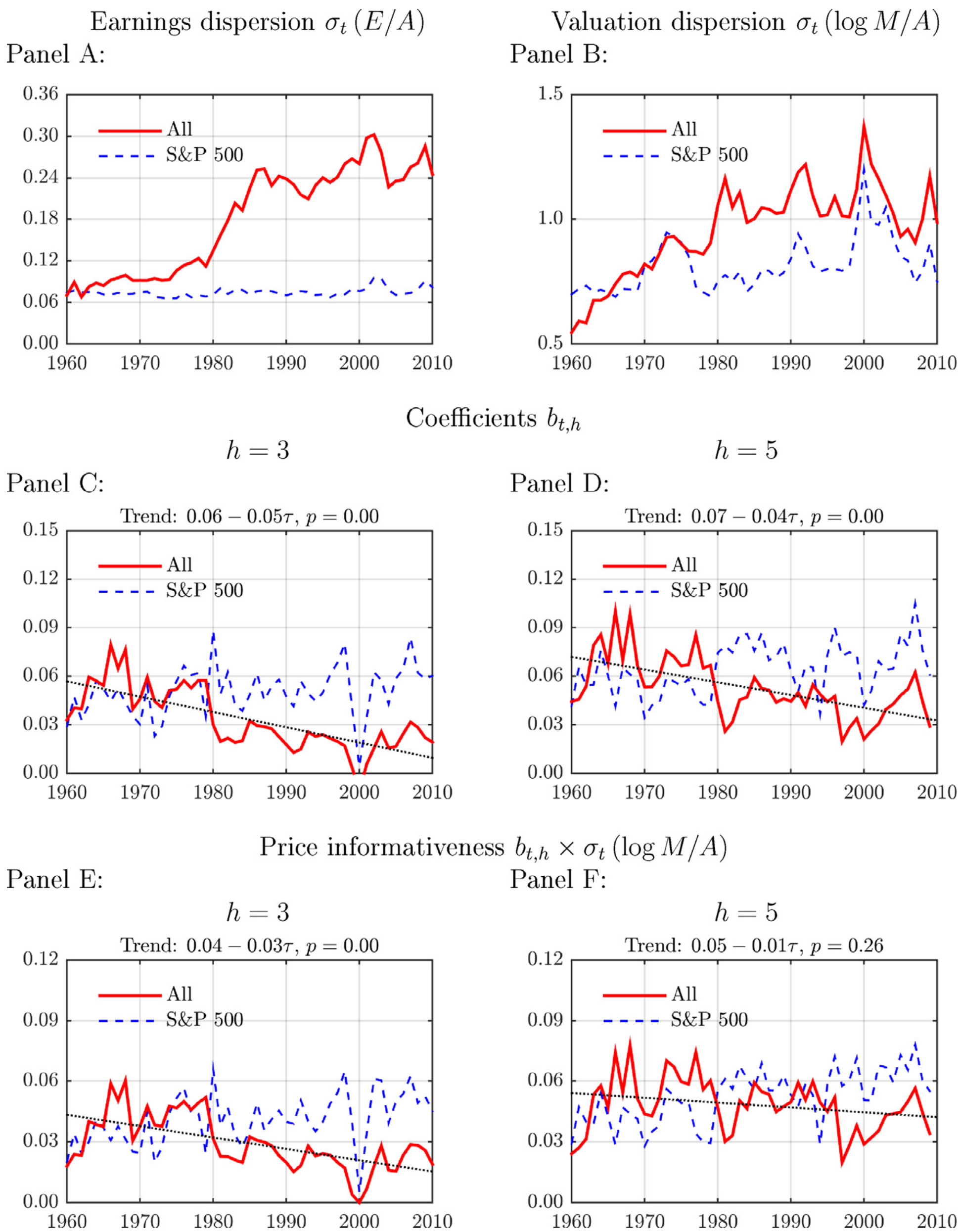


**Fig. C1.** Price informativeness, all firms. The figure shows earnings dispersion $\sigma_t(E/A)$, valuation dispersion $\sigma_t(\log M/A)$, coefficients $b_{t,h}$, and price informativeness $b_{t,h} \times \sigma_t(\log M/A)$ from the forecasting regression (15), run separately for S&P 500 firms and for all firms from 1960 to 2014. The dispersions are measured as the cross-sectional standard deviations in each year. Above Panels C–F is a linear time trend $\tau$ normalized to zero and one at the beginning and end of the sample (plotted in black dots) with $p$-value based on Newey–West standard errors with five lags.

**Table C2**
Price informativeness over time, all firms. This table presents time series regressions of price informativeness by horizon for all firms. Price informativeness is calculated as in Eq. (16) using estimates from the cross-sectional forecasting regression (15). The price informativeness series are shown in Fig. C.1. In this table we regress the time series of price informativeness at a given horizon $h = 1, 3, 5$ years on a set of indicator variables corresponding to each decade in our sample (the baseline decade, 1960–1969, is absorbed by the constant). There are no five-year price informativeness estimates for 2010–2014 because our sample ends in 2014. Newey-West standard errors with five lags are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. The sample contains all non-financial firms from 1960 to 2014.

| | Price informativeness (×100) | | |
|---|---|---|---|
| Decade | $h = 1$ (1) | $h = 3$ (2) | $h = 5$ (3) |
| Constant (1960–1969 level) | 2.526*** | 3.813*** | 4.982*** |
| | (0.214) | (0.644) | (0.807) |
| 1970–1979 | 0.305 | 0.711 | 0.854 |
| | (0.220) | (0.709) | (0.978) |
| 1980–1989 | −1.276*** | −1.188* | −0.317 |
| | (0.274) | (0.654) | (0.868) |
| 1990–1999 | −1.902*** | −1.882*** | −0.466 |
| | (0.221) | (0.679) | (0.980) |
| 2000–2009 | −1.944*** | −1.907** | −0.852 |
| | (0.277) | (0.759) | (0.880) |
| 2010–2014 | −1.854*** | −2.266*** | |
| | (0.292) | (0.653) | |
| $R^2$ | 81.8% | 61.3% | 19.3% |
| Number of observations | 54 | 52 | 50 |

median is smaller, from 10.2% to 6.1%, indicating increased left-skewness. Many of these firms have consistently negative earnings.

Next, we replicate the analysis from Section 5.3 for firms beyond the S&P 500. The results are presented in Fig. C.1 and Table C.2. Panels A and B of Fig. C.1 show that the two groups differ greatly on observable characteristics. From Panel A, uncertainty has increased drastically among all firms as suggested by the increase in their earnings dispersion. This dispersion has grown from about the same level as for S&P 500 firms in 1960 to about four times as high by 2000. From Panel B, there has been a parallel rise in the dispersion of market valuations among all firms versus a steady, much less pronounced, rise among S&P 500 firms.

The upswings in the dispersion series for all firms correspond to the growth of Nasdaq in the late 1970s and 1980s and the dot-com boom in the 1990s. (if Nasdaq firms are removed from the sample, the changes are much less pronounced.) Both episodes are associated with a large inflow of younger, smaller, and more uncertain firms (Fama and French, 2004). Therefore, the sample of all firms has seen large compositional shifts that imply it is not comparable over time. For S&P 500 firms, no evidence exists of such changes. In particular, their earnings dispersion is virtually constant over the whole 50-year period.

To see the effects of the compositional changes among all firms, we can look at our informativeness measures, which are shown in Panels E and F of Fig. C.1 (Panels C and D show the forecasting coefficients). In contrast to S&P 500 firms whose price informativeness has risen, for the set of all firms it appears to have declined. The decline occurs in the same years as the rise in the dispersion measures in Panels A and B. This suggests that it is indeed due to changing firm composition.

The apparent decline is more pronounced at the short horizon. As the trend lines in Fig. C.1 and the estimates in Table C.2 show, one-year informativeness for all firms falls by a highly significant 73% from the 1960s to the 2000s, and five-year informativeness falls by an insignificant 17% (at three years, the drop is 60%). From Table 2, for S&P 500 firms, one-year informativeness is flat, and the increase at five years is about 50%. Thus, for both samples, there is a comparable relative improvement at the long end. This suggests that the one-year informativeness series helps to tease out the confounding compositional changes.

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