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Jennie Bai
Thomas Philippon
Alexi Savov

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ABSTRACT

The finance industry has grown, financial markets have become more liquid, information technology has undergone a revolution. But have 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 traded options, and growth firms. Prices have also become a stronger predictor of investment and investment a stronger predictor of cash flows. These results suggest increased revelatory price efficiency.

Jennie Bai
Georgetown University
3700 O St. N.W.
Washington DC, 20057
jb2348@georgetown.edu

Thomas Philippon
New York University
Stern School of Business
44 West 4th Street, Suite 9-190
New York, NY 10012-1126
and NBER
tphilipp@stern.nyu.edu

Alexi Savov
Stern School of Business
New York University
44 West Fourth Street, Suite 9-85
New York, NY 10012
and NBER
asavov@stern.nyu.edu

Fama (1970) 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.[1] Institutional investing has become dominant and spending on price discovery has increased.[2] The financial sector's share of GDP has doubled. To assess whether these trends have led to progress towards Fama's ideal, we ask: Have financial market prices become more informative?

To answer this question, we first derive a welfare-based measure of price informativeness and then document its evolution over time. Using U.S. stock market data from 1960 to 2014, we find that among comparable firms price informativeness has increased at medium and long horizons (three to five years) while remaining stable at short horizon (one year). Our results from a number of tests support the interpretation that greater information production in financial markets has contributed to an increase in the efficiency of capital allocation.

Our first task is to come up with the right measure of informativeness. 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 predictor. 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

[1] NYSE trading volume is up 10^3 times since 1960.

[2] Based on French (2008), spending on price discovery has risen from 0.3% to 1% of GDP since 1980.

S&P 500 firms whose stable characteristics allow for a fairly clean comparison over time. We show that price informativeness is increasing with horizon, consistent with prices capturing differences in growth rates across 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 since the time-to-build literature suggests that investment plans take over a year to implement, with the cash flows materializing farther down the road.[3]

Our key result is that price informativeness has increased at the three- and five-year horizons. The upward trend is steady throughout the fifty-year sample and its cumulative effect is economically significant: price informativeness at the longer horizons is over 50% higher in 2010 than in 1960, and the increase is statistically significant. Price informativeness at the one-year horizon, which is smaller to begin with, is relatively unchanged.

The increase in price informativeness is not explained by changes in return predictability. Since 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.[4]

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 R&D spending (though not CAPX). The increase is already apparent at the short one-year horizon, as one would expect given that investment precedes earnings. Thus, when it comes to real decisions like R&D (for which market information is

[3]For instance, Koeva (2000) finds that "the average construction lead time for new plants is around two years in most industries".

[4]For completeness, we also calculate our price informativess measure 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 this comparison potentially misleading. This is readily apparent from trends in observable characteristics such as idiosyncratic volatility and earnings dispersion (measures of uncertainty), which have increased 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.

arguably particularly useful), the informativeness of prices has also increased.

It is important to note that more informative prices do not necessarily imply that financial markets have generated an improvement in welfare. Market prices contain information produced independently by market participants as well as information disclosed to the market by the firm. It is primarily the independent, market-produced component of price informativeness that contributes to the efficiency of capital allocation.[5] 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 the manager.

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 place their trades, 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 two-way feedback between firms and markets allows us to frame many of the existing models in the literature.

Our framework shows that we can distinguish an increase in market-produced information (RPE) from a pure increase in disclosure by looking at aggregate efficiency, the predicted variation of future cash flows based on the manager's full information set. Under a pure-disclosure interpretation, aggregate efficiency should remain the same even as price informativeness (FPE) rises. Although the manager's information is not observed, it gets reflected in investment. Specifically, our model shows 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 managers have. Measuring investment as either R&D alone or R&D and CAPX together, we find that the predicted variation of earnings from investment has increased. We also find that the cross-sectional dispersion of R&D has increased.[6] We interpret these findings to suggest

[5] We say "primarily" because there are other decision makers besides a firm's insiders who might benefit from a more informative price. These include shareholders, competitors, entrants, customers, suppliers, targets, acquirers, and regulators. Nevertheless, we view the distinction between market-produced and disclosed information as a useful, if understated, way of assessing the contribution of market prices to aggregate efficiency.

[6] The lack of increase in CAPX informativeness and dispersion may be due to the overall decline of CAPX.

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 disclosure story, it remains possible that the observed rise in price informativeness is explained by an increase in information production inside firms (to explain the rise in aggregate efficiency) combined with an increase in disclosure (to explain the rise in FPE). Teasing out this hypothesis is challenging and it requires that we come up with additional predictions we can test. We construct and test four such predictions that exploit cross-sectional differences between firms. While neither test is perfect, the totality of the evidence supports the interpretation that 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.[7] Interestingly, dispersion has increased so that 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. The CBOE began listing options in 1973 and has been adding new listings in a staggered manner ever since. 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, again consistent with the RPE view.

For our third cross-sectional test, we enrich our model with cross-sectional differences between firms. Specifically, we incorporate the natural feature that a firm's cash flows from

The median S&P 500 firm had CAPX of 8% of assets in 1980 versus 4% in 2010 (see Figure 1).

[7]We go beyond the S&P 500 for this test because it provides greater cross-sectional differences.

growth options may not be perfectly correlated with its cash flows from assets in place. Our idea then is that firm insiders hold an advantage in producing information about assets in place. For instance, existing product lines provide internal data that only insiders can access. Corporate finance theory further suggests that managers, who after all put the existing assets into place, may possess superior knowledge about their productivity. Growth options, on the other hand, are typically valued by making comparisons to other firms and by analyzing market trends, and here the market may have the advantage (or at least less of a disadvantage). Based on this reasoning, under the RPE view that market-based information has increased we would expect price informativeness to increase more for firms with a lot of growth options (growth firms), whereas under the view that internal information plus disclosure have increased we would expect greater improvement among firms with fewer growth options (i.e. value firms). Consistent with the RPE view, we find that price informativeness has risen for growth firms whereas it has remained nearly unchanged for value firms. This result is interesting from a broader perspective as it indicates that the increase in the information content of market prices is concentrated among hard-to-value firms where it is most needed.

In our final test, we compare price informativeness for 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 as well as increases the incentives of market participants to produce more information (RPE). Consistent with this idea, we find that stocks with higher turnover on average have higher price informativeness. Since liquidity in general and turnover in particular have been increasing strongly over the past five decades, this finding helps to explain the observed rise in overall price informativeness.

The rest of this paper proceeds as follows: Section 1 reviews the literature, Section 2 derives our informativeness measure, Section 3 describes the data, Section 4 presents results, and Section 5 concludes.

1 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 (1) and our main contribution is empirical.

The information production role of financial markets is part of a classic literature in economics traced 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 in the spirit of this literature, one that is easily taken to the data.

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

The U.S. time series represents a particularly important setting because over the last few decades the U.S. financial sector has grown six times faster than GDP (Philippon 2015). At its peak in 2006, it contributed 8.3% to U.S. GDP compared to 2.8% in 1950 (see Philippon (2015) and Greenwood and Scharfstein (2012) 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 a relationship in aggregate U.S. data, we seek to provide a partial answer by examining the information content 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 (2011) provide a model in which rents in the financial sector attract an excessive share of the economy's human capital. Philippon and Reshef (2012) document 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 this important effort of measuring value added in the financial sector.

A large theoretical literature with seminal papers by Grossman and Stiglitz (1980), Glosten and Milgrom (1985), 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, which they call revelatory price efficiency (RPE), from what is already known and merely reflected in prices which they call forecasting price efficiency (FPE). 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 sub-samples of firms where RPE or FPE is expected to prevail.

Recent theoretical work on asset prices and real efficiency includes Dow and Gorton (1997), Subrahmanyam and Titman (1999), Goldstein and Guembel (2008), Ozdenoren and Yuan (2008), Bond, Goldstein, and Prescott (2010), Goldstein, Ozdenoren, and Yuan (2013), Kurlat and Veldkamp (2015), 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 2, we use our theoretical framework to discuss these papers in some detail, and we use their common features to construct testable predictions.

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 non-synchronicity (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 lower 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 non-synchronicity 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, O'Hara, and Paperman 1996), which is based on order flow. Our contribution here is to derive a welfare-based measure which quantifies the information contained in prices for real outcomes and is easily computed from readily available data.

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 in 2000 and Sarbanes-Oxley in 2002. Considerable debate remains regarding the effects of these changes; even their direction is unsettled.[8] We find no evidence of structural breaks in informativeness around these reforms, though possibly because their effects to take hold over a longer period of time. In any case, 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, Zha, and Sloan (2014)). This literature establishes both that earnings information drives returns and that returns do not always fully respond to earnings information. This is among the reasons why we include current earnings as an additional predictor in our forecasting regressions. There is also evidence that the value relevance of earnings has actually declined over our sam-

[8]Heflin, Subramanyam, and Zhang (2003) find no evidence of increased volatility around earnings announcements after Reg. FD, or significant deterioration in analyst forecast accuracy, which suggests that the information available to market participants was not reduced. In contrast, Wang (2007) reports that after the passage of Reg. FD, some firms cut back on issuing earnings guidance. However, Bushee, Matsumoto, and Miller (2004) provide evidence that disclosure remained constant or even increased after the passage of Reg. FD. Kothari, Ramanna, and Skinner (2009) find that firms reduced their withholding of bad news relative to good news after Reg. FD was implemented.

ple period (Collins, Maydew, and Weiss 1997), which would bias our results downward. 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.

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.

2 Theoretical framework and discussion

The main contribution of our paper is empirical, but we need a theoretical framework to clarify the concept of price informativeness and interpret our empirical results. We build such a framework from two essential components: a q-theory/aggregate efficiency block and an information environment block.

Q-theory and aggregate efficiency: Consider a firm with ex-post fundamental value

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

where $\overline{k}$ represents assets in place, k is investment in new capital, z is a productivity shock, and γ is an adjustment cost parameter. This specification is consistent with constant returns to scale as in the standard q-theory literature following Hayashi (1982).

Investment is chosen to maximize firm value under the *manager's* (more generally, the decision maker's) information set $\mathcal{I}_m$: $k^\star = \operatorname{argmax}_k \mathbb{E}\left[v(z,k)\,|\,\mathcal{I}_m\right]$.[9] We have normalized the discount rate to zero for simplicity (we address discount rates in Section 4.3). This leads to

[9] Note that this specification is quite general. We refer to $\mathcal{I}_m$ as the information set of the manager, but we can also interpret $\mathcal{I}_m$ as the information available to the owners of the firm, or to the board of directors, for giving incentives to the manager. Bond, Edmans, and Goldstein (2012) explain that "even though this second [incentives] channel does not involve active learning from the price, it is ultimately similar to the first [direct learning] channel, in that market prices end up having a real effect due to their informational role."

the well-known q-theory investment equation

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

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

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

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

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

We are interested in the efficiency of capital allocation across firms, so we consider a large number of ex-ante identical firms (same $\overline{k}$) 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

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

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.

Information environment: Our next goal is to understand how managers learn and how prices are determined. 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 contained in p 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 ϵ_η and ϵ_s are independent, so we can think of η and s as the two fundamental sources of information that society can use to improve capital allocation.

In practice market participants and managers also share common sources of information (in addition to 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 $\epsilon_{\eta'} \sim N\left(0, \sigma_{\eta'}^2\right)$ is orthogonal to ϵ_η and ϵ_s. The disclosure signal η' 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.[10] To summarize, the information set of the manager is $\mathcal{I}_m = \{\eta, \eta', p\}$ and the information set of informed traders is $\mathcal{I}_\tau = \{\eta', s\}$.

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, but 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 is traded in financial markets. Recall that v is the total value of the firm. In practice, it can be the case that equity is publicly traded but debt it not, or perhaps that the traded security is an option or a credit derivative.[11] So let us define $\mathcal{F}(z, k)$ as the payoff of the claim that is traded in financial markets. An important

[10] Kurlat and Veldkamp (2015) study optimal disclosure from the viewpoint of investors.
[11] See Philippon (2009) for q-theory using bond prices instead of equity prices.

particular case is of course $\mathcal{F}(z,k) = v(z,k)$ with $v(\cdot)$ as in equation (3). Since the informed traders' information set consists of η' and s, the equilibrium price typically takes the form

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

where u is noise trading, and α and β are endogenous coefficients that are part of the rational expectations equilibrium. Exactly how to solve for these coefficients, and whether we actually 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 (9).

Equilibrium and basic feedback: To summarize, most models in the literature boil down to two equations which we restate for convenience:

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

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

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 for our analysis, is common to all models we discuss below, even though they differ in the complexity of the other interactions between value and prices.

Advanced feedback: 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.[12] In

[12] Formally, they 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 obviously equivalent to assuming that z is traded directly. Subrahmanyam and Titman (1999) 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 where a claim on the total firm's cash flow is sold. But since 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. This is correct as long as we take information sets as given, though we know from the work of Edmans, Goldstein, and Jiang (2015) and others that the feedback matters once we introduce endogenous information acquisition or strategic trading.

that case the pricing equation (11) does not depend on the mapping $k^\star$ in (10) and the model remains linear and tractable. Our model in the appendix adopts this approach. It can always be interpreted as a linear approximation of a more complex model, and the approximation is good as long as $k^\star/\bar{k}$ is not too large.

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 and this determines the equilibrium price. Dow and Gorton (1997) show that this can lead to multiple equilibria.[13] In one equilibrium managers invest based on prices and this 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. The trader knows that whatever information is revealed will be used to increase firm value. This helps her make money when the news is good, but hurts her when the news is bad. Taking this asymmetric payoff into account, the trader forms an asymmetric trading strategy and this leads to asymmetric revelation of good and bad news. These effects rely on the basic feedback and on strategic behavior by large traders who understand that they influence prices.[14]

Empirical predictions: The simple framework outlined above has so far allowed us to have a fairly precise discussion of the existing literature. Our next task is to formulate specific

[13]In their model managers are clueless, $\sigma_\eta^2 = \infty$, and returns on assets in place are independent of z, which is indeed 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.

[14]It is also important to specify what traders learn about. Bresnahan, Milgrom, and Paul (1992) argue that speculators have stronger incentives to learn about assets in place than about growth options. Learning about assets in place makes prices more informative but investment no more efficient. This distinction is somewhat artificial, however, because it relies on infinite adjustment costs on existing assets (so they cannot be scaled) and small adjustment costs on new assets.

predictions that we can test empirically.

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

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

FPE measures the total amount of information about future payoffs contained in market prices. At the same time, FPE is only a forecasting concept. As explained above, aggregate efficiency depends on the information of the manager:

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

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

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

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. On the other hand, 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 (σ_s^2, σ_η^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 all models. In particular, we test the following:

Prediction 1. *All else equal,*

(i) a decrease in σ_s^2 (traders produce more information) increases $\mathcal{V}_{FPE}$, $\mathcal{V}_{RPE}$ and $\mathcal{V}_M$.

(ii) *a decrease in* σ_η^2 *(firms produce more information) increases* $\mathcal{V}_{FPE}$ *and* $\mathcal{V}_M$ *but not* $\mathcal{V}_{RPE}$*.*

(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 (η 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 (η' 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 and aggregate efficiency.

Using investment to learn about welfare. One issue of course is that aggregate efficiency $\mathcal{V}_M$ is not observed, but we can bound it between two measurable quantities:

Claim 1. *Aggregate efficiency* $\mathcal{V}_M$ *is bounded between*

$$\mathbb{V}\mathtt{ar}\left(\mathbb{E}\left[\frac{v}{\overline{k}}\middle| k^\star\right]\right) \;\leq\; \mathcal{V}_M \;\leq\; \gamma\mathbb{V}\mathtt{ar}\left(\frac{k^\star}{\overline{k}}\right). \tag{15}$$

The inequality on the right comes from the first-order condition (2). In our stylized framework, since $\gamma\frac{k^\star}{\overline{k}} = \mathbb{E}\left[z \mid \eta, p\right]$, investment perfectly reveals the information set of the manager and we get an equality. In the real world, investment is noisy and lumpy and there might be shocks to investment costs that increase the measured variance. In this case we get 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 the cash flows of assets in place and growth options are perfectly correlated as in (1), investment is an optimal forecast of total cash flows and we get 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, and we get a strict inequality (we explore this case in Section 4.7 below).

We are now ready to begin the empirical analysis, which centers on Prediction 1. As we noted, this prediction is common to models in the literature. To motivate it further, we derive Prediction 1 formally in the model we present in Appendix A.

3 Data and summary statistics

In this section we describe the main aspects of our data and how we construct our sample.

Data sources: Our sample is annual from 1960 to 2014. We obtain stock prices from 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. 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.

Sample selection: Unless otherwise noted, we limit attention to S&P 500 non-financial firms. These firms represent the bulk of the value of the U.S. 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 all firms, whose composition has changed drastically. We report results for the universe of all firms in the appendix and summarize them in the text.

Measures: Our main equity valuation measure is the log-ratio of market capitalization M to total assets A, $\log M/A$.[15] Our main cash flow variable is earnings measured as EBIT. In Appendix B we show that our main results are robust to using alternative measures such as EBITDA, 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 2 and note that we are predicting $v/\overline{k} \approx 1 + z$). In particular, it incorporates growth between t and $t + h$ by scaling by date-t assets. Unlike prices, we do not take logs because it is the level of cash flows that matters for aggregate efficiency.

Correcting for delisting: We must account for firm delisting to ensure that our forecasting regressions are free of survivorship bias.[16] We do so as follows: 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 two-digit SIC industry. We use the earnings accruing to this portfolio to fill in the earnings of the delisted firm. We do the same for investment.

Adjusting for inflation: We adjust for inflation using the GDP deflator. This is necessary because it is real price informativeness that matters for welfare. Since inflation is multiplicative, differences in future nominal cash flows between firms are larger than in real cash flows. This biases the forecasting coefficient upward, particularly during periods of high inflation.[17]

[15] 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 2). In practice, we find that taking logs works slightly better because it mitigates skewness in the data. In Appendix B we show that our main results are robust to incorporating the book value of debt to control for leverage effects. We leave debt out in the main analysis because market values are not generally available.

[16] Survivorship bias would arise if the relationship 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. Since 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 delisting tracks the merger waves of the 1980s and 1990s.

[17] 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 years of

Summary statistics: Table I presents summary statistics for our main sample of S&P 500 firms. The first set of columns covers the full period from 1960 to 2014, whereas the second and third sets cover its first and second half. They show that firms have become larger and their profits have grown with the economy. Yet profitability (earnings over assets) is stable both in levels and cross-sectional dispersion. This is true of current as well as future profitability (measured against current assets), our key left-side variables. Market valuations, our key right-side variable, have risen with the overall market but their cross-sectional dispersion is only slightly higher (skewness has increased somewhat). Investment has shifted a bit from CAPX to R&D and R&D has become more right-skewed, but overall investment rates are stable.

Figure 1 depicts the cross-sectional distribution of several characteristics over time by plotting their median (red line) and their 10th to 90th percentile range (gray shading) in a given year. The top two panels confirm that the distributions of the valuation ratio $\log M/A$ and profitability E/A have remained stable, and the bottom two panels confirm that R&D has become more right-skewed and CAPX has declined in importance.

While the underlying characteristics of these firms have remained stable, their trading environment has changed drastically. As Table I shows, share turnover has increased five-fold, institutional ownership has risen by about half, and a large majority of firms now have their options listed on the CBOE. 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 4.5 to 4.8 below.

The stability among S&P 500 firms stands in sharp contrast to the broader sample of all firms, whose characteristics are presented in Table A.II 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 arguably also harder to value since many lack a consistent earnings record. These

the 1970s and early 1980s. Second, we did not correct for delistings, which have increased somewhat in the latter part of our sample. And third, we did not consider the long five-year horizon.

compositional changes imply that the sample of firms outside the S&P 500 is not comparable over time. We present results for these firms in the appendix for completeness.

4 Results

Estimation: We first 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. Specifically, in each year $t = 1960, \ldots, 2014$ and at every horizon $h = 1, \ldots, 5$, we run

$$\frac{E_{i,t+h}}{A_{i,t}} = a_{t,h} + b_{t,h} \log\left(\frac{M_{i,t}}{A_{i,t}}\right) + c_{t,h}\left(\frac{E_{i,t}}{A_{i,t}}\right) + d^s_{t,h}\mathbf{1}^s_{i,t} + \epsilon_{i,t,h}, \tag{16}$$

where i is a firm index and $\mathbf{1}^s$ is a sector (one-digit SIC code) indicator.[18] These regressions give us a set of coefficients indexed by year t and horizon h.

From Section 2, price informativeness $\mathcal{V}_{FPE}$ is the predicted variance of future cash flows from market prices (equation (12)). We compute it here with the minor change of taking a square root, which gives meaningful units (dollars of future cash flow per dollar of current assets). From regression (16), price informativeness in year t at horizon h is the forecasting coefficient $b_{t,h}$ multiplied by the standard deviation of the forecasting variable $\log M/A$:

$$\left(\sqrt{\mathcal{V}_{FPE}}\right)_{t,h} = b_{t,h} \times \sigma_t\left(\log\left(M/A\right)\right). \tag{17}$$

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

Price informativeness by horizon: Figure 2 gives a first look by plotting average price informativeness by horizon and sub-sample. 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

[18] Table A.I in the appendix provides the estimates for a sample year (see Appendix B for details).

2000). From a capital allocation perspective, it is therefore the medium and long horizons that are especially important.

The red line in Figure 2 plots price informativeness at each horizon averaged over the full length of our sample (from 1960 to 2014). As expected, informativeness is positive; market prices are positive predictors of future earnings. More importantly, informativeness is increasing with horizon. The reason is that while current earnings are already a good predictor of earnings in one year, prices are useful for predicting earnings farther out.[19] This provides further motivation for focusing on longer horizons as we do.

The dashed black and dash-dotted blue lines in Figure 2 plot average price informativeness for the first and second halves of our sample. We see that informativeness is higher in the later half at every horizon. The increase is itself increasing with horizon: one-year informativeness is only slightly higher while three- and five-year informativeness show a much larger increase (we look closely at the magnitude and significance of this increase in the next section). From here on, for conciseness we focus on horizons of one, three, and five years ($h = 1, 3, 5$). As Figure 2 indicates, informativeness at the intermediate horizons falls in between.

4.1 Price informativeness over time

Figure 3 plots the time series of our estimates. The lines in each panel hold horizon fixed and look across time.[20] The two left panels plot the forecasting coefficients $b_{t,h}$ from regressions (16). The coefficients are always positive; prices and future earnings are positively related. They are typically higher at the longer horizons, again consistent with current earnings being a powerful predictor at short horizons and market prices being more useful farther out (see Figure A.1). We note a drop in the coefficients at the end of the NASDAQ boom in 2000, but this drop is short-lived and does not influence the long-run trend.

Our key result can be found in the center panels of Figure 3, which plot price informativeness over time. While informativeness is relatively flat at the one-year horizon, it shows

[19] Figure A.1 in the appendix 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 (see Appendix B for details). Thus, current earnings are relatively more informative at short horizons and prices are relatively more informative at long horizons.

[20] Since our data ends in 2014, our last estimates of price informativeness at the three- and five-year horizons are from 2011 and 2009, respectively. This is why we the horizontal axis ends in 2010.

a clear upward trend at the three- and five-year horizons. The increase is from about 0.03 in 1960 to 0.05 in 2010 at the three-year horizon and from 0.04 to 0.07 at the five-year horizon. Although the estimates can be noisy from year to year, the upward trend is steady throughout the five decades of our sample.[21] These results show that the extent to which market prices help to distinguish firms that will deliver high profits in the future from those that will not has increased over the past five decades.

The right two panels of Figure 3 show the contribution of market prices to the regression R^2. Whereas our price informativeness measure captures the amount of information contained in market prices—this is what matters for welfare—the marginal R^2 captures the fraction of the total variance of future earnings that market prices explain (conditional on current earnings). The plots show that the marginal R^2 has increased similarly to price informativeness.

As a formal test, we run regressions of our price informativeness series at each horizon on a set of dummy variables, one for each decade in our sample:

$$\left(\widehat{\sqrt{\mathcal{V}_{FPE}}}\right)_{t,h} = a_h + \sum_d b_{d,h} \times \mathbf{1}_t^d + \epsilon_{t,h} \tag{18}$$

for decades of d = 1970–79,..., 2010–14 (the baseline, omitted decade is 1960–69).[22] We report Newey-West standard errors with five lags to account for potential autocorrelation.[23]

Table II presents the results. Overall, they confirm the pattern in Figure 3. The intercepts are positive, significant, and increasing across horizons. Within the one-year horizon, the coefficients on the decade dummy variables tend to be small, never larger than a quarter of

[21] Indeed, there is no evidence for structural breaks anywhere in our sample, including the years 2000, 2001, and 2002 when the important reforms of Regulation Fair Disclosure, decimalization, and the Sarbanes-Oxley Act were implemented. We report and discuss the results of structural break tests in Table A.IV and Appendix D. We find that the evolution of price informativeness is described well by a simple linear time trend. We interpret this to suggest that the observed changes are driven by deeper, slow-moving trends (e.g. information technology, institutional investing, liquidity) rather than changes in disclosure requirements which tend to be discrete in nature (we address slow-moving changes in disclosure in Section 4.4 below).

[22] Recall that our data ends in 2014, so our last estimate of five-year informativeness is for 2009. This is why in the third column in Table II there is no coefficient for 2010–14. The same rule applies to remaining tables.

[23] 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 at the five-year horizon, and this is why we use a lag of five (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. Our results are robust to alternative choices.

the intercept, and often insignificant. Thus, one-year informativeness has not changed much over the course of our sample (at most it has increased mildly). Looking at three- and five-year informativeness, on the other hand, we see coefficients that are large, highly significant, and in some cases over half the size of the intercept, especially in the later decades of our sample. For instance, five-year price informativeness is about fifty percent higher in the 2000s than the 1960s. Since our measure is welfare-based, this represents a sizable increase. Table II thus shows that the increase in medium- and longer-term price informativeness is both statistically and economically significant.

Robustness: Figure A.2 with discussion in Appendix B shows that the increase in price informativeness is robust to a number of variations. First, we add debt to the valuation ratio to control for possible leverage effects (that is we use $\log\left[\left(M+D\right)/A\right]$ instead of $\log\left(M/A\right)$).[24] Second, we use alternative measures of future cash flows, specifically EBITDA, net income, and cash flows from operations. All measures consistently show an increase in price informativeness at the three- and five-year horizons.

Price informativeness outside the S&P 500: Figure A.3 and Table A.III with discussion in Appendix C replicate the analysis of this section for the universe of all firms. As we saw in Table A.II, the composition of these firms has changed dramatically. Likely as a result of these changes, price informativeness outside the S&P 500 appears to decrease. 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 indeed as Fama and French (2004) show, the observable changes are to a significant degree driven by the growing numbers of NASDAQ stocks. Interestingly, the short-horizon informativeness drops the most, so again there is relative improvement at the long end. We return to this sample in Section 4.5 below when we look at institutional ownership. For now, the important point is that these observations lead us to focus on the S&P 500.

4.2 Market prices and investment

We have so far seen that for comparable firms market prices today contain more information about future cash flows. A natural follow-up question is whether the greater informativeness

[24] We do not adopt this as our main specification because debt is measured at book value not market value.

extends to real firm decisions. Indeed, our framework predicts that as prices become more informative, they should also predict investment more strongly.

To examine this prediction, we calculate the predicted variation of investment from prices. Following the procedure used to calculate price informativeness (the predicted variation of earnings from prices), we run our forecasting regressions (16) 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

$$\frac{R\&D_{i,t+h}}{A_{i,t}} = a_{t,h} + b_{t,h} \log\left(\frac{M_{i,t}}{A_{i,t}}\right) + c_{t,h}\left(\frac{E_{i,t}}{A_{i,t}}\right) + d_{t,h}\left(\frac{R\&D_{i,t}}{A_{i,t}}\right) + e^{s}_{t,h}\mathbf{1}^{s}_{i,t} + \epsilon_{i,t,h}. \quad (19)$$

Mandatory disclosure of R&D began in 1972 and so we restrict the sample for the R&D regression accordingly.[25] The predicted variation of investment from prices is then $b_{t,h} \times \sigma_t\left(\log\left(M/A\right)\right)$. The results of this estimation are presented in Figure 4 and Table III.

Figure 4 confirms that prices are positively related to future investment measured as either R&D or CAPX. Looking closely at CAPX first (right two panels), there is no visible trend in predicted variation. Table III shows this formally. As we saw in Table I and Figure 1, CAPX has been trending down (the opposite is true for R&D). Thus, structural forces appear to be leading the importance of CAPX to diminish.

The key result of Figure 4 is that the predicted variation of R&D from prices has increased by a large factor over our sample (left two panels); it is about four times higher in 2010 than in 1960. Table III shows that this rise is highly statistically significant. Unlike for earnings, the upward trend here 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 especially valuable.

[25] Prior to 1972 only about 50 S&P 500 firms report R&D. After 1972 the number jumps to 250. CAPX is available throughout. The results are the same if we restrict the CAPX regression to the same period as the R&D regression.

4.3 Market prices and returns

Our results so far show that price informativeness has increased. Our next task is to investigate the source of this result. One possibility which we consider in this section is that the increase is due to a decrease in the cross-sectional predictability of returns. As Campbell and Shiller (1988) point out, asset prices are a combination of expected cash flows and expected returns. 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 might fall, the distribution of risk loadings (betas) might 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 at all.

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 regressions (16) but with returns on the left instead of earnings:

$$\log R_{i,t\to t+h} \quad = \quad a_{t,h} + b_{t,h} \log\left(\frac{M_{i,t}}{A_{i,t}}\right) + c_{t,h}\left(\frac{E_{i,t}}{A_{i,t}}\right) + d^s_{t,h}\mathbf{1}^s_{i,t} + \epsilon_{i,t,h}, \tag{20}$$

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 prices in year t at horizon h is $b_{t,h} \times \sigma_t\left(\log\left(M_{i,t}/A_{i,t}\right)\right)$. The results from this estimation are presented in Figure 5 and Table IV.

As Figure 5 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). There are many theories, both rational and behavioral, 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 main result in Figure 5 is that the predicted variation of returns from prices (solid red lines) shows no sign of a trend in either direction. Although the year-to-year estimates are noisy (this is due to the high variability of returns), the series is essentially flat at all horizons.[26] For comparison, we have also plotted our price informativeness measure (dashed black lines), which climbs steadily throughout the sample as we saw in Figure 3.

Table IV presents a formal test. We see a couple of significant decade-indicator coefficients, but their signs alternate between positive and negative.[27] Based on these results, we conclude that there is no evidence of a change in the relationship between prices and expected returns that can account for the observed increase of price informativeness.

4.4 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 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. For instance, total information may have remained unchanged but the amount of information firms disclose may have increased, perhaps due to more accurate financial reporting. This would make prices more informative (FPE would go up) but it would not significantly improve real allocations (RPE would remain the same).[28]

We can test the disclosure hypothesis using Prediction 1 of our framework in Section 2. Prediction 1 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 to see if aggregate efficiency has increased with price informativeness. Of course this exercise is of interest more broadly as aggregate efficiency is a key factor in economic growth.

As we argued in Claim 1, although aggregate efficiency is not observed we can bound it from below by the predicted variation of cash flows from investment and from above by the

[26]The brief spike around 2000 in the predicted variation of returns (their covariance with prices turns more negative) coincides with the end of the NASDAQ boom when many growth firms experienced very low returns.

[27]Perhaps a more powerful test given the noisiness of the estimates is to simply regress the predicted variation in returns on a time trend. When we do so the coefficients are small, alternate signs, and are never more than a fraction of a standard error from zero: -0.03 with s.e. 0.04, 0.03 with s.e. 0.08, and 0.08 with s.e. 0.14 for $h = 1, 3$, and 5 (Newey-West standard errors with five lags).

[28]Recall these terms stand for "forecasting price efficiency" and "revelatory price efficiency" from Bond, Edmans, and Goldstein (2012), see Section 2 for discussion.

dispersion of investment across firms. We take this approach here.

From Figure 1 and Table I dispersion in investment rates has increased in the case of R&D but not CAPX. The cross-sectional standard deviation of the ratio of CAPX to total assets is similar in the first and second halves of our sample (7.5% and 7.0%). At the same time, the median of the distribution has fallen by a third from 6.4% and 4.2% (the mean has dropped similarly from 8.4% to 6.4%). Thus we see a general decline in importance of CAPX.

By contrast, for R&D we see a dramatic increase in dispersion. The cross-sectional standard deviation of R&D scaled by total assets has nearly doubled from 2.8% in the first half of our sample to 5.0% in the second half. From Figure 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 to 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.

As we argued in Claim 1, however, the variation in investment rates is only an upper bound on aggregate efficiency. To calculate the lower bound, we need to measure the predicted variation of earnings from investment. We do this by replacing market prices with investment in our by now standard forecasting regressions:

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

We include R&D and CAPX side by side to extract as much information from investment as possible. As with market prices, we take logs to mitigate skewness.[29] 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 in Figure 6 and Table V. We include a specifications with R&D as the sole predictor and one with both R&D and CAPX. The predicted variation of earnings

[29]We did not take logs in Section 4.2 because investment there serves as a real outcome variable and not an information signal. We take logs here because it mitigates skewness and thus improves forecastability.

in Figure 6 (solid red line) is noisier than price informativeness, arguably due to measurement error and the lumpiness of investment. To facilitate assessment given this noisiness, we include a linear time trend (dashed black line).

Figure 6 shows a mild increase in earnings informativeness at the three-year horizon and a larger increase at the five-year horizon. The cumulative increase at the five-year horizon is about 50% in each specification, which is similar to the rise in price informativeness. Interestingly, CAPX matters most at the end of the NASDAQ boom in the late 1990s when many R&D-intensive firms ended up having low earnings. Table V conducts a formal test, which shows that the increase in five-year investment informativeness is statistically significant at the 10% level with R&D only and the 5% level with both R&D and CAPX.

Our results thus show that the variation in investment and the predicted variation of earnings from investment have both increased, at least when it comes to R&D.[30] Based on the logic of Claim 1, these findings suggest that aggregate efficiency, the efficiency of capital allocation in the economy, 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.

4.5 Institutional ownership and price informativeness

The key remaining question is whether this increased information production has taken place in markets or inside firms. In the framing of Section 2, we want to distinguish 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

[30]Looking at both measures is especially useful because they make it unlikely that our results are driven by changes in measurement error, a significant concern when it comes to investment. Changes in measurement error tend to push the two measures in opposite directions, whereas we see them moving in the same direction.

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. In the remaining sections 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 and 90th percentiles among all firms in 2014 are 12% and 94%, whereas among S&P 500 firms they are 61% and 94%. In other words, essentially all S& 500 firms are dominated by institutional investors whereas among all firms there is still a significant number with low levels of institutional ownership. 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, then that 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.

To run our test, we split firms into groups with high and low institutional share with the median institutional share in each year as the cutoff.[31] We then run the forecasting regressions (16) separately within each group and calculate its price informativeness as in (17).

Figure 7 presents the results. The left panel shows the average institutional share for the high and low groups over time. While both have been trending up, the high group has seen a somewhat larger increase (solid red line) so that the gap between them has grown.

The second and third panels of Figure 7 plot price informativeness. Recall from Section 4.1 that price informativeness outside the S&P 500 firms appears to decline, likely due to compositional changes. Figure 7 shows that the decline is entirely contained among firms with low institutional ownership (dashed black lines). The high group has much higher price

[31] Results are very similar if we use a fixed cutoff like one third though in that case the groups are unbalanced.

informativeness and it shows no sign of a decrease. The differences are very large: three-year price informativeness averages 0.044 for the high group versus 0.015 for the low group. At the five-year horizon these numbers are 0.067 and 0.046. The two groups are far enough apart that their price informativeness series never cross.

We provide a formal test in Table VI. Specifically, 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 horizons. Since institutional ownership data is only available after 1980, it is harder to test for trends, yet from the three- and five-year horizons we see that the gap in informativeness has been expanding over time just as the underlying gap in institutional share in Figure 7 has grown.

The results of this section demonstrate a strong relationship 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 (RPE).

4.6 Option listings and price informativeness

In the second cross-sectional test we compare price informativeness for firms with and without traded options.[32] The idea behind our test is that option markets 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.

Figure 8 shows 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 only present for the group with option listings.

We provide a formal test in Table VII where we again regress the difference in price informativeness between the two groups on decade dummies. The negative intercept suggests that listed firms actually had lower price informativeness in the 1970s when options first began trading. In latter decades, however, we see positive and significant coefficients, indicating that

[32]The CBOE began listing options of firms in 1973. By the end of our sample there are 77 S&P 500 firms without option listings.

the growth in price informativeness is concentrated among firms with option listings.

Based on the idea that options facilitate market-based information production, these results are also consistent with the view that the increased price informativeness we see is associated with greater revelatory price efficiency (RPE).

4.7 Growth options and price informativeness

So far we have tried to disentangle RPE and FPE by exploiting cross-sectional variation in information production in markets. In this section we complement this approach by exploiting cross-sectional variation in information production inside firms. To do this we first extend our framework from Section 2 by incorporating firm heterogeneity. A particularly relevant source of heterogeneity empirically is differences in the balance between growth options and assets in place. To capture such differences, we relax the assumption that growth options and assets in place are perfectly correlated by replacing (1) with

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

where z and $\tilde{z}$ are not be perfectly correlated. This case allows FPE and RPE to evolve differently for firms with more growth options (low $\overline{k}$) than firms with more assets in place (high $\overline{k}$). We call the former growth firms and the latter 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 while 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 do not have. This type of advantage is likely to be smaller for future products. For firms that depend on future growth, the relevant information valuation methods rely on comparisons to other firms and analysis of market trends. Here market participants might have an advantage or at least less of a disadvantage.[33] We can now state

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

(i) a decrease in σ_s^2 (traders produce more information) increases $\mathcal{V}_{FPE}$ more for growth firms (low $\overline{k}$) than value firms (high $\overline{k}$).

(ii) a decrease in σ_η^2 (firms produce more information) increases $\mathcal{V}_{FPE}$ more for value firms (high $\overline{k}$) than value firms (low $\overline{k}$).

Under Assumption 1, traders focus on valuing growth options. As their information increases, the FPE of growth firms rises more than value firms. Managers, on the other hand, 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. Of course, this is not a perfect test but we think it contributes to the overall picture that emerges from all our tests.[34]

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 are the growth stocks and the low-valuation group are the value stocks. We then calculate price informativeness separately for each group.

The results are presented in Figure 9 and Table VIII. Looking at Figure 9, 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 Figure 9, Table VIII (first three columns) 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 the view that the market has a relative advantage in producing information about growth firms, these results support the interpretation that RPE has increased. They are also

[33]For simplicity we write that market participants do not learn about z, but all we need is that they learn relatively more about $\tilde{z}$.

[34]For instance, growth firms are more uncertain and may be less transparent. Note, however, that our test is not about the overall difficulty of valuing growth firms versus value firms. Rather, 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.

of interest more broadly as the prospects of growth firms are inherently harder to assess so any additional information is likely of high value.

4.8 Liquidity and price informativeness

In our final cross-sectional test we examine the relationship 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 is in part why we pose the question of whether financial market prices have become more informative. After all, it is through trading that private information enters the market. The opportunity to trade in a liquid market also increases the incentive to produce information in the first place.

The upward trend in price informativeness we documented in Section 4.1 lines up well with the underlying trend in liquidity. That said, a more stringent test is to see whether higher liquidity is associated with higher price informativeness in the cross section. Accordingly, 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.

The results are presented in Figure 10. The first panel plots average (log) turnover rates. As expected, there is a strong upward trend for both groups. There is also some convergence as the gap has narrowed over time. This is in contrast to institutional share which shows divergence (Figure 4.5).

The main result in Figure 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. Moreover, there is mild convergence as price informativeness for the low-turnover group catches up with the high-turnover group towards the end of the sample.

The last three columns of Table VIII 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, the difference in five-year informativeness between the two groups is about two points, which is 50% of the level for the low-turnover group. Looking at the decade dummies, most are negative though few are statistically significant. The negative coefficients confirm that the price informativeness of the two groups has become more similar just as their turnover rates have been converging.

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.

5 Conclusion

The past few decades have brought enormous changes to 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 simple question: Have financial market prices become more informative? The answer to this question is important for capital allocation and for gauging the economic 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 market prices help to separate firms that will be productive in the future from those that will not.

We find that financial market prices *have* become more informative, specifically at the key medium and long horizons of three and five years. Price informativeness today is over 50% higher than in 1960. We present further evidence to suggest that the increase reflects greater revelatory price efficiency; that markets today produce more information that is useful for allocating investment and in doing so are contributing to the efficiency with which capital is allocated throughout the economy.

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Appendix

A Appendix Model

In this section we provide a full-fledged model of information production and trading as an example of the framework in Section 2. The model shares the basic setup of Equations (1)–(8). Following Subrahmanyam and Titman (1999), we assume the traded claim has payoff z (see our discussion of this assumption in Section 2).There are n informed traders who choose their demand x to maximize a standard mean-variance objective:

$$\max_x \; x\mathbb{E}\left[z-p|\,\eta',s\right]-\frac{\rho}{2}x^2\mathbb{V}\mathtt{ar}\left[z|\,\eta',s\right], \tag{A.1}$$

which leads to the usual demand curve

$$x = \frac{\mathbb{E}\left[z|\,\eta',s\right]-p}{\rho\mathbb{V}\mathtt{ar}\left[z|\,\eta',s\right]}. \tag{A.2}$$

From (7) and (8),

$$\mathbb{E}\left[z|\,\eta',s\right] = \frac{h_s s+h_{\eta'}\eta'}{h_z+h_s+h_{\eta'}} \tag{A.3}$$

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 η'. We also get that

$$\mathbb{V}\mathtt{ar}\left[z|\,\eta',s\right] = \frac{1}{h_z+h_s+h_{\eta'}}. \tag{A.4}$$

Therefore, the demand of each trader is

$$x = \frac{1}{\rho}\left[h_s s+h_{\eta'}\eta'-p\left(h_z+h_s+h_{\eta'}\right)\right] \tag{A.5}$$

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

$$nx = u \tag{A.6}$$

and we get the equilibrium price

$$\left(h_z+h_s+h_{\eta'}\right)p = h_s s+h_{\eta'}\eta'-\frac{\rho}{n}u. \tag{A.7}$$

Next we want to understand what the manager learns. Since she knows η' she can observe

$$s' = s-\frac{\rho}{nh_s}u = z+\epsilon_s-\frac{\rho}{nh_s}u \tag{A.8}$$

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

$$\gamma \frac{k^\star}{\overline{k}} = \mathbb{E}\left[z \middle| \mathcal{I}_m\right] = \frac{h_\eta \eta + h_{s'} s'}{h_z + h_\eta + h_{s'}}, \tag{A.9}$$

where

$$h_{s'} = \frac{1}{\sigma_{\epsilon_s}^2 + \left(\frac{\rho}{n h_s}\right)^2 \sigma_u^2} = \frac{h_s}{1 + \left(\frac{\rho}{n}\right)^2 \sigma_u^2}. \tag{A.10}$$

To compute the efficiency of the economy as in (13), we substitute (6) and (A.8) into (A.9) and obtain

$$\mathbb{E}\left[z \middle| \mathcal{I}_m\right] = \frac{\left(h_\eta + h_{s'}\right) z + h_\eta \epsilon_\eta + h_{s'} \left(\epsilon_s - \frac{\rho}{n h_s} u\right)}{h_z + h_\eta + h_{s'}}, \tag{A.11}$$

and so aggregate efficiency is

$$\mathbb{V}\mathtt{ar}\left(\mathbb{E}\left[z \middle| \mathcal{I}_m\right]\right) = \frac{\left(h_\eta + h_{s'}\right)^2 \sigma_z^2 + h_\eta + h_{s'}}{\left(h_z + h_\eta + h_{s'}\right)^2} = \left(\frac{h_\eta + h_{s'}}{h_z + h_\eta + h_{s'}}\right) h_z^{-1}. \tag{A.12}$$

We can thus state

Proposition A.1. *Aggregate efficiency is increasing in internal information h_η, external information h_s, and uncertainty h_z^{-1}.*

Proof. Recall from (13) that aggregate efficiency is $\mathbb{V}\mathtt{ar}\left(\mathbb{E}\left[z \middle| \mathcal{I}_m\right]\right)$. The proof follows by substituting (A.10) into (A.12) and taking derivatives. □

The informativeness of prices, on the other hand, depends on all the noises. We have

$$\left(h_z + h_s + h'\right) p = h_s s + h' \eta' - \frac{\rho}{n} u \tag{A.13}$$

$$= \left(h_s + h'\right) z + h_s \epsilon_s + h' \left(\epsilon_\eta + \epsilon_{\eta'}\right) - \frac{\rho}{n} u \tag{A.14}$$

so observing the price is equivalent to observing

$$\pi = \left(1 + \frac{h_z}{h_s + h'}\right) p = z + \frac{h_s}{h_s + h_{\eta'}} \epsilon_s + \frac{h_{\eta'}}{h_s + h_{\eta'}} \left(\epsilon_\eta + \epsilon_{\eta'}\right) - \frac{\rho}{\left(h_s + h_{\eta'}\right) n} u \tag{A.15}$$

and we have

$$\mathbb{E}\left[z \middle| p\right] = \frac{h_\pi \pi}{h_\pi + h_z}, \tag{A.16}$$

where

$$h_{\pi} = \frac{1}{\mathbb{V}\mathtt{ar}\left(\frac{h_s}{h_s+h_{\eta'}}\epsilon_s + \frac{h_{\eta'}}{h_s+h_{\eta'}}\left(\epsilon_\eta + \epsilon_{\eta'}\right) - \frac{\rho}{\left(h_s+h_{\eta'}\right)n}u\right)} = \frac{\left(h_s + h_{\eta'}\right)^2}{h_s + h_{\eta'} + \frac{\rho^2}{n^2}\sigma_u^2}. \quad \text{(A.17)}$$

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

$$\mathbb{V}\mathtt{ar}\left(\mathbb{E}\left[z|\, p\right]\right) = \mathbb{V}\mathtt{ar}\left(\frac{h_\pi\left(z + \frac{h_s}{h_s+h_{\eta'}}\epsilon_s + \frac{h_{\eta'}}{h_s+h_{\eta'}}\left(\epsilon_\eta + \epsilon_{\eta'}\right) - \frac{\rho}{\left(h_s+h_{\eta'}\right)n}u\right)}{h_\pi + h_z}\right) \quad \text{(A.18)}$$

$$= \frac{h_\pi}{h_\pi + h_z}h_z^{-1}. \quad \text{(A.19)}$$

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

$$\mathbb{V}\mathtt{ar}\left(\mathbb{E}\left[z|\, \eta, \eta', s'\right]\right) - \mathbb{V}\mathtt{ar}\left(\mathbb{E}\left[z|\, \eta, \eta'\right]\right) = \left(\frac{h_\eta + h_{s'}}{h_z + h_\eta + h_{s'}} - \frac{h_\eta}{h_z + h_\eta}\right)h_z^{-1}. \quad \text{(A.20)}$$

We have the following comparative statics:

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_η leads to an increase in aggregate efficiency, an increase in the predicted variance of cash flows from investment, and, if disclosure is positive, to an increase in FPE but not RPE; and

(iii) an increase in $h_{\eta'}$, holding h_η constant, only leads to an increase in FPE.

Proof. The results follow by taking derivatives in the expressions for aggregate efficiency, (A.12), FPE, (A.19), and RPE, (A.20). 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 2.

Free entry There are several ways to capture changes in information technology. We can simply assume that signals become more informative, as in the privious proposition. 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

$$U = \frac{1}{2\rho}\frac{\left(\mathbb{E}\left[z - p|\, \eta', s\right]\right)^2}{\mathbb{V}\mathtt{ar}\left[z|\, \eta', s\right]} = \frac{1}{2\rho}\frac{\left(\frac{h_s s + h_{\eta'}\eta'}{h_z+h_s+h_{\eta'}} - p\right)^2}{\frac{1}{h_z+h_s+h_{\eta'}}}. \quad \text{(A.21)}$$

Substituting for the price from (A.13), we get

$$U = \frac{\left(\frac{\rho}{n}u\right)^2}{2\rho\left(h_z + h_s + h_{\eta'}\right)}. \tag{A.22}$$

So expected utility of becoming an informed trader is

$$\mathbb{E}\left[U\right] = \frac{\rho\sigma_u^2}{2\left(h_z + h_s + h_{\eta'}\right)}\frac{1}{n^2}. \tag{A.23}$$

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

$$n = \sqrt{\frac{1}{\psi}\frac{\rho\sigma_u^2}{2\left(h_z + h_s + h_{\eta'}\right)}}. \tag{A.24}$$

The number of traders who enter depends on the cost of information, the amount of noise trading, and the signal precisions.[35] This shows how a lower cost of information increases RPE and how we can tease it out from RPE. These predictions map into the framework we presented in Section 2.

B Price informativeness over time, robustness

Table A.I shows the estimates of our cross-sectional regressions (16) for 2009, the last year for which we have data at the five-year horizon. We focus on horizons of one, three, and five years. As Table A.I, 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 coefficient. As Figure A.1 shows, the coefficient on current earnings on typically declines with horizon. The year 2009 is somewhat unusual since 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.

Figure A.1 plots the average coefficients from our cross-sectional forecasting regressions (16) by horizon. The format of the figure follows Figure 2. Like the coefficients on prices, the coefficients on earnings are slightly higher in the second half of the sample, but since the cross-sectional standard deviation of earnings is the same (see Figure 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 quasi-permanent effect. These results support the view that current earnings are relatively more informative at short horizons whereas prices are relatively more informative at long horizons. They thus provide further motivation for focusing on price informativeness at longer horizons.

Figure A.2 replicates the analysis in Section 4.1 under a number of variations. In the first variation, we replace the market value of equity M with the sum of the market value

[35] We note that in this simple model disclosure increases entry because it is assumed that disclosure is only observed 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.

of equity and the book value of long-term debt D in calculating the valuation ratio in the forecasting regressions 16. This ensures that our measure is not picking up changes in the cross-sectional relationship between firm leverage and future earnings. As the first column of Figure A.2 shows, price informativeness continues to increase at the three-and five-year horizon even when we adjust for debt.

The remaining columns of Figure A.2 show robustness to alternative measures of firm cash flows. In the main text we 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 flow from operations (CFO) as alternatives. In the case of EBITDA and net income the resulting price informativeness series evolve very similarly as with EBIT. In the case of CFO, data is only available following the promulgation of FASB rule 95 in 1987. This makes it hard to assess trends but we note that the series using CFO are similar to those using the other measures.

C Beyond the S&P 500

Table A.II presents summary statistics for the universe of firms. Compared to the S&P 500, these firms are smaller, 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 importantly, 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 also fallen from 9% of total assets to -0.6%. The drop in the median is smaller, from 10.2% to 6.1%, indicating increased left-skewness. Indeed, many of these firms have consistently negative earnings.

Next, we replicate the analysis from Section 4.1 for firms beyond the S&P 500. The results are presented in Figure A.3 and Table A.III. The top two panels of Figure A.3 show that the two groups differ greatly on observable characteristics. From the top left panel, 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 the top right panel, 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 80s and the dot-com boom in the 1990s. (Indeed, if we remove NASDAQ firms from the sample the changes are a lot less pronounced.) Both episodes are associated with a large inflow of younger, smaller, and more uncertain firms (see 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, there is no evidence of such changes. In particular, their earnings dispersion is virtually constant over the whole fifty-year period.

To see the effects of the compositional changes among all firms, we can look at our informativeness measures, which are shown in the bottom two panels of Figure A.3 (the middle two panels 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 the top panels. This suggests that it is indeed due to changing firm composition.

Interestingly, the apparent decline is more pronounced at the short horizon. As Table A.III shows, one-year informativeness for all firms falls by a highly significant 73% from the 1960s to the 2000s, whereas five-year informativeness falls by an insignificant 17% (at three years the drop is 60%). Recall from Table II that for S&P 500 firms one-year informativeness is flat, whereas 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.

D Tests for a structural break in price informativeness

In this section we examine the evidence for a structural break in price informativeness. The adoption of Regulation Fair Disclosure in 2000 and the passage of the Sarbanes-Oxley Act in 2002 are likely candidates. These reforms had a large impact on firms' disclosure requirements. 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 should lead to detectable changes in our price informativeness series. More broadly, we ask whether there is evidence of a structural break at any point in our sample.

To test for structural breaks, we first form the null hypothesis that price informativeness has increased linearly over our sample from 1960 to 2014. Specifically, we run a regression of price informativeness at each horizon (shown in Figure 3) on a constant and a linear time trend. We normalize the linear time trend to zero in 1960 and one in 2014. This allows us to interpret the constant as the value of price informativeness in 1960 and the sum of the constant and slope coefficient as the value of price informativeness in 2014. The results are in Table A.IV. 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 1960, while the three- and five-year informativeness series are 62% and 85% higher, respectively.

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 regression estimates in Table A.IV. 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).

Since 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 (Sarbanes-Oxley). The results are also reported in Table A.IV. 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. Rather, informativeness has been increasing steadily throughout our fifty-year sample. This makes it less likely that the increase is driven by changes in disclosure requirements which are discrete in nature.

Table I. Summary statistics

Means, medians, and standard deviations of key variables, S&P 500 sample. Market capitalization is from CRSP in millions of dollars as of the end of March. Total assets, research and development (R&D), capital expenditure (CAPX), and earnings (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 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 twelve 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 CBOE. The sample consists of S&P 500 non-financial firms, 1960 to 2014.

	Full sample			1960-1985			1986-2014		
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
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
Firm-year obs.		24,701			12,350			12,351	

Table II. Price informativeness over time

Time series regressions of price informativeness by horizon. Price informativeness is calculated as in formula (17) using estimates from the cross-sectional forecasting regressions (16). The resulting price informativeness series are shown in Figure 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. Since our sample ends in 2014, there are no five-year price informativeness estimates for the period 2010–2014. We report Newey-West standard errors with 5 lags in parentheses. The sample consists of S&P 500 non-financial firms from 1960 to 2014.

	Price informativeness ($\times 100$)		
Horizon h (years):	$h = 1$	$h = 3$	$h = 5$
Constant	2.001***	3.111***	4.123***
	(0.059)	(0.184)	(0.111)
1970–79	0.020	0.707*	-0.106
	(0.092)	(0.417)	(0.378)
1980–89	0.405**	1.075***	1.874***
	(0.197)	(0.332)	(0.134)
1990–99	0.413*	1.406***	1.489***
	(0.240)	(0.331)	(0.397)
2000–09	0.503***	1.561**	2.143***
	(0.185)	(0.583)	(0.311)
2010–14	0.314	0.840***	
	(0.288)	(0.253)	
R^2	12.2%	19.5%	53.3%
Obs.	54	52	50

Table III. Market prices and investment

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 (19) and $\sigma_t (\log M/A)$ is the cross-sectional standard deviation of $\log M/A$. The resulting predicted variation of investment from prices series are shown in Figure 4. 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. Since our sample ends in 2014, there are no five-year predicted variation estimates for the period 2010–2014. We report Newey-West standard errors with 5 lags in parentheses. The sample consists of S&P 500 non-financial firms from 1960 to 2014. Data on R&D starts in 1972, hence the omitted category for R&D is 1970–79.

	Predicted variation of investment from prices ($\times 100$)					
	R&D			CAPX		
Horizon h (years):	$h=1$	$h=3$	$h=5$	$h=1$	$h=3$	$h=5$
Constant	0.134***	0.379***	0.636***	0.942***	1.867***	2.206***
	(0.027)	(0.076)	(0.153)	(0.212)	(0.357)	(0.325)
1970–79				-0.325	-0.238	-0.244
				(0.232)	(0.396)	(0.353)
1980–89	0.153***	0.669***	0.908***	0.411	1.209**	1.930***
	(0.048)	(0.091)	(0.160)	(0.250)	(0.541)	(0.610)
1990–99	0.147	0.779**	0.920***	-0.166	0.630	0.813**
	(0.088)	(0.287)	(0.249)	(0.216)	(0.470)	(0.337)
2000–09	1.028***	1.264***	1.761***	-0.266	-0.911**	-0.903**
	(0.097)	(0.127)	(0.298)	(0.302)	(0.370)	(0.344)
2010–14	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%
Obs.	42	40	38	54	52	50

Table IV. Market prices and returns

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 (20) and $\sigma_t\,(\log M/A)$ is the cross-sectional standard deviation of $\log M/A$. The resulting series are shown in Figure 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. Since our sample ends in 2014, there are no five-year estimate for the period 2010–2014. We report Newey-West standard errors with 5 lags in parentheses. The sample consists of S&P 500 non-financial firms from 1960 to 2014.

	Predicted variation of returns from prices (×100)		
Horizon h (years):	$h = 1$	$h = 3$	$h = 5$
Constant	-3.214***	-8.712***	-11.101***
	(0.274)	(0.907)	(2.162)
1970–79	-1.197	-0.884	-4.449
	(0.983)	(3.054)	(4.081)
1980–89	0.395	4.686**	5.894*
	(0.607)	(1.787)	(3.416)
1990–99	1.172**	3.416**	4.592
	(0.502)	(1.371)	(2.888)
2000–09	-6.421*	-3.947	-4.987
	(3.196)	(6.322)	(9.293)
2010–14	2.491***	5.189***	
	(0.371)	(0.934)	
R^2	23.2%	13.6%	14.4%
Obs.	54	52	50

Table V. **Aggregate efficiency**

Time series regressions of the predicted variation of earnings from investment by horizon. The predicted variation of earnings from investment is calculated as $\sigma_t\left(b_{t,h}\log R\&D/A + c_{t,h}\log CAPX/A\right)$ where $b_{t,h}$ and $c_{t,h}$ are the forecasting coefficient of R&D and CAPX in regression (21). We also chow results for R&D only ($c_{t,h} = 0$). The resulting predicted variation series are shown in Figure 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. Since our sample ends in 2014, there are no five-year estimate for the period 2010–2014. We report Newey-West standard errors with 5 lags in parentheses. The sample consists of S&P 500 non-financial firms from 1960 to 2014.

	Predicted variation of earnings from investment (×100)					
	R&D only			R&D and CAPX		
Horizon h (years):	$h=1$	$h=3$	$h=5$	$h=1$	$h=3$	$h=5$
Constant	0.438***	0.911***	1.299***	0.678***	1.243***	1.700***
	(0.111)	(0.260)	(0.207)	(0.057)	(0.205)	(0.225)
1980–89	-0.018	0.192	0.596	0.283**	0.600	1.018***
	(0.189)	(0.473)	(0.361)	(0.124)	(0.409)	(0.299)
1990–99	0.227*	0.533*	0.396	0.287*	0.646**	0.559**
	(0.121)	(0.299)	(0.344)	(0.159)	(0.290)	(0.245)
2000–09	0.146	0.540	0.992*	0.386	0.587**	0.907***
	(0.149)	(0.495)	(0.520)	(0.270)	(0.252)	(0.389)
2010–14	-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%
Obs.	42	40	38	42	40	38

Table VI. Institutional ownership and price informativeness
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 regressions (16) and calculating the product of the forecasting coefficient and the standard deviation of market prices, $b_{t,h} \times \sigma_t (\log M/A)$. The resulting price informativeness series are shown in Figure 7. 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. Since our sample ends in 2014, there are no five-year price informativeness estimates for the period 2010–2014. We report Newey-West standard errors with 5 lags in parentheses. The sample consists of all non-financial firms from 1980 to 2014 when institutional ownership data is available.

	Price informativeness ($\times 100$) high $-$ low institutional ownership		
Horizon h (years):	$h=1$	$h=3$	$h=5$
Constant	2.526***	2.842***	2.376***
	(0.304)	(0.123)	(0.255)
1990–99	0.805**	1.996***	2.981***
	(0.387)	(0.309)	(0.452)
2000–09	0.700	1.401***	1.623**
	(0.522)	(0.331)	(0.650)
2010–14	-0.249	2.040***	
	(0.312)	(0.129)	
R^2	22.6%	49.6%	56.3%
Obs.	33	31	29

Table VII. Option listings and price informativeness

Time series regressions of the difference in price informativeness between firms with and without option listings. Price informativeness is obtained separately for each group by running the forecasting regressions (16) and calculating the product of the forecasting coefficient and the standard deviation of market prices, $b_{t,h} \times \sigma_t (\log M/A)$. The resulting price informativeness series are shown in Figure 8. For this table 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. Since our sample ends in 2014, there are no five-year price informativeness estimates for the period 2010–2014. We report Newey-West standard errors with 5 lags in parentheses. The sample consists of S&P 500 non-financial firms from 1973 to 2014 (the CBOE began listing firms in 1973).

	Price informativeness ($\times$100) listed − unlisted firms		
Horizon h (years):	$h = 1$	$h = 3$	$h = 5$
Constant	-0.873***	-1.491***	-1.623***
	(0.162)	(0.446)	(0.390)
1980–89	0.682**	1.111**	0.573
	(0.285)	(0.498)	(0.780)
1990–99	1.335***	2.136**	2.188
	(0.294)	(0.906)	(1.601)
2000–09	1.077***	2.455***	2.445**
	(0.376)	(0.759)	(0.961)
2010–14	1.217***	1.810***	
	(0.199)	(0.457)	
R^2	22.0%	21.7%	13.0%
Obs.	41	39	37

Table VIII. Growth options, turnover, and price informativeness

Time series regressions of the difference in price informativeness between value and growth firms (first three columns) and between high-turnover and low-turnover firms (last three columns). 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. 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. Price informativeness is obtained separately for each group by running the forecasting regressions (16) and calculating the product of the forecasting coefficient and the standard deviation of market prices, $b_{t,h} \times \sigma_t\,(\log M/A)$. The resulting price informativeness series are shown in Figures 9 and 10. For this table we regress the difference in price informativeness between growth and value firms and between high- and low-turnover firms at a given horizon $h = 1, 3, 5$ years on a set of indicator variables corresponding to each decade in our sample. Since our sample ends in 2014, there are no five-year price informativeness estimates for the period 2010–2014. We report Newey-West standard errors with 5 lags in parentheses. The sample consists of S&P 500 non-financial firms from 1960 to 2014.

	Price informativeness (×100)					
	Growth − value firms			High − low turnover firms		
Horizon h (years):	$h = 1$	$h = 3$	$h = 5$	$h = 1$	$h = 3$	$h = 5$
Constant	0.847**	2.591***	3.813***	1.298***	2.012***	2.109**
	(0.403)	(0.393)	(0.315)	(0.464)	(0.634)	(0.802)
1970–79	0.031	-0.521	-1.574***	-0.683	-0.057	-0.186
	(0.395)	(0.535)	(0.437)	(0.475)	(0.648)	(1.068)
1980–89	0.862*	0.837	1.599*	-0.614	-2.294**	-2.646*
	(0.442)	(0.584)	(0.800)	(0.500)	(0.920)	(1.568)
1990–99	1.588***	2.987***	3.029***	0.227	0.560	0.375
	(0.450)	(0.586)	(0.497)	(0.561)	(0.776)	(0.849)
2000–09	0.759*	0.867	1.465**	-0.199	-0.832	-0.584
	(0.449)	(0.730)	(0.676)	(0.506)	(0.960)	(0.942)
2010–14	0.136	0.484		-0.593	-2.064***	
	(0.457)	(0.474)		(0.599)	(0.651)	
R^2	40.5%	36.4%	49.3%	13.1%	23.6%	17.9%
Obs.	54	52	50	54	52	50

Table A.I. Example cross-sectional regression from 2009

We report a sample cross-sectional forecasting regression (16) 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 (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). Note however that these standard errors are not used in subsequent analysis since we use the time series variation in the estimates to form standard errors in our time series regressions (this is equivalent to a Fama-Macbeth regression). The sample consists of S&P 500 non-financial firms for 2009.

	E_{2009+h}/A_{2009}		
Horizon h (years):	$h = 1$	$h = 3$	$h = 5$
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 F.E.	Yes	Yes	Yes
R^2	62.9%	50.4%	37.9%
Obs.	424	423	420

Table A.II. Summary statistics, all firms

Means, medians, and standard deviations of key variables, all firms. Market capitalization is from CRSP in millions of dollars as of the end of March. Total assets, research and development (R&D), capital expenditure (CAPX), and earnings (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 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 twelve 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 CBOE. The sample consists of non-financial firms, 1960 to 2014.

	Full sample			1960-1985			1986-2014		
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
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
$E(t+5)/A$	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
Firm-year obs.		211,984			80,561			131,423	

Table A.III. Price informativeness over time, all firms

Time series regressions of price informativeness by horizon for all firms. Price informativeness is calculated as in (17) using estimates from the cross-sectional forecasting regressions (16). The resulting price informativeness series are shown in Figure A.3. We then 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. Since our sample ends in 2014, there are no five-year price informativeness estimates for the period 2010–2014. We report Newey-West standard errors with 5 lags in parentheses. The sample consists of all non-financial firms from 1960 to 2014.

	Price informativeness (×100)		
Horizon h (years):	$h = 1$	$h = 3$	$h = 5$
Constant	2.526***	3.813***	4.982***
	(0.214)	(0.644)	(0.807)
1970–79	0.305	0.711	0.854
	(0.220)	(0.709)	(0.978)
1980–89	-1.276***	-1.188*	-0.317
	(0.274)	(0.654)	(0.868)
1990–99	-1.902***	-1.882***	-0.466
	(0.221)	(0.679)	(0.980)
2000–09	-1.944***	-1.907**	-0.852
	(0.277)	(0.759)	(0.880)
2010–14	-1.854***	-2.266***	
	(0.292)	(0.653)	
R^2	81.8%	61.3%	19.3%
Obs.	54	52	50

Table A.IV. Tests for a structural break in price informativeness

We test for structural breaks in the evolution of price informativeness over time. Price informativeness is calculated as in formula (17) using estimates from the cross-sectional forecasting regressions (16). The resulting series are shown in Figure 3. For this table we regress each series on a constant and a linear time trend. The linear time trend is normalized to 0 in 1960 and 1 in 2014, hence the constant can be interpreted as the value of price informativeness in 1960 and the sum of the constant and the slope coefficient can be interpreted as the value of price informativeness in 2014. Newey-West standard errors with 5 lags are reported in parentheses. 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 adoption years of Regulation Fair Disclosure, 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 consists of S&P 500 non-financial firms from 1960 to 2014.

	Price informativeness ($\times 100$)		
Horizon h (years):	$h = 1$	$h = 3$	$h = 5$
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%
Obs.	54	52	50
Test for an unknown break point:			
Highest likelihood break point	1996	1974	1980
Supremum Wald statistic (χ^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 (χ^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 (χ^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 (χ^2)	0.678	3.762	1.076
p-value	0.712	0.152	0.584

Figure 1. **Summary statistics**

The sample consists of non-financial firms in the S&P 500 index from 1960 to 2014. Each panel shows medians (red line) and 10th to 90th percentile range (gray shading). $\log M/A$ is the log ratio of market capitalization to total assets. E/A is EBIT over assets. $R\&D/A$ and $CAPX/A$ are research and development and capital expenditure over assets. All quantities are adjusted for inflation.

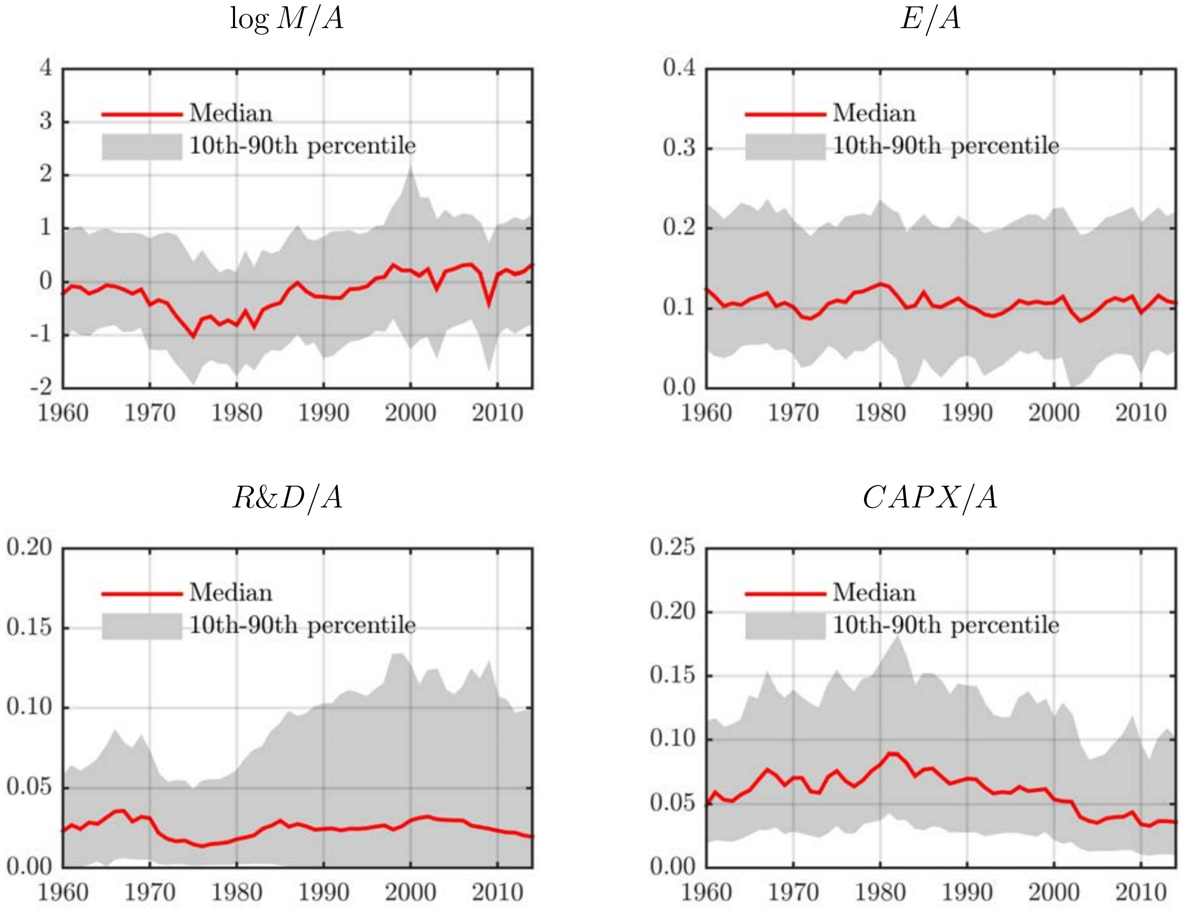


Figure 2. Average price informativeness by horizon and sub-sample
This figure shows average price informativeness calculated from the cross-sectional forecasting regressions (16):

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

where M is market cap, A is total assets, E is earnings (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 $b_{t,h} \times \sigma_t\left(\log M/A\right)$. The horizontal axis represents horizon h. The solid red line shows price informativeness at horizon h averaged over the full sample, i.e. $\frac{1}{55}\sum_{t=1960}^{2014} b_{t,h} \times \sigma_t\left(\log M/A\right)$. 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 consists of S&P 500 non-financial firms from 1960 to 2014.

Average price informativeness $\frac{1}{T}\sum_t b_{t,h} \times \sigma_t\left(\log M/A\right)$

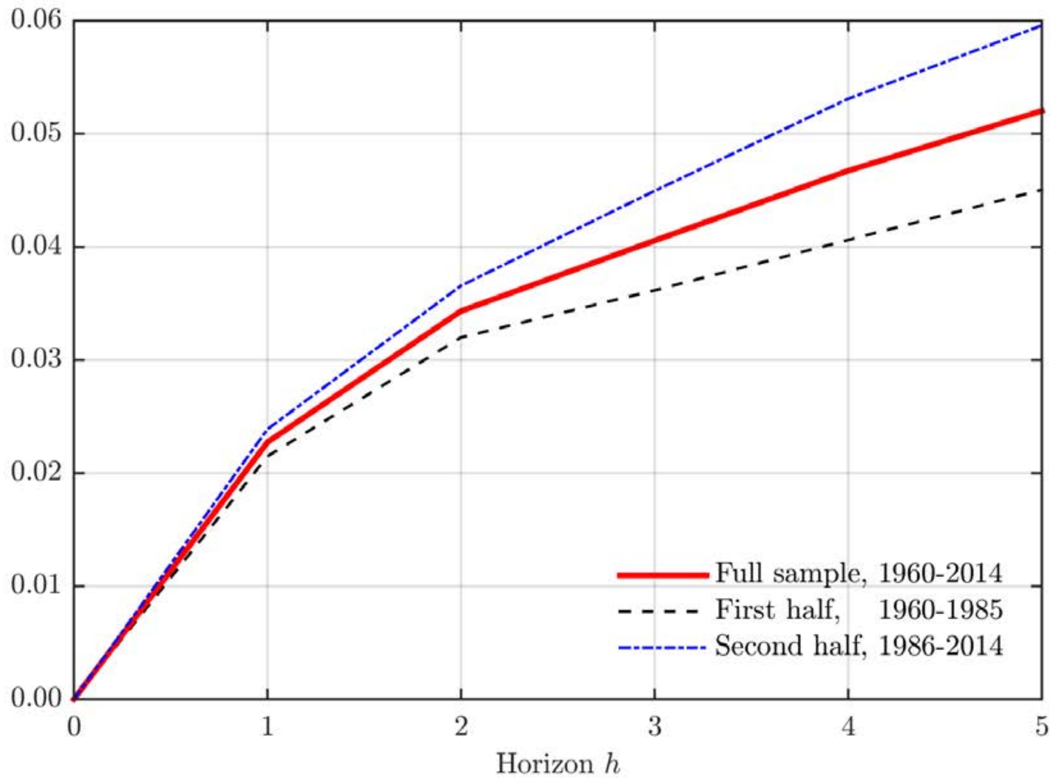


Figure 3. Price informativeness over time

Results from the cross-sectional forecasting regressions (16):

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

where M is market cap, A is total assets, E is earnings (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 coefficients $b_{t,h}$ are plotted inside a 95% confidence interval. Price informativeness is $b_{t,h} \times \sigma_t (\log M/A)$. 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 consists of S&P 500 non-financial firms from 1960 to 2014.

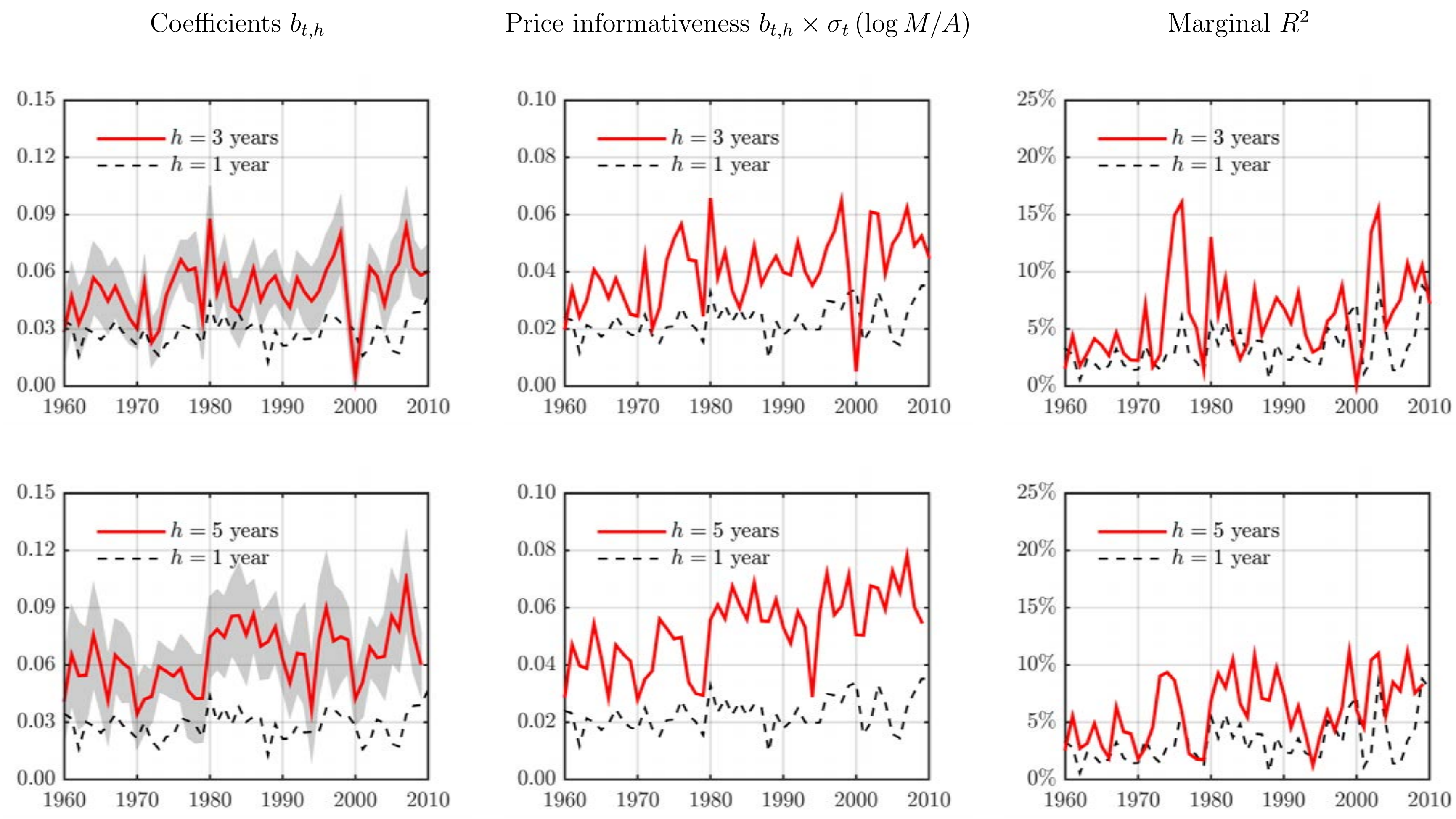


Figure 4. Market prices and investment

The predicted variation of investment from prices calculated from the cross-sectional forecasting regressions (19):

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

where M is market cap, A is total assets, $R\&D$ is research and development spending, E is earnings (EBIT), and $\mathbf{1}^s$ is a sector (one-digit SIC code) indicator variable. 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 $b_{t,h} \times \sigma_t(\log M/A)$. The sample consists of S&P 500 non-financial firms from 1960 to 2014. Data on R&D starts in 1972.

Predicted variation of investment from prices $b_{t,h} \times \sigma_t(\log M/A)$

R&D | CAPX

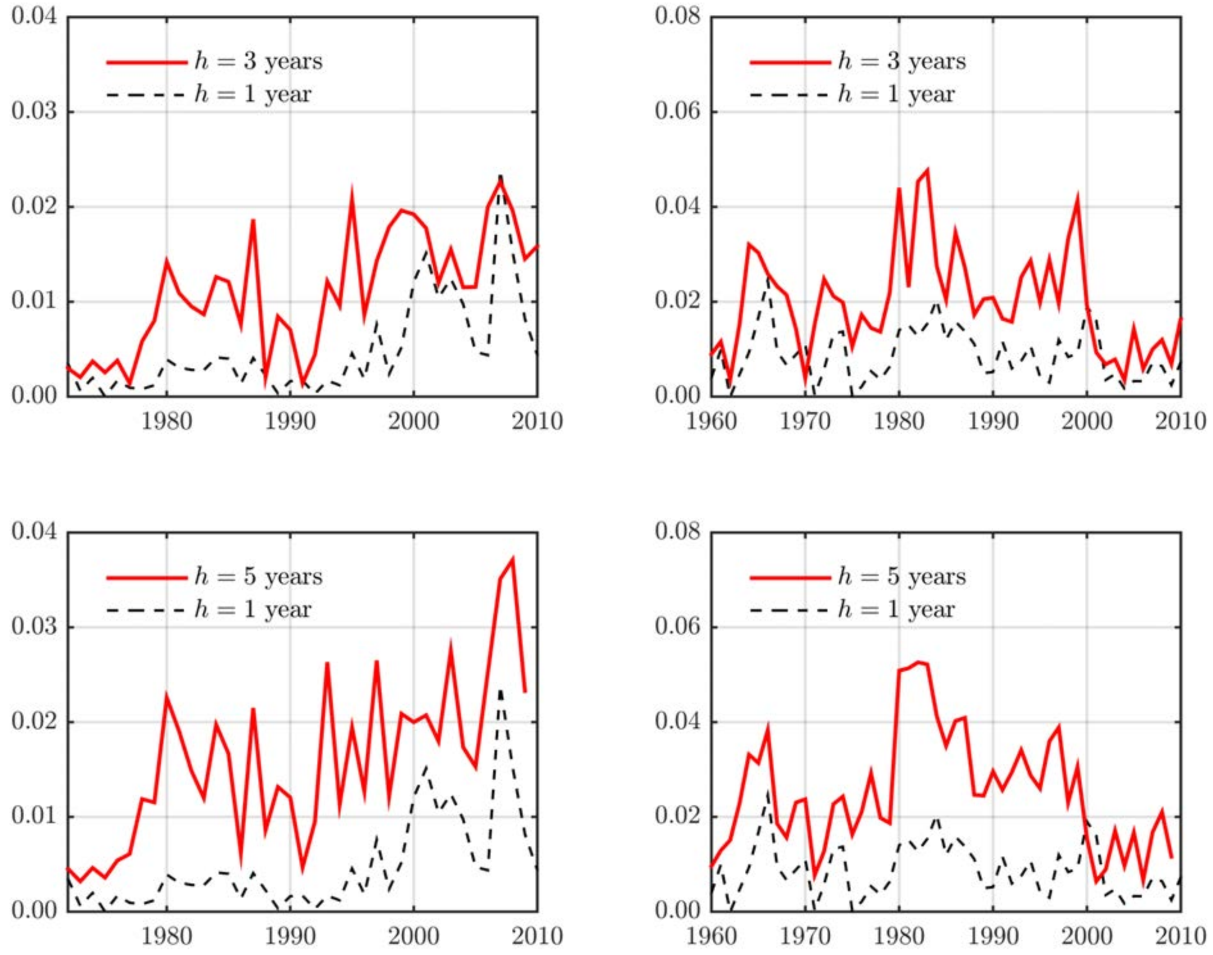


Figure 5. **Market prices and returns**

The predicted variation of returns from prices calculated from the cross-sectional return predictability regressions (20):

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

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 (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 $b_{t,h} \times \sigma_t\left(\log M/A\right)$. We also plot price informativeness (the predicted variation of earnings from prices) for comparison (dashed black lines). The sample consists of S&P 500 non-financial firms from 1960 to 2014.

Predicted variation of returns from prices $b_{t,h} \times \sigma_t\left(\log M/A\right)$

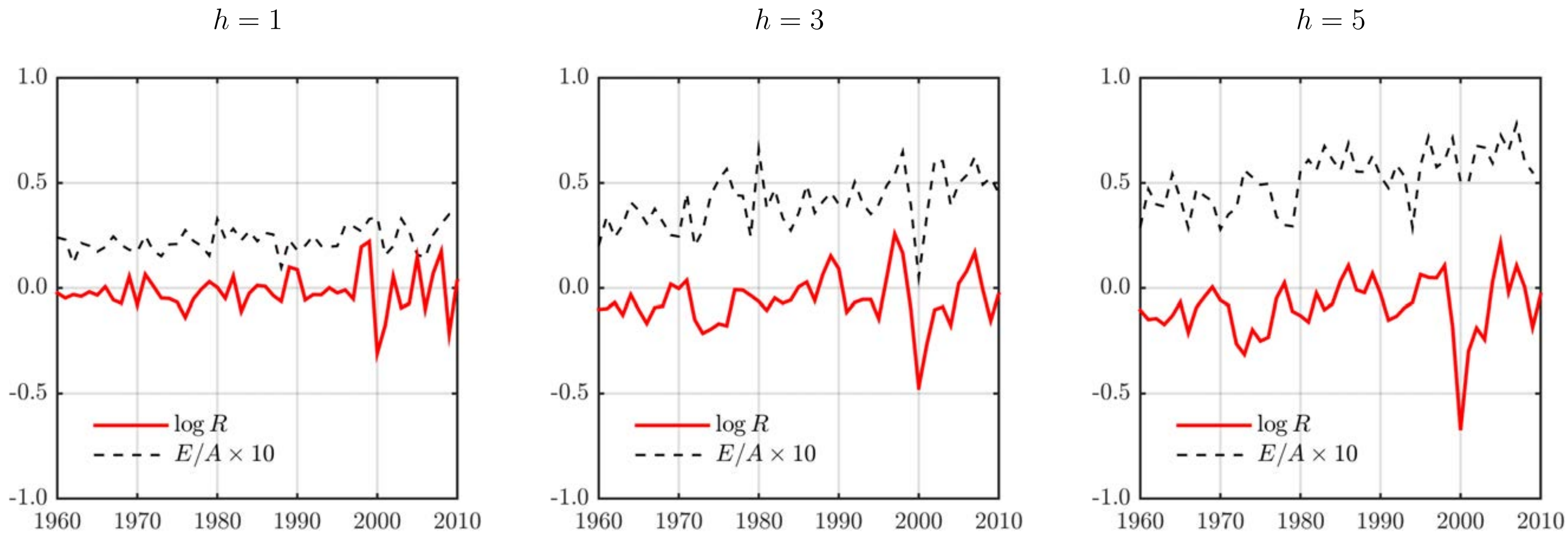


Figure 6. Aggregate efficiency

The predicted variation of earnings from investment calculated from the forecasting regressions (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 (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 $\sigma_t\left(b_{t,h}\log R\&D/A + c_{t,h}\log CAPX/A\right)$. We also plot a linear time trend (dashed black lines). The sample consists of S&P 500 non-financial firms from 1972 to 2014 (R&D data is not available prior to 1972).

Predicted variation of earnings from investment

R&D only | R&D and CAPX

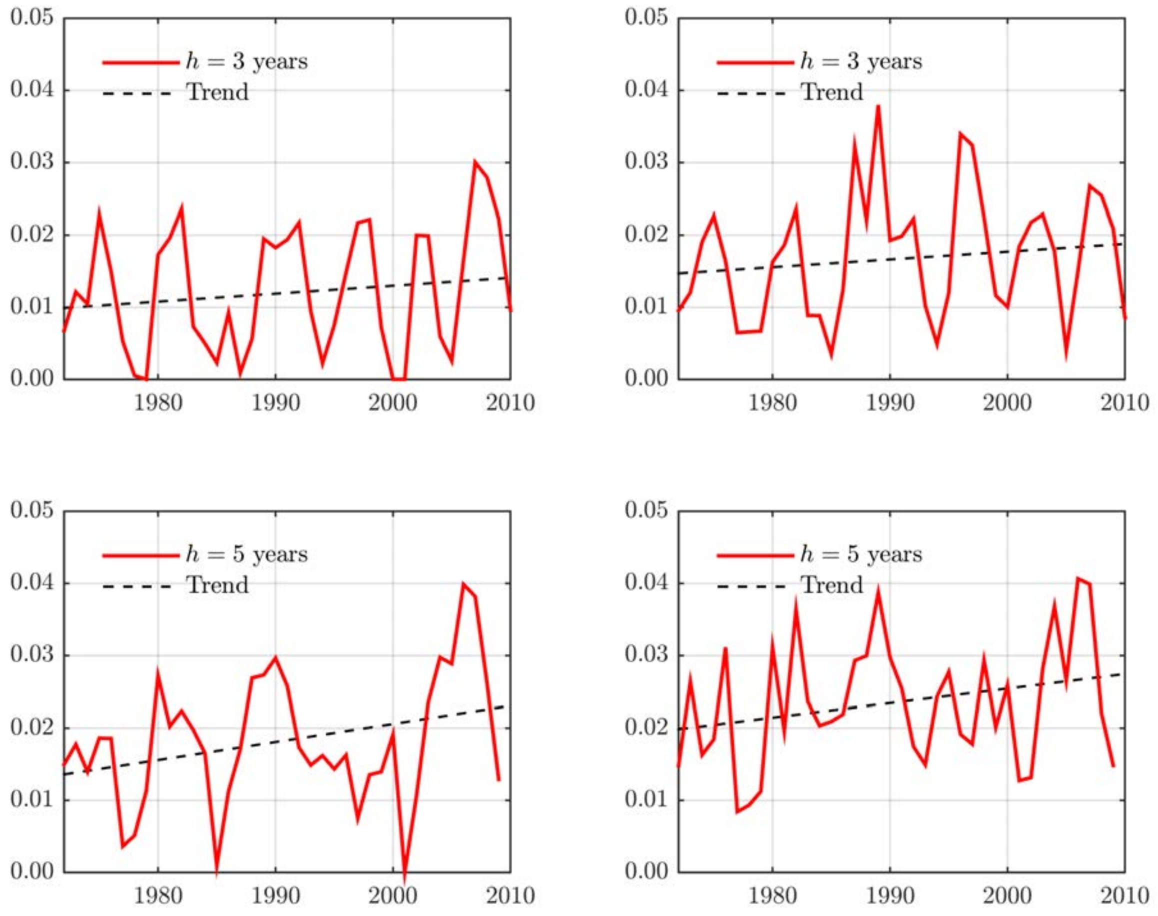


Figure 7. **Institutional ownership and price informativeness**

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. The left panel plots the average institutional share for firms in each group. Price informativeness is obtained separately for each group by running the forecasting regressions (16) and calculating the product of the forecasting coefficient and the standard deviation of market prices, $b_{t,h} \times \sigma_t (\log M/A)$. The sample consists of all non-financial firms from 1980 to 2014 (institutional ownership data is not available before 1980).

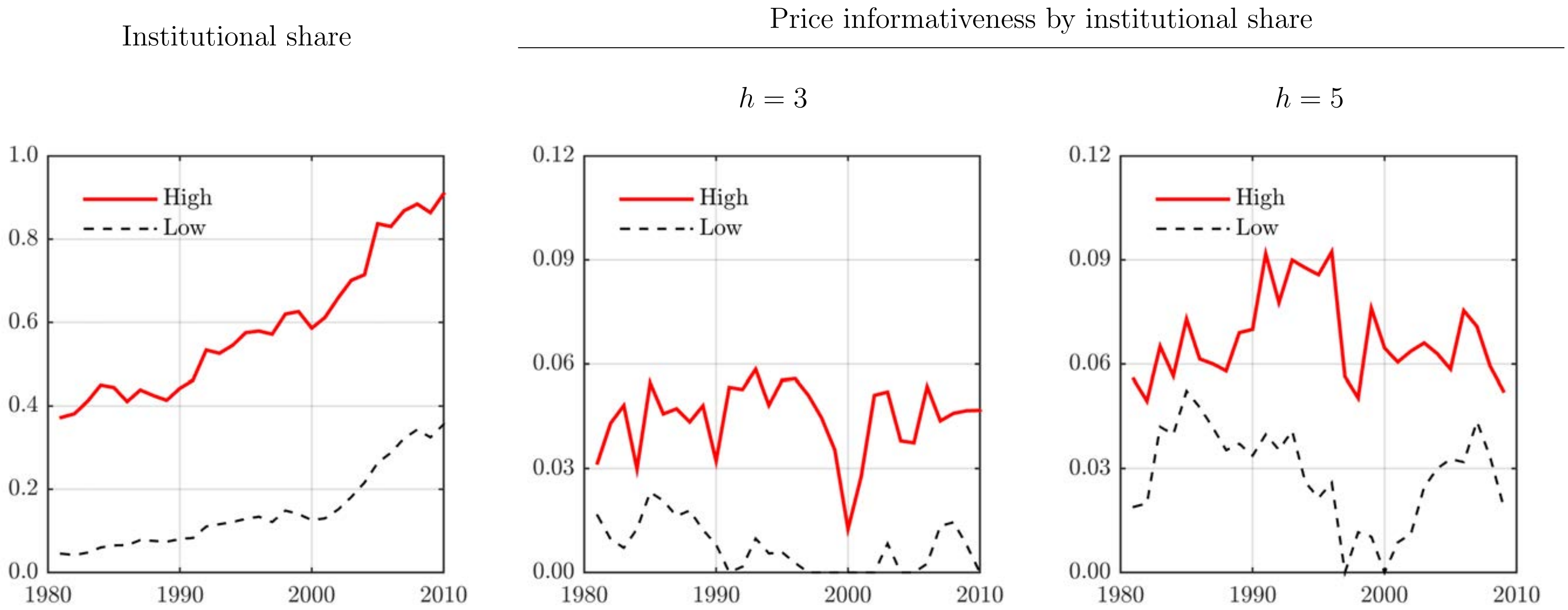


Figure 8. Option listings and price informativeness
We compare price informativeness for firms with and without option listings. Price informativeness is obtained separately for each group by running the forecasting regressions (16) and calculating the product of the forecasting coefficient and the standard deviation of market prices, $b_{t,h} \times \sigma_t\,(\log M/A)$. The sample consists of S&P 500 non-financial firms from 1973 to 2014 (the CBOE began listing firms in 1973).

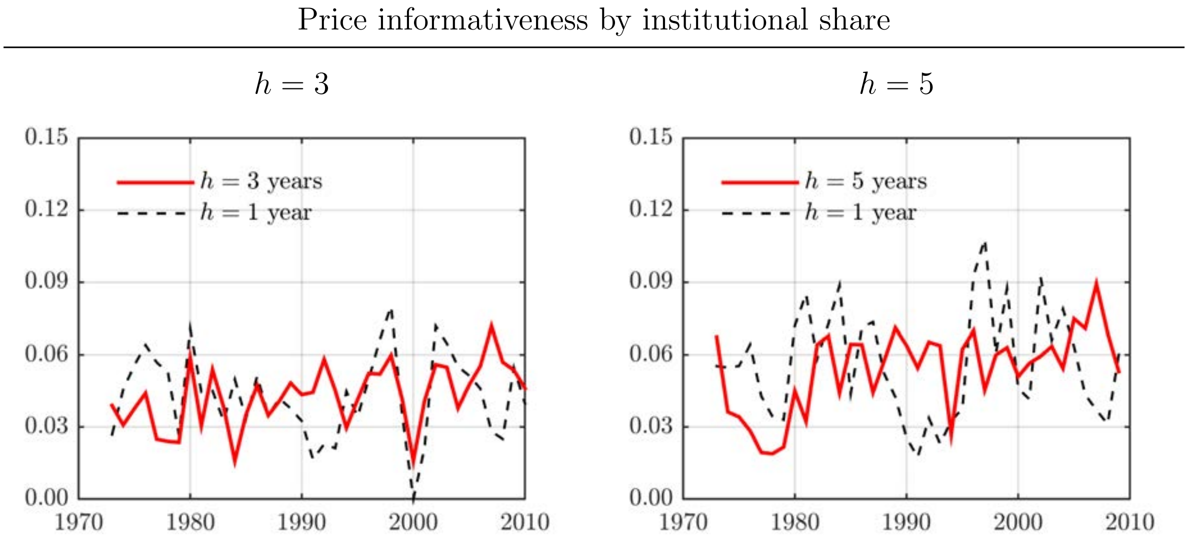


Figure 9. Growth options and price informativeness
We compare price informativeness for firms with high and low valuation ratios, using the median value of the valuation ratio $\log M/A$ in each year as the cutoff. We refer to high-valuation firms as growth firms and low-valuation firms as value firms. Price informativeness is obtained separately for each group by running the forecasting regressions (16) and calculating the product of the forecasting coefficient and the standard deviation of market prices, $b_{t,h} \times \sigma_t (\log M/A)$. The sample consists of S&P 500 non-financial firms from 1960 to 2014.

Price informativeness by level of valuation

Low valuation (value firms) | High valuation (growth firms)

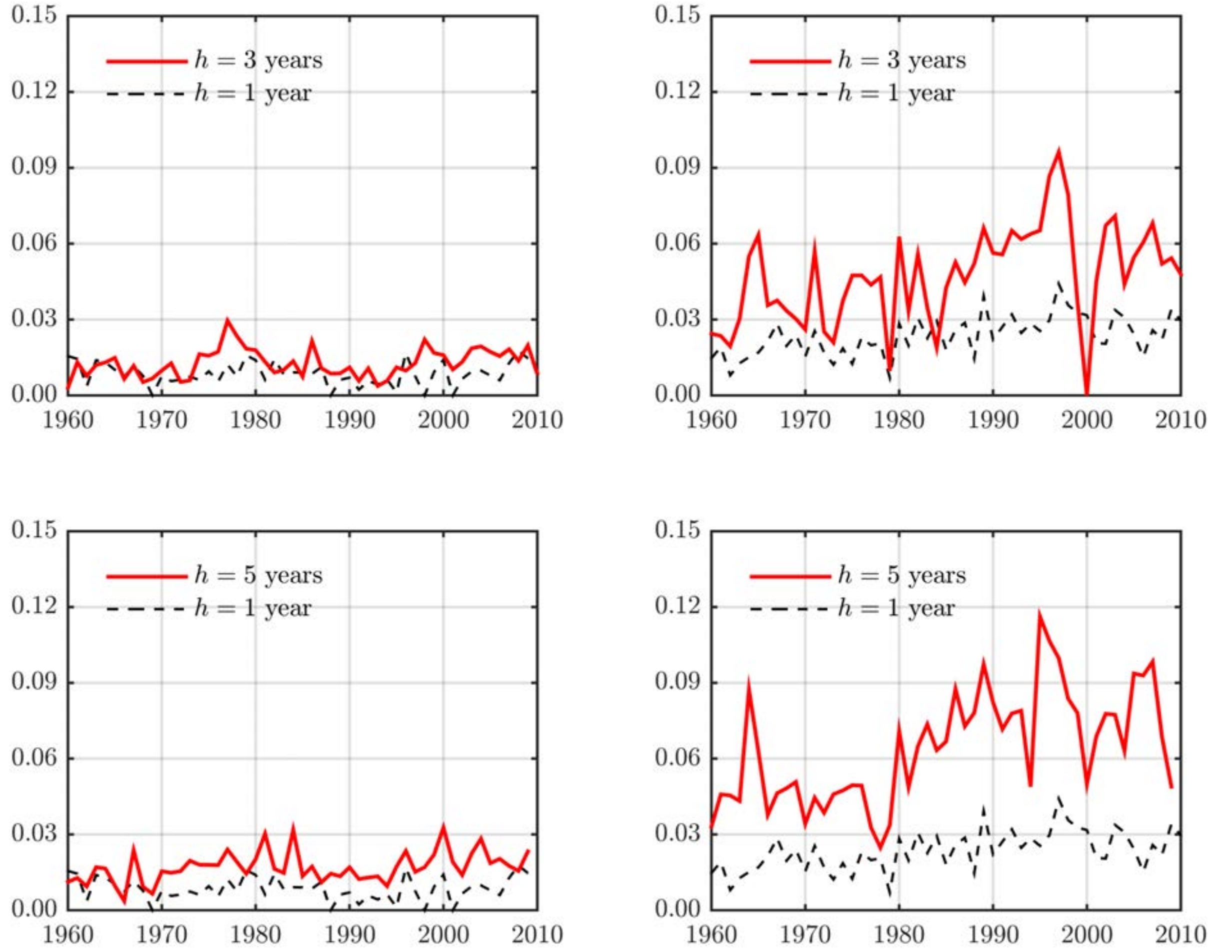


Figure 10. **Liquidity and price informativeness**
We compare price informativeness for firms with high and low levels of share turnover, using the median turnover in each year as the cutoff. The left panel plots the average log turnover for firms in each group. Price informativeness is obtained separately for each group by running the forecasting regressions (16) and calculating the product of the forecasting coefficient and the standard deviation of market prices, $b_{t,h} \times \sigma_t (\log M/A)$. The sample consists of S&P 500 non-financial firms from 1960 to 2014.

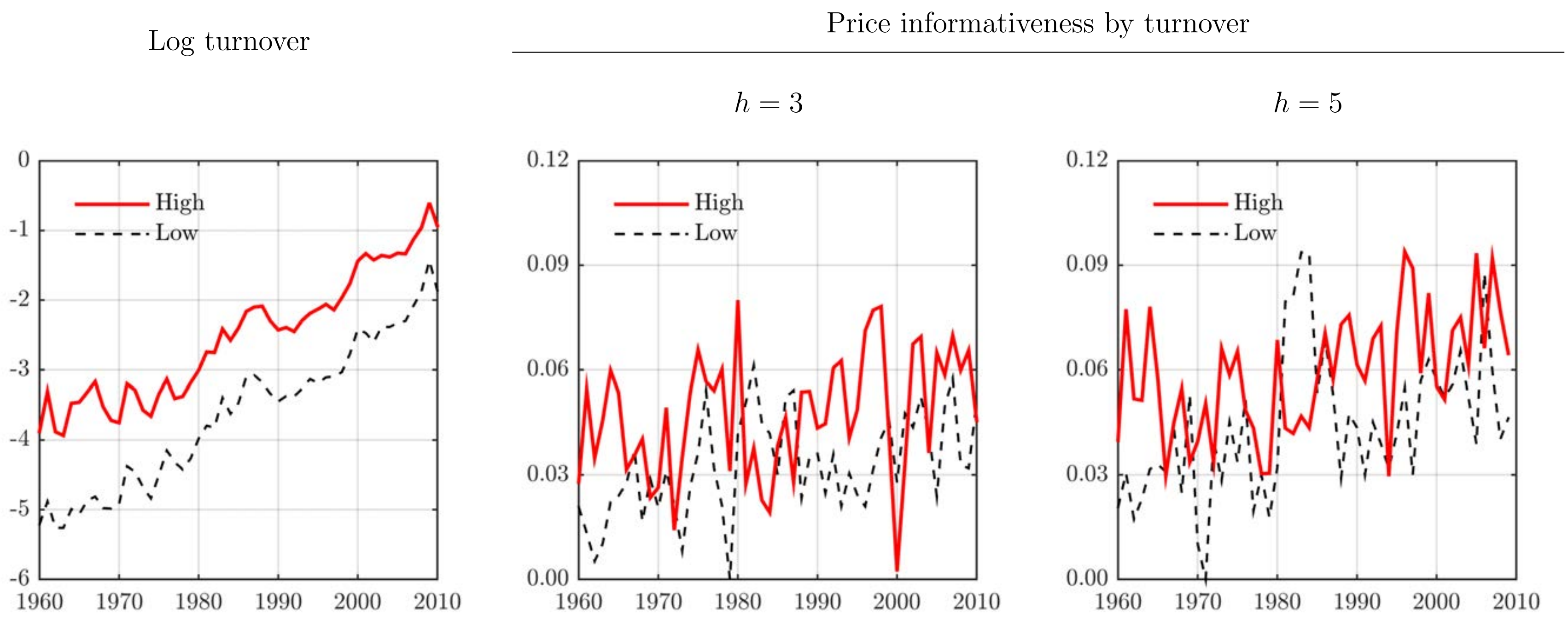


Figure A.1. **Average cross-sectional coefficients by horizon and sub-sample**
This figure shows average coefficients calculated from the cross-sectional forecasting regressions (16):

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

where M is market cap, A is total assets, E is earnings (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 to 1985, and the dash-dotted blue line is for the second half, 1986 to 2014. The sample consists of S&P 500 non-financial firms from 1960 to 2014.

Coefficients on prices $b_{t,h}$ | Coefficients on earnings $c_{t,h}$

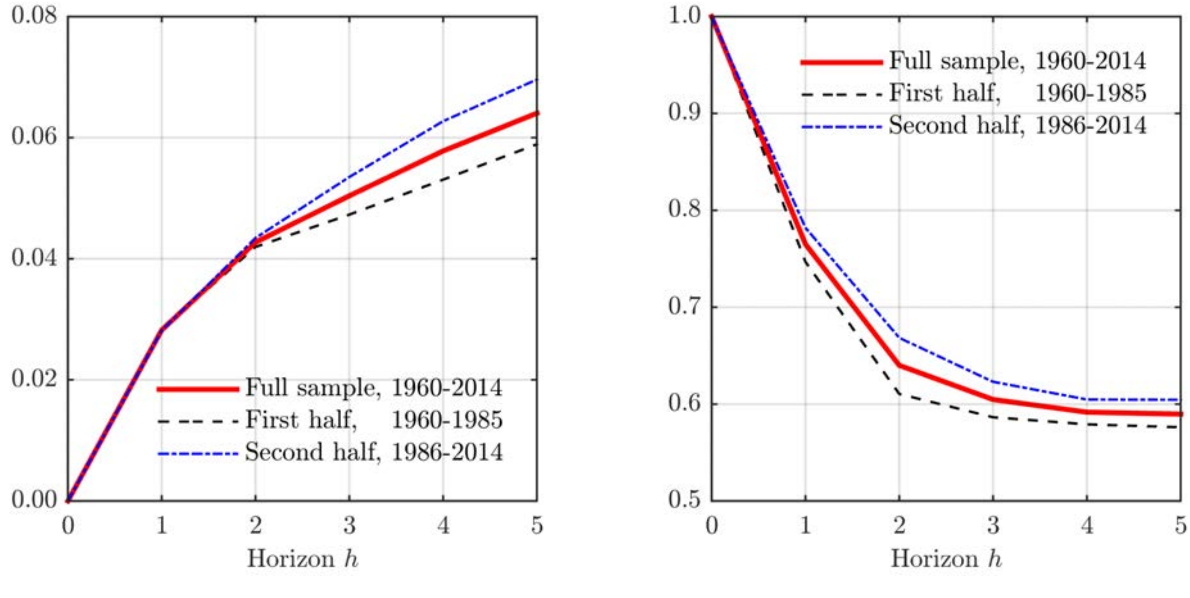


Figure A.2. Price informativeness, robustness

We report price informativeness under several variations. Price informativeness is calculated by running the forecasting regressions (16) and taking the product of the forecasting coefficient and the standard deviation of market prices, $b_{t,h} \times \sigma_t (\log M/A)$. In the first column, we add the book value of debt in calculating the valuation ratio (that is we use $M + D$ instead of M). In the second column, we use EBITDA instead of EBIT to measure earnings. In the third and fourth columns we use net income and cash flow from operations (CFO). The sample consists of S&P 500 non-financial firms from 1960 to 2014 (CFO is only available after the introduction of FASB rule 95 in 1987).

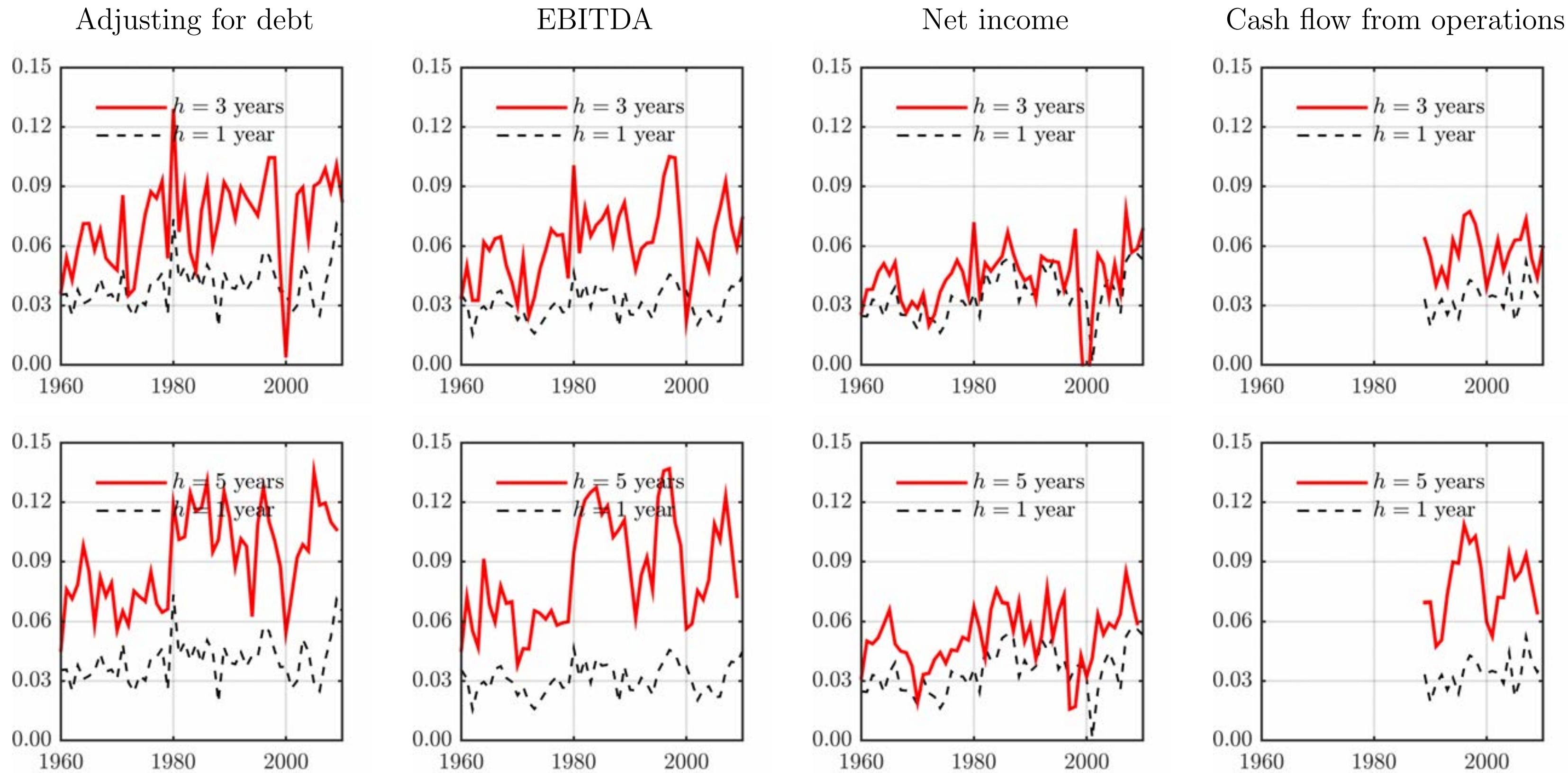
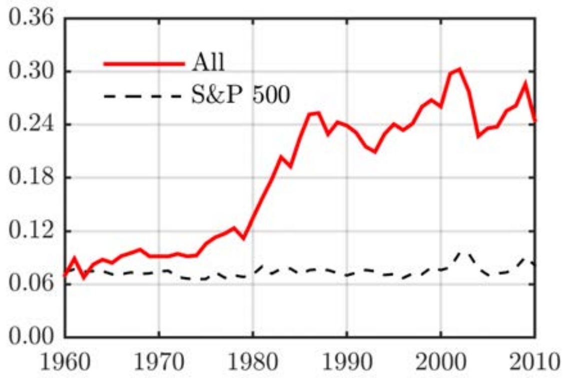


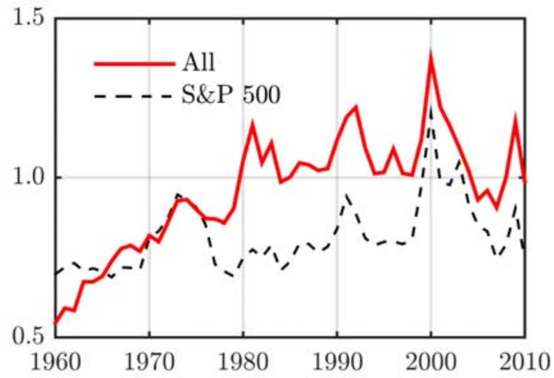
Figure A.3. Price informativeness, all firms

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 regressions (16), run separately for S&P 500 firms and all firms between 1960 and 2014. The dispersion series are measured as the cross-sectional standard deviations in E/A and $\log M/A$ in a given year.

Earnings dispersion $\sigma_t\,(E/A)$

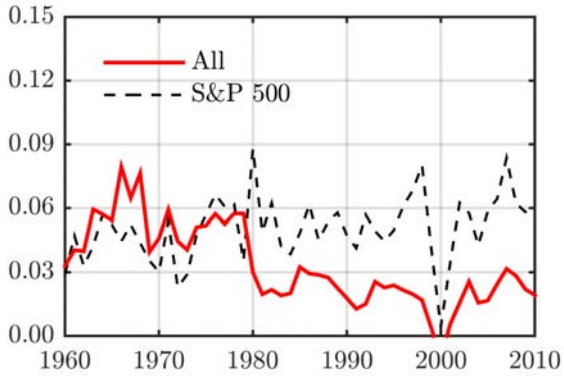


Valuation dispersion $\sigma_t\,(\log M/A)$

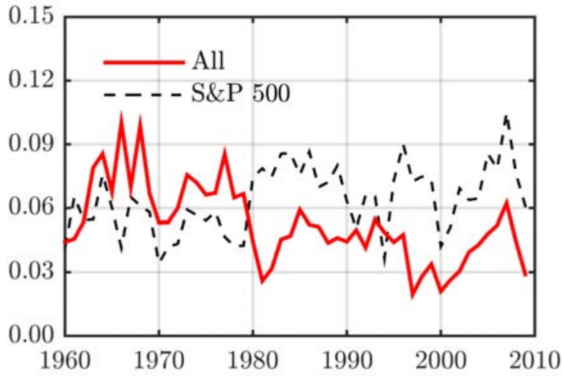


Coefficients $b_{t,h}$

Three-year horizon $h = 3$

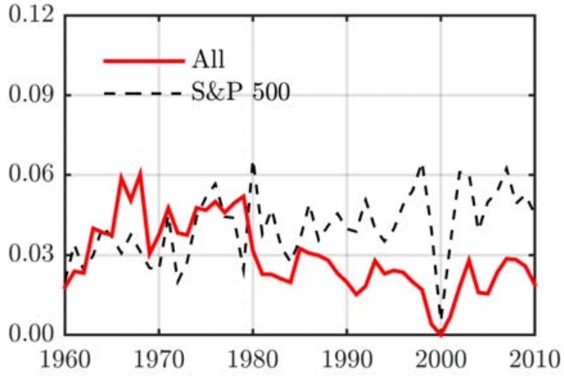


Five-year horizon $h = 5$



Price informativeness $b_{t,h} \times \sigma_t\,(\log M/A)$

Three-year horizon $h = 3$



Five-year horizon $h = 5$