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Idiosyncratic volatility: An indicator of noise trading?

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ABSTRACT

We investigate the market efficiency implications of firm-specific return variation measured by absolute idiosyncratic volatility. We find that the absolute idiosyncratic volatility (the variance of the residual from an asset-pricing model) displays a positive and robust relationship to mispricing, which reflects an increasing role of noise traders. Previous literature has produced similar – or opposing – results. We deepen our understanding of the previous conflicting results by showing that (1) market volatility by itself is associated with mispricing, (2) absolute idiosyncratic volatility is associated with mispricing even when controlling for market volatility, (3) the strength of the association between absolute idiosyncratic volatility and mispricing depends on the level of market volatility, and (4) absolute and relative measures of idiosyncratic volatility have opposing associations with mispricing. Our findings contribute to the existing literature by reconciling the mixed results for the relationship between idiosyncratic volatility and mispricing displayed in the previous literature.

1. Introduction

What is the essence of idiosyncratic volatility? Based on asset-pricing models, idiosyncratic volatility measures the part of the variation in returns that cannot be explained by the particular asset-pricing model used. However, beyond the stale econometric definition of idiosyncratic volatility, there is little consensus regarding the meaning of firm-specific return variation in the context of market efficiency. Previous studies have argued that idiosyncratic volatility can reflect either capitalization of private information into stock prices or noise trading. Roll (1988) first pointed out that U.S. firms' stock returns display low R-squared values when estimated by common asset pricing models; the average R-squared is about 20% for daily returns' models and about 35% when monthly returns are used. In the conclusion (p. 566) of his article, Roll suggested that his evidence seems to imply that idiosyncratic volatility is indicative of either "informed trading" or "occasional frenzy" unrelated to concrete information. Over the years since Roll (1988), the debate on which of the two aforementioned views of idiosyncratic volatility is more appropriate has been fueled by numerous studies often exposing contradicting views.

We contribute to this stream of the literature by exploring a fundamental question: how does idiosyncratic volatility relate to equity mispricing? Our contribution is twofold. First, we show that absolute idiosyncratic volatility (the variance of the residual from an asset-pricing model) displays a positive and robust relationship to multiple measures of mispricing (based on either accounting information or alternatively abnormal stock returns). Thus, we find that larger values of absolute idiosyncratic volatility reflect an increasing role of noise traders. Second, we show that the interaction between market volatility, idiosyncratic volatility, and R-squared is an important aspect for understanding the mixed results in the previous literature. Specifically, we show that market volatility by itself is associated with mispricing in such a way that (1) the magnitude of the association between absolute idiosyncratic volatility and mispricing depends on the level of market volatility and (2) absolute and relative measures of idiosyncratic volatility show opposing associations with mispricing.[3]

Using cross-country data, Morck et al. (2000) find that stocks in countries with stronger property rights have higher absolute idiosyncratic volatility. They argue that strong property rights promote informed arbitrage, leading to more firm-specific information and thus high absolute idiosyncratic volatility. Durnev et al. (2003) find that firms and industries with greater relative idiosyncratic volatility display greater stock price informativeness. They

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[3] Since we distinguish absolute and relative measures of idiosyncratic volatility, we will use two terms, "absolute" and "relative" throughout the paper.

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define informativeness as the amount of information stock prices contain about future earnings, which they estimate from a regression of current stock returns against future earnings changes. They argue that if relative idiosyncratic volatility reflects the capitalization of private information into prices, high relative idiosyncratic volatility is a sign of active trading by informed arbitrageurs and implies that the stock price is tracking its fundamental value closely. In addition, Jin and Myers (2006) in a study involving stock returns from 40 countries over the 1990–2001 period test whether limited information (lack of transparency) can affect the division of risk bearing between inside managers and outside investors. They provide evidence consistent with the notion that if a firm is less transparent, insiders will be able to capture more firm-specific risk. Greater opaqueness leads to lower amounts of firm-specific risk absorbed by outside investors and therefore to lower levels of idiosyncratic volatility, i.e. high levels of R-squared. In this context, opaqueness (reflected in low levels of idiosyncratic volatility) limits the ability of outside investors to evaluate changes in cash flows, and consequently their equity valuation will be less accurate. The *informed trading hypothesis* predicts that idiosyncratic volatility and mispricing are negatively related because high idiosyncratic volatility levels are associated with more trading by informed investors who trace the firm's fundamental value.

On the other hand, in line with Roll's alternative interpretation of idiosyncratic volatility as "occasional frenzy", idiosyncratic volatility can reflect noise trading. For example, Bhagat et al. (1985) show that firms with higher equity issuing costs have higher firm-specific daily stock return volatility, which is a proxy for asymmetric information between firm insiders and outsiders. Krishnaswami and Subramaniam (1999) use absolute idiosyncratic volatility as a measure of information asymmetry and find that firms engage in spin-offs to reduce information asymmetry. Kelly (2014) provides evidence that a low market model R-squared (i.e., high relative idiosyncratic volatility) is indicative of a poor information environment with greater impediments to informed trade. If higher levels of idiosyncratic volatility reflect greater impediments to informed trades and/or informational asymmetry, then they should be associated with noise trading. Furthermore, Pontiff (2006) shows that risk-averse arbitrageurs assign smaller portfolio weights to stocks with higher absolute idiosyncratic volatility due to the difficulty in hedging idiosyncratic volatility of individual stocks as argued by Shleifer and Vishny (1997). De Long et al. (1990) show that the unpredictability of noise traders' beliefs generates a risk in the asset price that hinders rational arbitrageurs from aggressively betting against them. Dontoh et al. (2004) find that noisy trading activity reduces the association between stock prices and accounting information such as earnings and book values. In this view, named the *noise trading hypothesis* and supported by numerous empirical studies,[4] it is predicted that the relationship of idiosyncratic volatility and mispricing is positive because in the presence of noise trading and arbitrage costs, stock prices will deviate from fundamental value.

To test the relationship between stock mispricing and idiosyncratic volatility, we use an absolute measure of idiosyncratic volatility.[5] Thus, in our study, absolute idiosyncratic volatility is the main independent variable in an empirical model of stock mispricing, which is measured based on accounting information or alternatively abnormal stock returns. Theoretically, the level of mispricing can be affected by either noise trading and/or the rate of private information that gets absorbed into prices. Our empirical tests provide strong and robust evidence in support of the noise trading hypothesis. When we classify firms into groups by independently sorting on absolute idiosyncratic volatility and mispricing levels, we find that average mispricing levels tend to monotonically increase as one compares stocks with low levels of absolute idiosyncratic volatility to those with high levels of absolute idiosyncratic volatility. In our multiple regression analysis, we first estimate a linear regression model of different mispricing proxies on absolute idiosyncratic volatility and find that mispricing increases in absolute idiosyncratic volatility, consistent with the noise trading hypothesis.

Our results are not driven by the model of returns used to estimate the absolute idiosyncratic volatility measures or by the choice of estimation methodology. We conduct various robustness tests based on alternative absolute idiosyncratic volatility measures, constructed by adding industry returns, including the Fama–French (1993) three factors, the Carhart (1997) four-factor model, and using weekly returns in lieu of daily returns. We also use ex-ante measures of mispricing and show the results do not change, consistent with the view that there is high alpha persistence. In addition, we re-estimate models using several other estimation methods, such as a time-series average of regressions (Fama and MacBeth, 1973), a firm-fixed effect regression, and a cluster-correcting model. Throughout these different robustness checks, our results remain unaltered.

We furthermore show that outliers do not drive our results. First, we transform the absolute idiosyncratic volatility measure into ranks from 0 to 1 and then test the relationship between ranks and mispricing measures. Second, we exclude thinly traded stock. Third, we sort absolute idiosyncratic volatility into deciles by assigning dummy values and we control for these dummies instead of our original measure of absolute idiosyncratic volatility in the main regression model. Again, throughout all three robustness tests our results remain unaltered.

Finally, we test for a potential non-linear relationship between absolute idiosyncratic volatility and mispricing. A multivariate regression shows that the inflection point of the inverted U-shaped curve is beyond the 99th percentile, which indicates that for all practical purposes we confirm the noise trading hypothesis.

In the second part of the paper, we deepen our understanding of the reasons for the lack of consensus in the existing literature by investigating the interaction between market volatility, idiosyncratic volatility, and R-squared - the denominator of the relative idiosyncratic volatility, which is an alternative measure, often used in the literature. First, we show that market volatility by itself is associated with mispricing and that absolute idiosyncratic volatility is associated with mispricing even when controlling for market volatility. Second, we show that the strength of the association between absolute idiosyncratic volatility and mispricing depends on the level of market volatility. Finally, we show that - due to the above interaction between market volatility, idiosyncratic volatility, and R-squared - absolute and relative measures of idiosyncratic volatility have opposing associations with mispricing.

[4] Examples of studies that argue or show that more firm-specific return variation captures noise are: Xu and Malkiel (2003), Hou et al. (2005), Kelly (2014), Mashruwala et al. (2006), Pontiff (2006), Ashbaugh-Skaife, Gassen, and LaFond (2006), Chan and Hameed (2006), Griffin, Kelly, and Nadari (2007), and Teoh, Yang and Zhang (2008).

[5] To test the relationship between stock mispricing and idiosyncratic volatility, one can use either an absolute or a relative measure of idiosyncratic volatility. As addressed in Li et al. (2014), choosing between relative and absolute idiosyncratic volatility is crucial in research settings addressing the determinants of idiosyncratic volatility because absolute and relative idiosyncratic volatility have often provided conflicting evidence that can be interpreted either as in support of a noise or an information hypothesis. In fact, although most studies using relative idiosyncratic volatility seem to adopt an information view, their perspective is not unchallenged (e.g., see Kelly (2014)). Similarly, the absolute idiosyncratic volatility measure has not been always viewed as a measure of private information incorporation into prices but also as a measure of arbitrage risk (e.g. see Doukas et al. (2010)). We use an absolute measure of idiosyncratic volatility in our main analysis but in our elaborations we will show why the two measures may provide conflicting results.

Our findings contribute directly to the existing literature by displaying a positive and robust relationship between absolute idiosyncratic volatility and multiple measures of mispricing. Moreover, our findings contribute to the ongoing debate on the pricing of idiosyncratic volatility by examining the essence of idiosyncratic volatility.[6]

In a recent paper, Stambaugh et al. (2015) combine the effect of arbitrage asymmetry with the arbitrage risk represented by idiosyncratic volatility to explain the puzzling negative relation between idiosyncratic volatility and average return. They view idiosyncratic volatility as arbitrage risk and argue that short sellers face greater impediments than purchasers for many equities. They document that the negative effect of idiosyncratic volatility on average return among overpriced stocks is stronger than the positive effect among underpriced stocks. Our additional tests that account for the two sides of mispricing show that overpriced stocks dominate the relationship between idiosyncratic volatility and mispricing. Extending Stambaugh et al. (2015), our findings help reconcile the conflicting results for the relationship between idiosyncratic volatility and mispricing displayed in the previous literature.

The rest of the paper is organized as follows. In the next section, we describe the data selection process and the measures of idiosyncratic volatility and equity mispricing. Section 3 explains the empirical methodologies, and reports univariate and regression test results. Section 4 provides several robustness tests. Section 5 investigates the interaction between market volatility, idiosyncratic volatility, and R-squared and the consequences for the association between idiosyncratic volatility and equity mispricing. The last section concludes.

2. Data and measures

We extract return data from the Center for Research in Securities Prices (*CRSP*) where NYSE, AMEX, and NASDAQ stocks are listed. The initial sample includes all firms in CRSP from 1980 to 2012, omitting financial (SIC 6000–6999) and utility (SIC 4900–4999) firms. We also exclude firms if their industry affiliation is not clear (i.e., SIC codes are missing). For the measure of idiosyncratic volatility, we use daily stock returns. Accounting and financial data are drawn from Compustat. Firms with market value of equity less than $20 million are excluded in order to avoid cases of firms with distorted valuation multiples used in the construction of the mispricing measures. These requirements result in a final sample that includes 6016 firms with 39,279 firm-year observations covering the 33-year period from 1980 to 2012.

2.1. Measure of idiosyncratic volatility

We estimate R-squared and idiosyncratic volatility variables for each stock for each calendar year using daily data to regress stock returns on the returns of the market index.[7] The regression model estimated for each stock i in year t is as follows.

$$r_{i,d,t} = \alpha_0 + \beta_1 r_{m,d,t} + e_{i,d,t}, \tag{1}$$

where $r_{i,d,t}$ is the excess return for stock i on day d in year t, and $r_{m,d,t}$ is the value-weighted excess market index return on the day d in year t. From this regression equation, the measure of absolute idiosyncratic volatility is defined as $\sigma^2_{ie,t} = \sigma^2_{i,t} - (\sigma^2_{im,t}/\sigma^2_{m,t})$, where $\sigma^2_{i,t} = \mathrm{Var}(r_{i,d,t})$, $\sigma^2_{m,t} = \mathrm{Var}(r_{m,d,t})$, and $\sigma_{im,t} = \mathrm{Cov}(r_{i,d,t}, r_{m,d,t})$. The Appendix describes the R-squared and the idiosyncratic volatility variable, and Table 1 presents descriptive statistics for these measures over the sample period, 1980 to 2012. The average R-squared is about 0.135, a value that is similar to that shown in other studies (e.g., 0.15 in Kelly, 2014) but lower than the average R-squared of 0.20 and 0.35 computed from daily and monthly returns, respectively, reported in Roll (1988). This relatively low average R-squared for our sample is consistent with the increase in idiosyncratic volatility observed over the recent years and reported in Campbell et al. (2001).[8] In our sample, idiosyncratic volatility on average represents about 86% of total individual stock volatility. This is in line with Ferreira and Laux (2007) who report that idiosyncratic volatility on average represents more than 85% of total individual stock volatility.

2.2. Measures of mispricing

We measure firm mispricing in two alternative ways, based on accounting information or stock returns. First, the usefulness of accounting numbers has been proved by previous studies (e.g., Dontoh et al., 2004; Fung et al., 2010) although they have not reached a complete consensus.[9] Basically, firm mispricing is measured as the deviation of a firm's equity value from its intrinsic or fundamental value. We employ five alternative mispricing measures based on values. The first four measures employ different techniques in estimating intrinsic value benchmarks, while the last one is an index that combines these four individual measures.

Mispricing1: the absolute value of the natural logarithm of the ratio between the stock price and its intrinsic value obtained from Ohlson's (1995) residual income valuation model. *Mispricing1* is computed at the end of June of each year.

$$Mispricing1_{i,t} = \mathrm{Abs}\left\{\ln\left[Price_{i,t} / \ I(Value)_{i,t}\right]\right\}, \tag{2}$$

where $Price_{i,t}$ is the CRSP stock price at the end of June of each year, and $I(Value)_{i,t}$ is the intrinsic value using the residual income model (Ohlson, 1995) with median values of analysts' forecasts issued in June, as was done in Frankel and Lee (1998). There is strong empirical evidence in support of the residual income valuation ratio, Value/Price, as an indicator of mispricing.[10]

[6] Ang et al. (2006) find a negative relation between absolute idiosyncratic volatility and returns. Their findings are supported in a follow-up study (Ang et al., 2009) providing out-of sample evidence from different countries. These results in Ang et al. (2006, 2009) are in contradiction with existing theoretical predictions (Merton, 1987; Malkiel and Xu, 2006; Barberis and Hunag, 2001) and have been challenged empirically by Bali and Cakici (2008), Fu (2009), and Huang et al. (2010). Ang et al. (2009) concede that their evidence of a negative relationship between idiosyncratic volatility and returns is puzzling, but also a global phenomenon not necessarily attributable to exposure to systematic risk. In support of a possible negative relationship between idiosyncratic volatility and returns, Boyer et al. (2010) show that absolute idiosyncratic volatility is a strong predictor of idiosyncratic skewness, and that expected idiosyncratic skewness is a priced component of stock returns which leads to low expected returns. They find absolute idiosyncratic volatility to be a strong predictor of idiosyncratic skewness. In addition, Guo et al. (2014) and Fink et al. (2012) argue that Fu's (2009) finding of the positive relation between expected return and idiosyncratic volatility is caused by the use of contemporaneous information in the conditional variance model, and that the positive relation disappears after controlling for such information.

[7] In robustness tests, we also use idiosyncratic volatilities obtained from regressions of stock returns on the returns of the industry indices along with market returns, or alternatively, on the Fama and French (1993) three factors and the Carhart (1997) four factors. We also estimate using weekly returns in lieu of daily returns.

[8] This view has been challenged by Bekaert et al. (2012) who examine idiosyncratic volatility in 23 developed equity markets (including the U.S. for the period 1964 to 2008) and find no evidence of an upward trend.

[9] Lev and Zarowin (1999), Francis and Schipper (1999), and Core et al. (2003) document that the value relevance of accounting information proxied by the R-squared values of the regressions of stock market prices (or the changes in these prices) on accounting numbers declines over time. However, modifying the fundamental values originally constructed by Aboody et al. (2002) and Subramanyam and Venkatachalam (2007), Fung et al. (2010) show that the declining trend in R-squared of the association between stock prices and accounting information disappears.

[10] Lee et al. (1999) report that V/P predicts one-month-ahead returns on the Dow 30 stocks better than aggregate book-to-market. Frankel and Lee (1998) also show that the residual income value is a better predictor than book value of the cross-section of contemporaneous stock prices, and that V/P is a predictor of the one-year-ahead cross-section of returns. In addition, D'Mello and Shroff (2000) apply V/P to measure mispricing of equity repurchases.

Table 1
Descriptive statistics.
Reported are descriptive statistics for our sample firms. The sample contains 44,639 firm-year observations (6956 firms) over the period 1980–2012. *IV*=idiosyncratic volatility. R^2 = R-squared measured using a regression of stock returns on the returns of the market index. σ_e^2/σ^2= the variance of residuals divided by the variance of returns. *Mispricing1*=the mispricing measure based on the Ohlson (1995) model. *Mispricing2*=the mispricing measure based on the Rhodes-Kropf et al. (2005) model. *Mispricing3*=the mispricing measure based on the Berger and Ofek (1995) model. *Mispricing4*=the mispricing measure based on the industry-adjusted market-to-book ratio. *Mispricing index*=the index that combines the yearly ranks of the four individual mispricing measures. *Abs(alpha1), Abs(alpha3)*, and *Abs(alpha4)*=the absolute value of alpha obtained from the one-, three-, and four-factor models, respectively. *Size*=the log of one plus total assets. *Leverage*=the ratio of long-term debt to total assets. *Profitability*=return on assets. *Age*=the log of one plus firm age. *Diversification*=a diversification dummy that takes one if the firm operates in multi-segments and zero otherwise. *Dividend*=a dividend-payer dummy. *Sales growth*=sales growth rate in the past three years. *Skewness*=the scaled measure of the third moment of the residual obtained by the regression of daily return on market return and industry return. *Scaled trading volume*=the average over the year of the daily trading volume scaled by the number of outstanding shares. Refer to the Appendix for detailed variable definitions.

Variables	N	Mean	Standard deviation	5th percentile	Median	95th percentile
Idiosyncratic volatility						
IV	39,259	0.0892	0.1024	0.0134	0.0558	0.2726
R^2	39,259	0.1351	0.1299	0.0031	0.0953	0.4030
σ_e^2/σ^2	39,259	0.8649	0.1299	0.5970	0.9047	0.9969
Mispricing						
Mispricing1	39,259	0.8272	0.6619	0.0751	0.6894	2.1297
Mispricing2	39,259	0.3417	0.3034	0.0241	0.2589	0.9654
Mispricing3	39,259	0.5330	0.4577	0.0369	0.4170	1.4097
Mispricing4	39,259	0.3290	0.3116	0.0155	0.2344	0.9873
Mispricing index	39,259	0.4782	0.1901	0.1965	0.4584	0.8310
Abs(alpha1)	39,259	0.1285	0.1264	0.0082	0.0927	0.3755
Abs(alpha3)	39,259	0.1248	0.1229	0.0078	0.0901	0.3616
Abs(alpha4)	39,259	0.1228	0.1218	0.0076	0.0877	0.3576
Firm characteristics						
Size	39,259	20.1865	1.6746	17.8148	19.9764	23.3149
Leverage	39,259	0.1835	0.1631	0.0000	0.1595	0.4876
Profitability	39,259	0.0565	0.1111	−0.1043	0.0603	0.1979
Age	39,259	2.5884	0.8658	1.0986	2.6391	4.0943
Diversification	39,259	0.4345	0.4957	0.0000	0.0000	1.0000
Dividend	39,259	0.5559	0.4969	0.0000	1.0000	1.0000
Sales growth	39,259	0.7081	1.2215	−0.2332	0.3793	2.7158
Skewness	39,259	0.2931	0.9723	−1.3683	0.3054	1.7059
Scaled trading volume	39,259	0.0060	0.0061	0.0009	0.0038	0.0187

Mispricing2: the absolute value of the firm-specific component of the difference between market value and fundamental value, based on the procedure outlined in Rhodes-Kropf et al. (2005). This procedure differs from the residual income valuation approach in the sense that it does not rely on analysts' earnings forecasts. According to Rhodes-Kropf et al. (2005), fundamental value (*Value*) is estimated by decomposing the market-to-book into two components: a measure of price to fundamentals (ln(*Market*/*Value*)), and a measure of fundamentals to book value (ln(*Value*/*Book*)). The first component captures the part of book-to-market associated with mispricing. In extreme cases where markets perfectly price stocks, this component would be equal to zero, otherwise positive (overvaluation) or negative (under-valuation). This component is further decomposed into firm-specific and industry-specific mispricing. In our tests, we use the firm-specific mispricing component based on Model III of Rhodes-Kropf et al. (2005) that also accounts for net income and leverage effects.

$$\begin{aligned}\ln(Market_{i,t}) = \alpha_{0j,t} + \alpha_{1j,t}\ln(Book_{i,t}) + \alpha_{2j,t}\ln(Net\ Income)^{+}_{i,t} \\ + \alpha_{3j,t}I_{(<0)}\ln(Net\ Income)^{+}_{i,t} \\ + \alpha_{4j,t}\ln(Leverage_{i,t}) + \varepsilon_{i,t}\end{aligned} \tag{3}$$

where *Market* is firm's market value at the end of June of each year, *Book* is book value, *Net Income*$^+$ is absolute value of net income, $I_{(<0)}$ is an indicator function for negative net income observations, and *Leverage* is the leverage ratio.

Mispricing3: The absolute value of the excess value based on the Berger and Ofek (1995) approach. The absolute excess value is computed at the end of June of each year as the natural logarithm of the ratio between a firm's capital and its imputed value.

$$Mispricing3_{i,t} = \mathrm{Abs}\left\{\ln\left[Capital_{i,t}/I(Capital)_{i,t}\right]\right\}, \tag{4}$$

where $Capital_{i,t}$ is total capital, which is market value of equity plus book value of debt, $I(Capital_{i,t})$ is the imputed value derived as the product of firm sales and the median capital to sales ratio in the firm's primary industry.

Mispricing4: The absolute value of the excess value based on the industry-adjusted market-to-book ratio.

$$Mispricing4_{i,t} = \mathrm{Abs}\left\{\ln\left[MB_{i,t}/Median(MB)_{j,t}\right]\right\}, \tag{5}$$

where, $MB_{i,t}$ is the market to book ratio for firm *i* at the end of June of each year, and $Median(MB_{j,t})$ is the *j*th industry median of MB_t. Several empirical studies have utilized *MB* as a mispricing measure (see, among others, Walkling and Edmister, 1985; Rau and Vermaelen, 1998; Ikenberry et al., 1995). However, as Rhodes-Kropf et al. (2005) point out, the market to book ratio can be viewed as not only a proxy for misvaluation but also as a measure of future growth opportunities and managerial ability.

Mispricing index: It combines the four individual mispricing measures described above.[11] The mispricing index is constructed each year for each observation $i=1,\ldots,N$ as:

$$Mispricing\,index_i = \frac{1}{N}\frac{1}{K}\sum_{k}^{K} Rank_k(Mispricing_{i,k}), \tag{6}$$

where $Rank_k(Mispricing_{i,k})$ is the rank function, which assigns a rank for each observation from least misvalued (rank of one) to most misvalued (rank of *N*). $Mispricing_{i,k}$ is the *k*th measure of mispricing for firm *i* in the sample, and *K* represents the dimensions of mispricing measures. The denominator, *K*, averages the ranks by

[11] In constructing the mispricing index, we employ the methodology outlined in Butler et al. (2005). In their paper, they create a liquidity index that aggregates the rankings of six different liquidity measures.

Table 2
Correlations among idiosyncratic volatility and mispricing measures.
This table reports the correlation coefficients among idiosyncratic volatility and mispricing measures. *IV* = idiosyncratic volatility. *Mispricing1* = the mispricing measure based on the Ohlson (1995) model. *Mispricing2* = the mispricing measure based on the Rhodes-Kropf et al. (2005) model. *Mispricing3* = the mispricing measure based on the Berger and Ofek (1995) model. *Mispricing4* = the mispricing measure based on the industry-adjusted market-to-book ratio. *Mispricing index* = the index that combines the yearly ranks of the four individual mispricing measures. *Abs(alpha1), Abs(alpha3)*, and *Abs(alpha4)* = the absolute value of alpha obtained from the one-, three-, and four-factor models, respectively. *** denotes statistical significance at the 1% level.

	IV	*Mispricing1*	*Mispricing2*	*Mispricing3*	*Mispricing4*	*Mispricing index*	*Abs(alpha1)*	*Abs(alpha3)*
Mispricing1	0.1499***							
	[0.000]							
Mispricing2	0.1585***	0.1778***						
	[0.000]	[0.000]						
Mispricing3	0.1304***	0.1293***	0.2893***					
	[0.000]	[0.000]	[0.000]					
Mispricing4	0.1069***	0.1311***	0.5713***	0.3555***				
	[0.000]	[0.000]	[0.000]	[0.000]				
Mispricing index	0.1105***	0.2487***	0.7164***	0.6040***	0.7542***			
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]			
Abs(alpha1)	0.4883***	0.1211***	0.2059***	0.1122***	0.1722***	0.1391***		
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]		
Abs(alpha3)	0.4907***	0.1271***	0.2130***	0.1168***	0.1769***	0.1485***	0.8922***	
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	
Abs(alpha4)	0.4848***	0.1199***	0.2164***	0.1217***	0.1804***	0.1515***	0.8668***	0.9688***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]

the number of mispricing values available for each firm in the sample in a particular year. Finally, dividing by N, we scale the *Mispricing index* from zero (least mispriced) to one (most mispriced). We argue that the index provides a more complete picture of mispricing. Variable definitions and summary statistics for all measures are reported in the Appendix and Table 1, respectively.

Second, as an alternative approach to firm mispricing, we measure the absolute value of alphas from a market model. Thus, as opposed to the value deviation based mispricing measures above we now exploit return deviations. Specifically, we employ three alternative mispricing measures based on return deviations: *Abs(alpha1), Abs(alpha3)*, and *Abs(alpha4)*. These measures are the absolute values of alphas obtained from the one-, three-, and four-factor models, respectively.

$$r_{i,d,t} = \alpha_0 + \beta_1 r_{m,d,t} + e_{d,t}, \tag{7a}$$

$$r_{i,d,t} = \alpha_0 + \beta_1 r_{m,d,t} + \beta_2 SMB_{d,t} + \beta_3 HML_{d,t} + e_{d,t}, \tag{7b}$$

$$r_{i,d,t} = \alpha_0 + \beta_1 r_{m,d,t} + \beta_2 SMB_{d,t} + \beta_3 HML_{d,t} + \beta_4 UMD_{d,t} + e_{d,t}, \tag{7c}$$

where $r_{i,d,t}$ is the excess return for stock i on day d in year t, and $r_{m,d,t}$ is the value-weighted excess market index return on the day d in year t. *SMB* (small minus big) is the difference each day between the return on small and big firms, while *HML* (high minus low) is the daily difference of the returns on a portfolio of high book-to-market and low book-to-market firms and *UMD* (up minus down) is the momentum factor computed on a daily basis as the return differential between a portfolio of winners and a portfolio of losers.

Table 2 reports the correlation coefficients between (1) the eight mispricing measures (five measures based on values and three measures based on returns) and (2) between idiosyncratic volatility and the eight mispricing measures. All correlations between the eight mispricing measures are positive and statistically significant. The same applies for the correlations between idiosyncratic volatility and the mispricing measures.

3. Findings

3.1. Comparisons of mispricing levels: univariate analysis

In the first stage of our empirical investigation, we employ univariate tests designed to examine whether idiosyncratic volatility is correlated with the level of equity mispricing. We classify our sample firms into quintile groups based on the absolute idiosyncratic volatility and then compute the average value of mispricing measure for the sub-groups. Fig. 1 illustrates that average mispricing increases monotonically with absolute idiosyncratic volatility.

3.2. Idiosyncratic volatility and equity mispricing

Univariate tests can only provide limited, preliminary evidence on whether equity mispricing has truly a positive relationship with idiosyncratic volatility because a pattern could disappear after controlling for other factors that could potentially affect mispricing. The controlling variables are the log of one plus total assets (*Size*), the ratio of long-term debt to total assets (*Leverage*), return on assets (*Profitability*), the log of one plus firm age (*Age*), a diversification dummy (*Diversification*), and a dividend-payer dummy (*Dividend*). Since mispricing is expected to be related to growth opportunities and individuals' preference for skewness, we also include: *Sales growth,* measured as the growth rate in sales revenues over the past three years; and *Skewness*, the scaled measure of the third moment of the residual obtained by the regression of daily return on market return and industry return. Industry and year dummies are included. Descriptions of all variables can be found in the Appendix and descriptive statistics in Table 1. Following Thompson (2011), we cluster standard errors by both firm and time.[12]

If the patterns observed in the univariate tests persist, the regressions will show a significantly positive sign for the coefficient of absolute idiosyncratic volatility, which would lend support to the *noise trading* hypothesis. The results of the regression tests appear in Table 3. In the first five columns, we report results of regressions using mispricing measures based on values and in the

[12] The estimate of the variance-covariance matrix is: $V_{FIRM\&Time} = V_{Firm} + V_{Time} - V_{White}$, which combines the standard errors clustered by firm with the standard errors clustered by time. The White (1980) variance-covariance matrix is subtracted off to avoid double counting the diagonal of the variance-covariance matrix in the computation.

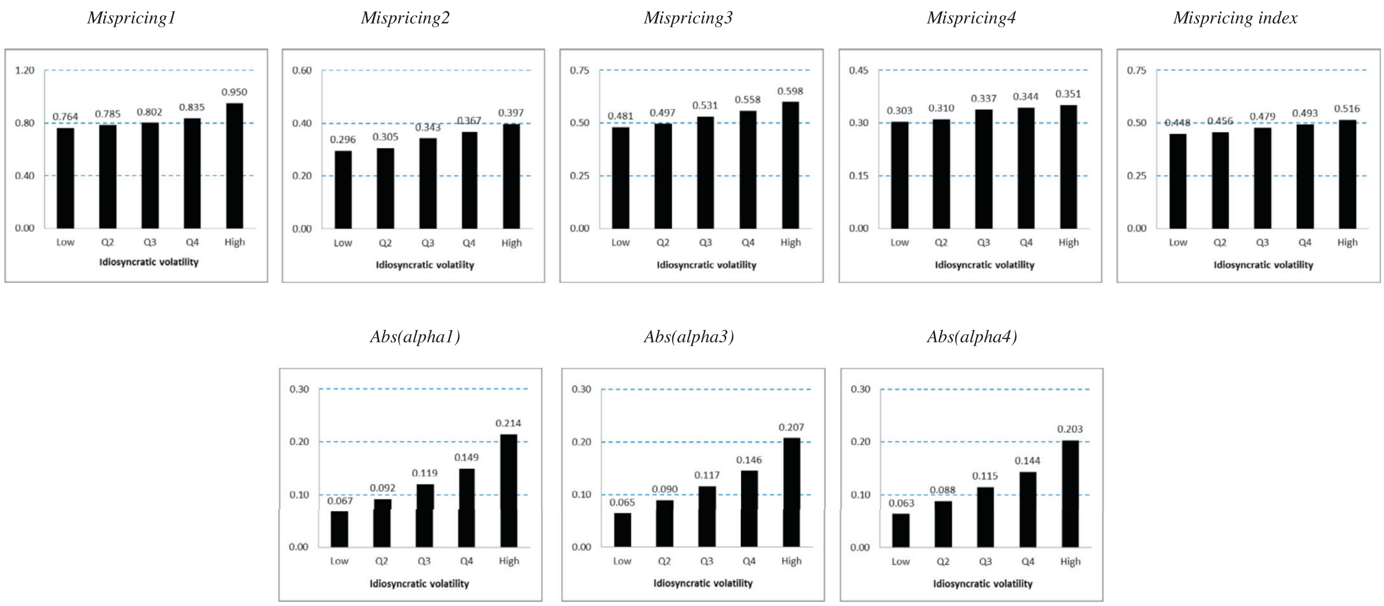

Fig. 1. Mispricing by idiosyncratic volatility.
This figure presents the averages of mispricing measures for the quintile sub-samples sorted on idiosyncratic volatility (*IV*). *Mispricing1* = the mispricing measure based on the Ohlson (1995) model. *Mispricing2* = the mispricing measure based on the Rhodes-Kropf et al. (2005) model. *Mispricing3* = the mispricing measure based on the Berger and Ofek (1995) model. *Mispricing4* = the mispricing measure based on the industry-adjusted market-to-book ratio. *Mispricing index* = the index that combines the yearly ranks of the four individual mispricing measures. *Abs(alpha1), Abs(alpha3)*, and *Abs(alpha3)* = the absolute value of alpha obtained from the one-, three-, and four-factor models, respectively. Refer to the Appendix for detailed variable definitions.

Table 3
Idiosyncratic volatility and equity mispricing.
This table reports the coefficient estimates of the regressions of mispricing on idiosyncratic volatility and other firm characteristics. *Mispricing1* = the mispricing measure based on the Ohlson (1995) model. *Mispricing2* = the mispricing measure based on the Rhodes-Kropf et al. (2005) model. *Mispricing3* = the mispricing measure based on the Berger and Ofek (1995) model. *Mispricing4* = the mispricing measure based on the industry-adjusted market-to-book ratio. *Mispricing index* = the index that combines the yearly ranks of the four individual mispricing measures. *Abs(alpha1), Abs(alpha3)*, and *Abs(alpha4)* = the absolute value of alpha obtained from the one-, three-, and four-factor models, respectively. *IV* = idiosyncratic volatility. *Size* = the log of one plus total assets. *Leverage* = the ratio of long-term debt to total assets. *Profitability* = return on assets. *Age* = the log of one plus firm age. *Diversification* = a diversification dummy that takes one if the firm operates in multi-segments and zero otherwise. *Dividend* = a dividend-payer dummy. *Sales growth* = sales growth rate in the past three years. *Skewness* = the scaled measure of the third moment of the residual obtained by the regression of daily return on market return and industry return. Industry and year dummies are included. Refer to the Appendix for detailed variable definitions. We use Thompson (2011) standard errors that cluster on firm and time, and *t*-statistics are shown in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable:	*Mispricing1*	*Mispricing2*	*Mispricing3*	*Mispricing4*	*Mispricing index*	*Abs(alpha1)*	*Abs(alpha3)*	*Abs(alpha4)*
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
IV	0.4582***	0.1905***	0.1902**	0.1989***	0.1319***	0.4916***	0.4926***	0.4712***
	(3.17)	(4.32)	(2.11)	(5.35)	(5.80)	(12.20)	(13.65)	(12.75)
Size	0.0282***	0.0022	0.0052	−0.0041	−0.0007	−0.0045***	−0.0032***	−0.0040***
	(3.10)	(0.74)	(1.00)	(−1.07)	(−0.29)	(−3.94)	(−2.91)	(−3.83)
Leverage	−0.2906***	−0.2741***	−0.3047***	−0.3465***	−0.2214***	0.0200***	0.0200***	0.0183***
	(−5.12)	(−8.94)	(−8.48)	(−12.10)	(−14.20)	(2.69)	(3.41)	(2.81)
Profitability	−0.9778***	0.2947***	−0.1754***	0.7506***	0.1828***	0.0504**	0.0514***	0.0519***
	(−11.50)	(8.61)	(−2.64)	(15.29)	(7.35)	(2.35)	(3.08)	(3.31)
Age	−0.0291***	−0.0104***	−0.0185**	−0.0138***	−0.0107***	−0.0028***	−0.0024***	−0.0025***
	(−3.29)	(−3.22)	(−2.53)	(−3.36)	(−4.19)	(−3.54)	(−3.15)	(−3.16)
Diversification	−0.0035	−0.0246***	−0.0036	−0.0359***	−0.0159***	0.0008	−0.0009	−0.0006
	(−0.32)	(−4.20)	(−0.32)	(−5.36)	(−3.65)	(0.46)	(−0.69)	(−0.42)
Dividend	−0.0200	−0.0219***	−0.0182	0.0050	−0.0083**	−0.0114***	−0.0120***	−0.0128***
	(−1.55)	(−3.50)	(−1.61)	(0.76)	(−2.04)	(−5.11)	(−4.38)	(−5.16)
Sales growth	0.0145**	0.0233***	0.0248***	0.0256***	0.0117***	0.0049***	0.0050***	0.0047***
	(2.42)	(10.73)	(5.89)	(8.94)	(9.72)	(5.10)	(4.91)	(5.53)
Skewness	0.0241***	0.0108***	0.0117***	0.0083***	0.0061***	0.0074**	0.0054***	0.0054***
	(4.35)	(6.33)	(4.40)	(4.62)	(5.86)	(2.49)	(3.72)	(4.51)
Constant	0.4140*	0.5553***	0.9884***	0.7735***	0.7204***	0.2357***	0.2061***	0.2224***
	(1.81)	(6.56)	(7.03)	(7.19)	(10.58)	(8.90)	(8.02)	(9.69)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	39,259	39,259	39,259	39,259	39,259	39,259	39,259	39,259
R^2	0.180	0.150	0.124	0.214	0.145	0.275	0.271	0.268

last three columns, we report results of regressions using mispricing measures based on returns. Consistently across all mispricing measures, the results in Table 3 show a significant positive relation between absolute idiosyncratic volatility and mispricing suggesting that higher absolute idiosyncratic volatility is associated with increased noise trading.

3.3. Overpriced stocks vs. underpriced stocks

In explaining the idiosyncratic volatility puzzle, Stambaugh et al. (2015) show a stronger negative effect of idiosyncratic volatility on average return among overpriced stocks than the positive effect among underpriced stocks. As constructed in Section 2.2, the mispricing measures take absolute values, allowing both overpriced and underpriced stocks to be indistinguishable. Based on the study of Stambaugh et al. (2015), the effect of idiosyncratic volatility on mispricing might be asymmetric due to short-sale impediments.

To operationalize this, we repeat the test separately for the overpriced and underpriced groups. Firms are classified into the overpriced (underpriced) group if the mispricing value before taking the absolute term is positive (negative). We then regress the model in Table 3 for both groups and test the coefficient difference.[13] To reserve space, Table 4 reports the estimated coefficient of absolute idiosyncratic volatility. Consistent with Stambaugh et al. (2015), our additional test generally shows that the relationship between absolute idiosyncratic volatility and mispricing is stronger for the overpriced stocks. The estimated coefficient of absolute idiosyncratic volatility is larger for all regressions. The difference in the coefficients between the two groups is statistically significant at least at the 10% level for 5 out of 7 cases.

This evidence on the asymmetric effect indicates that overpriced stocks dominate the relationship between idiosyncratic volatility and mispricing. Extending Stambaugh et al. (2015), our finding helps reconcile the conflicting results for the relationship between idiosyncratic volatility and mispricing displayed in the previous literature.

Table 4
Overpriced stocks vs. underpriced stocks.
This table reports the coefficient of absolute idiosyncratic volatility from the regressions in Table 3 separately for overpriced stocks and underpriced stocks. Firms are classified into the overpriced (underpriced) group if the mispricing value before taking the absolute term is positive (negative). *Mispricing1* = the mispricing measure based on the Ohlson (1995) model. *Mispricing2* = the mispricing measure based on the Rhodes-Kropf et al. (2005) model. *Mispricing3* = the mispricing measure based on the Berger and Ofek (1995) model. *Mispricing4* = the mispricing measure based on the industry-adjusted market-to-book ratio. *Mispricing index* = the index that combines the yearly ranks of the four individual mispricing measures. *Abs(alpha1)*, *Abs(alpha3)*, and *Abs(alpha4)* = the absolute value of alpha obtained from the one-, three-, and four-factor models, respectively. *IV* = idiosyncratic volatility. The controlling variables: *Size* = the log of one plus total assets. *Leverage* = the ratio of long-term debt to total assets. *Profitability* = return on assets. *Age* = the log of one plus firm age. *Diversification* = a diversification dummy that takes one if the firm operates in multi-segments and zero otherwise. *Dividend* = a dividend-payer dummy. *Sales growth* = sales growth rate in the past three years. *Skewness* = the scaled measure of the third moment of the residual obtained by the regression of daily return on market return and industry return. Refer to the Appendix for detailed variable definitions. We use Thompson (2011) standard errors that cluster on firm and industry, and *t*-statistics are shown in parentheses. The last column reports the test of coefficient difference between the group of overpriced stocks and that of underpriced stocks. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	[1]	[2]	[3]
	Overpriced	Underpriced	Coeff. difference test [1] – [2]
Dependent variable: *Mispricing1*			
IV	0.7086***	0.5805***	0.1281
	(5.48)	(2.73)	(0.51)
Dependent variable: *Mispricing2*			
IV	0.4953***	0.2571***	0.2382*
	(4.48)	(4.97)	(1.95)
Dependent variable: *Mispricing3*			
IV	0.4287**	0.3235***	0.1052
	(2.30)	(5.90)	(0.54)
Dependent variable: *Mispricing4*			
IV	0.4909***	0.2562***	0.2347**
	(4.65)	(10.76)	(2.17)
Dependent variable: *Abs(alpha1)*			
IV	0.6397***	0.3557***	0.2840***
	(16.01)	(8.19)	(4.81)
Dependent variable: *Abs(alpha3)*			
IV	0.6252***	0.3679***	0.2573***
	(13.83)	(9.36)	(4.30)
Dependent variable: *Abs(alpha4)*			
IV	0.6023***	0.3401***	0.2622***
	(12.58)	(7.98)	(4.09)

4. Robustness tests

In this section, we conduct several robustness checks, which aim at determining to which extent (if any) the previous findings are due to the particular model of returns used to estimate the absolute idiosyncratic volatility measure or to the estimation methodology used.

4.1. Alternative measures of idiosyncratic volatility

We start our robustness tests by using alternative measures of idiosyncratic volatility. First, we re-estimate idiosyncratic volatility by adding each firm's industry returns into the market model (Eq. (1)) as was suggested by other authors (Durnev et al., 2003, 2004; Kelly, 2014). The Fama-French 48 industry SIC classification code is used to define the industry. Second, we use idiosyncratic volatility estimates from the Fama-French three-factor model of returns (Fama and French, 1993). The three Fama-French factors are the excess return on the value-weighted market portfolio, R_m, the return on a zero investment portfolio measured as the difference between the return on a large firm portfolio and the return on a small firm portfolio, *SMB*, and the return on a zero investment portfolio estimated as the return on a portfolio of high book-to-market minus the return on a portfolio of low book-to-market stocks, *HML*. Third, we use the Carhart's (1997) four-factor model that includes the Fama-French (1993) three factors and the momentum factor. Fourth, we use weekly returns instead of daily returns in the calculation of idiosyncratic volatility to avoid a problem related to the missing observations from non-trading occurrences in daily data (Conrad and Kaul, 1988).

We retest our main models using the aforementioned alternative absolute idiosyncratic volatility measures. To save space, Table 5 only reports the results for the mispricing index regression models (columns 1–4) and the *Abs(alpha4)* regression models (columns 5–8). The former is an index comprised of the four mispricing measures based on values and the latter is highly correlated (please refer to Table 2) with the two other mispricing measures based on returns.[14] Table 5 confirms our previous conclusions.

[13] We do not include year and industry fixed effects in this test because the subsamples for positive mispricing and negative mispricing are highly clustered by time and industry. Accordingly, we account for this by clustering standard errors by time and industry in these tests.

[14] We obtain similar results to the ones presented here when we repeat the tests using the individual mispricing measures. These results are available upon request.

Table 5
Alternative measures of idiosyncratic volatility.
This table shows the regressions of mispricing on the alternative measures of idiosyncratic volatility and other firm characteristics. Columns [1] and [5] report results using idiosyncratic volatility estimates from a model controlling for the market returns and the industry returns according to the Fama-French 48 industry SIC classification. Columns [2] and [6] report results using idiosyncratic volatility estimates from the Fama and French (1993) three-factor model. Columns [3] and [7] report results using idiosyncratic volatility estimates from the Carhart (1997) four-factor model. Columns [4] and [8] report results using idiosyncratic volatility estimates from a model using weekly returns. *Mispricing index* = the index that combines the yearly ranks of the four individual mispricing measures. The individual mispricing measures are: *Mispricing1* = the mispricing measure based on the Ohlson (1995) model; *Mispricing2* = the mispricing measure based on the Rhodes-Kropf et al. (2005) model; *Mispricing3* = the mispricing measure based on the Berger and Ofek (1995) model; *Mispricing4* = the mispricing measure based on the industry-adjusted market-to-book ratio. *Abs(alpha4)* = the absolute value of alpha obtained from the four-factor model. *IV* = idiosyncratic volatility. *Size* = the log of one plus total assets. *Leverage* = the ratio of long-term debt to total assets. *Profitability* = return on assets. *Age* = the log of one plus firm age. *Diversification* = a diversification dummy that takes one if the firm operates in multi-segments and zero otherwise. *Dividend* = a dividend-payer dummy. *Sales growth* = sales growth rate in the past three years. *Skewness* = the scaled measure of the third moment of the residual obtained by the regression of daily return on market return and industry return. Industry and year dummies are included. Refer to the Appendix for detailed variable definitions. We use Thompson (2009) standard errors that cluster on firm and time, and *t*-statistics are shown in parentheses. *** and ** denote statistical significance at the 1% and 5% levels, respectively.

Dependent variable:	*Mispricing index*	*Mispricing index*	*Mispricing index*	*Mispricing index*	*Abs(alpha4)*	*Abs(alpha4)*	*Abs(alpha4)*	*Abs(alpha4)*
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
IV (industry model)	0.1386***				0.4884***			
	(5.85)				(13.14)			
IV (3 factor model)		0.1306***				0.4792***		
		(5.81)				(12.77)		
IV (4 factor model)			0.1307***				0.4854***	
			(5.69)				(13.15)	
IV (weekly return)				0.0251***				0.1168***
				(4.58)				(11.83)
Size	−0.0006	−0.0008	−0.0007	−0.0015	−0.0039***	−0.0040***	−0.0038***	−0.0051***
	(−0.26)	(−0.31)	(−0.31)	(−0.62)	(−3.94)	(−3.88)	(−3.84)	(−5.05)
Leverage	−0.2213***	−0.2215***	−0.2216***	−0.2211***	0.0184***	0.0178***	0.0177***	0.0204***
	(−14.19)	(−14.19)	(−14.19)	(−14.17)	(2.83)	(2.73)	(2.74)	(2.99)
Profitability	0.1824***	0.1814***	0.1810***	0.1762***	0.0488***	0.0499***	0.0496***	0.0548***
	(7.22)	(7.21)	(7.17)	(7.09)	(3.17)	(3.24)	(3.23)	(3.33)
Age	−0.0107***	−0.0107***	−0.0107***	−0.0109***	−0.0025***	−0.0025***	−0.0026***	−0.0023***
	(−4.18)	(−4.20)	(−4.21)	(−4.28)	(−3.10)	(−3.19)	(−3.24)	(−2.75)
Diversification	−0.0160***	−0.0159***	−0.0159***	−0.0159***	−0.0010	−0.0007	−0.0008	−0.0006
	(−3.67)	(−3.66)	(−3.66)	(−3.67)	(−0.71)	(−0.53)	(−0.58)	(−0.38)
Dividend	−0.0083**	−0.0084**	−0.0085**	−0.0089**	−0.0132***	−0.0131***	−0.0131***	−0.0124***
	(−2.06)	(−2.08)	(−2.09)	(−2.17)	(−5.34)	(−5.33)	(−5.32)	(−4.59)
Sales growth	0.0118***	0.0118***	0.0118***	0.0116***	0.0049***	0.0049***	0.0050***	0.0031***
	(9.72)	(9.67)	(9.68)	(9.58)	(5.87)	(5.79)	(5.89)	(3.43)
Skewness	0.0061***	0.0061***	0.0061***	0.0064***	0.0056***	0.0055***	0.0055***	0.0057***
	(5.86)	(5.91)	(5.91)	(6.16)	(4.62)	(4.53)	(4.53)	(4.39)
Constant	0.7193***	0.7218***	0.7216***	0.7376***	0.2212***	0.2225***	0.2195***	0.2446***
	(10.57)	(10.62)	(10.60)	(11.07)	(10.42)	(9.93)	(10.14)	(10.82)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	39,259	39,259	39,259	39,259	39,259	39,259	39,259	39,259
R^2	0.145	0.145	0.145	0.145	0.264	0.266	0.266	0.280

4.2. Expected abnormal returns

In Eqs. (7a), (7b), and (7c), the alphas are historical realized alphas. If alphas are not persistent over the sample period, using the realized measures is potentially problematic. Therefore, it is imperative to check whether or not the ex-ante mispricing measures generate significantly different results. We test this in two ways. First, we examine the time-series average of correlations among the realized and expected alphas. Second, we directly estimate the relationship between the expected alphas and absolute idiosyncratic volatility controlling for other characteristics.

Results are reported in Table 6. We find that the ex-ante alphas are not only highly correlated with each other but also with the realized alphas. All correlations are statistically significant at the 1% level. In Panel B, we find that the positive relationship is robust to the use of ex-ante measures of mispricing although the size of the estimated coefficient is reduced by 30 to 33%. We conclude that our results are consistent when ax-ante measures of mispricing are used in our analysis.

4.3. Alternative estimation methods

Next, we re-test the models using several alternative estimation methods suggested by the finance literature for estimating standard errors in panel datasets. According to Petersen (2009), the most common methods used in recent finance papers are the Fama and MacBeth (1973) procedure, fixed-effect regressions and cluster-correcting models. Petersen (2009) argues that any chosen method can be incorrect and yield different results in many cases. Therefore, we re-examine the relationship using all three methods to see whether our evidence persists.

First, it is plausible that prices may generally be high or low relative to their fundamental values in a given year. In pooled tests, a lack of independence across observations may cause *t*-statistics to be biased. To avoid this problem, we follow Fama and MacBeth (1973) by estimating separate regressions every quarter. Statistical significance of estimated coefficient is computed as: $t(\overline{\hat{\beta}_j}) = \overline{\hat{\beta}_j}/(s(\hat{\beta}_j)/\sqrt{n-1})$, where $\overline{\hat{\beta}_j}$ is the mean coefficient over the sample years, $s(\hat{\beta}_j)$ is the standard deviation of the quarterly estimates, and n is the number of quarters. Second, we use a firm

Table 6
Expected abnormal returns.
Panel A documents the time-series average of cross-sectional correlations among the realized and expected alphas. *Abs(alpha1), Abs(alpha3)*, and *Abs(alpha4)*=the absolute value of alpha obtained from the one-, three-, and four-factor models, respectively. *Abs(alpha1_exp), Abs(alpha3_exp)*, and *Abs(alpha4_exp)*=the absolute value of ex-ante alpha (i.e., one-year lagged value) obtained from the one-, three-, and four-factor models, respectively. Panel B reports the coefficient estimates of the regressions of expected abnormal returns on idiosyncratic volatility and other firm characteristics. *IV*=idiosyncratic volatility. *Size*=the log of one plus total assets. *Leverage*=the ratio of long-term debt to total assets. *Profitability*=return on assets. *Age*=the log of one plus firm age. *Diversification*=a diversification dummy that takes one if the firm operates in multi-segments and zero otherwise. *Dividend*=a dividend-payer dummy. *Sales growth*=sales growth rate in the past three years. *Skewness*=the scaled measure of the third moment of the residual obtained by the regression of daily return on market return and industry return. Industry and year dummies are included. Refer to the Appendix for detailed variable definitions. We use Thompson (2011) standard errors that cluster on firm and time, and *t*-statistics are shown in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Time-series average of cross-sectional correlations

	Abs(alpha1)	*Abs(alpha3)*	*Abs(alpha4)*	*Abs(alpha1_exp)*	*Abs(alpha3_exp)*
Abs(alpha3)	0.8800***				
	[0.000]				
Abs(alpha4)	0.8474***	0.9548***			
	[0.000]	[0.000]			
Abs(alpha1_exp)	0.1782***	0.1932***	0.1889***		
	[0.000]	[0.000]	[0.000]		
Abs(alpha3_exp)	0.1746***	0.1871***	0.1846***	0.8843***	
	[0.000]	[0.000]	[0.000]	[0.000]	
Abs(alpha4_exp)	0.1738***	0.1836***	0.1820***	0.8566***	0.9622***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]

Panel B: Regression analysis

Dependent variable:	*Abs(alpha1_exp)*	*Abs(alpha3_exp)*	*Abs(alpha4_exp)*
	[1]	[2]	[3]
IV	0.3306***	0.3354***	0.3294***
	(8.59)	(10.90)	(10.81)
Size	−0.0073***	−0.0055***	−0.0060***
	(−4.18)	(−3.91)	(−4.67)
Leverage	0.0172**	0.0100*	0.0091
	(2.57)	(1.71)	(1.34)
Profitability	0.1090***	0.0996***	0.1052***
	(5.01)	(6.35)	(6.30)
Age	−0.0076***	−0.0078***	−0.0076***
	(−5.46)	(−5.86)	(−6.13)
Diversification	0.0007	−0.0007	−0.0003
	(0.37)	(−0.46)	(−0.20)
Dividend	−0.0192***	−0.0195***	−0.0192***
	(−8.83)	(−8.13)	(−9.74)
Sales growth	0.0108***	0.0106***	0.0108***
	(7.97)	(10.10)	(10.38)
Skewness	−0.0000	0.0004	0.0000
	(−0.01)	(0.46)	(0.04)
Constant	0.2702***	0.2405***	0.2512***
	(6.65)	(7.73)	(8.95)
Industry dummies	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes
N	39,210	39,210	39,210
R^2	0.214	0.209	0.212

fixed-effect model to control for possible differences across firms. Third, we use a regression with standard errors adjusted for heteroscedasticity using White's (1980) method. This can be a proper model when unexplained deviations from the fundamental values are likely to persist within a firm.

Table 7 reports the results of these robustness checks for mispricing measures based on values (columns 1–3) and returns (columns 4–6). Table 7 shows that our previous results are confirmed using different estimation methods.

4.4. Further robustness tests

Table 8 provides four further robustness tests. *First*, we transform the absolute idiosyncratic variable into a rank from 0 to 1, and then test the relationship between the rank and mispricing measures. The first two columns in Table 8 display significant positive relationships between mispricing and absolute idiosyncratic volatility consistent with our previous results.

Second, we check if thinly traded stocks drive our results. We calculate scaled trading volume by the average over the year of the daily trading volume scaled by the number of outstanding shares. Then, we retest the models after dropping the lowest decile group. Columns 3–4 in Table 11 display significant positive relationships between mispricing and absolute idiosyncratic volatility consistent with our previous results.

Third, we re-estimate the absolute idiosyncratic volatility regressions by including the squared value of absolute idiosyncratic volatility to check for potential non-linear features. Columns 5–6 show that the coefficients for absolute idiosyncratic volatility remain significant and positive, but the columns also indicate a significant inverse U-shape relationship between absolute idiosyncratic volatility and mispricing. However, the inflection points in these regressions are beyond the 99th percentile of absolute idiosyncratic volatility. Thus, we conclude that a non-linear rela-

Table 7
Alternative estimation.
This table reports the alternative regressions of mispricing on idiosyncratic volatility and other firm characteristics. Columns [1] and [4] report results using the Fama and MacBeth (1973) approach. Columns [2] and [5] report results using the firm fixed-effects regression. Columns [3] and [6] report results using White's (1980) heteroscedasticity correction model. *Mispricing index* = the index that combines the yearly ranks of the four individual mispricing measures. The individual mispricing measures are: *Mispricing1* = the mispricing measure based on the Ohlson (1995) model; *Mispricing2* = the mispricing measure based on the Rhodes-Kropf et al. (2005) model; *Mispricing3* = the mispricing measure based on the Berger and Ofek (1995) model; *Mispricing4* = the mispricing measure based on the industry-adjusted market-to-book ratio. *Abs(alpha4)* = the absolute value of alpha obtained from the four-factor model. *IV* = idiosyncratic volatility. *Size* = the log of one plus total assets. *Leverage* = the ratio of long-term debt to total assets. *Profitability* = return on assets. *Age* = the log of one plus firm age. *Diversification* = a diversification dummy that takes one if the firm operates in multi-segments and zero otherwise. *Dividend* = a dividend-payer dummy. *Sales growth* = sales growth rate in the past three years. *Skewness* = the scaled measure of the third moment of the residual obtained by the regression of daily return on market return and industry return. Refer to the Appendix for detailed variable definitions. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	Fama–MacBeth (1973) approach	Firm-fixed effects	White (1980) standard errors	Fama–MacBeth (1973) approach	Firm-fixed effects	White (1980) standard errors
Dependent variable:	*Mispricing index* [1]	*Mispricing index* [2]	*Mispricing index* [3]	*Abs(alpha4)* [4]	*Abs(alpha4)* [5]	*Abs(alpha4)* [6]
IV	0.2867***	0.0788***	0.1319***	0.0106***	0.4747***	0.4712***
	(10.73)	(5.99)	(10.32)	(23.87)	(50.69)	(30.77)
Size	−0.0012	−0.0194***	−0.0007	−0.00005***	−0.0159***	−0.0040***
	(−0.84)	(−9.99)	(−0.96)	(−4.13)	(−11.55)	(−9.22)
Leverage	−0.1859***	−0.1423***	−0.2214***	0.0002***	0.0304***	0.0183***
	(−17.70)	(−16.30)	(−33.76)	(3.65)	(4.89)	(4.51)
Profitability	0.3055***	0.1110***	0.1828***	−0.0001	0.0715***	0.0519***
	(12.61)	(11.22)	(14.71)	(−0.50)	(10.16)	(6.03)
Age	−0.0078***	−0.0341***	−0.0107***	−0.00004*	−0.0007	−0.0025***
	(−7.35)	(−8.78)	(−8.25)	(−1.71)	(−0.26)	(−3.24)
Diversification	−0.0128***	−0.0088***	−0.0159***	−0.00002	0.0016	−0.0006
	(−5.57)	(−3.28)	(−7.83)	(−1.00)	(0.86)	(−0.48)
Dividend	−0.0168***	0.0082**	−0.0083***	−0.0003***	0.0023	−0.0128***
	(−6.76)	(2.46)	(−3.61)	(−6.36)	(0.99)	(−8.80)
Sales growth	0.0089***	0.0045***	0.0117***	0.0001***	0.0021***	0.0047***
	(8.11)	(4.96)	(13.00)	(6.06)	(3.32)	(7.05)
Skewness	0.0046***	0.0060***	0.0061***	−0.00003**	0.0057***	0.0054***
	(4.24)	(7.30)	(6.45)	(−2.01)	(9.72)	(8.54)
Constant	0.5901***	0.9558***	0.7204***	0.0028***	0.3606***	0.2224***
	(16.44)	(26.63)	(18.96)	(12.05)	(14.11)	(10.28)
Industry dummies	Yes	No	Yes	Yes	No	Yes
Year dummies	No	Yes	Yes	No	Yes	Yes
N (N of quarters)	(132)	39,259	39,259	(132)	39,259	39,259
R^2	0.158	0.051	0.145	0.227	0.146	0.268

tionship between idiosyncratic volatility and mispricing is not a relevant feature for the data range in question.

Fourth and last, we check if our previous results are driven by specific periods in time. Specifically, we want to test whether our results also hold for the most recent past (and thus are likely to be of interest for the future as well) or our results are primarily of historical relevance. We divide our period into three sub periods. Thus, we create two time dummies covering the years 1980 to 1990 ("Time 1") and 1991 to 2001 ("Time 2"), respectively. The time period covering the years 2002 to 2012 is our default. The last two columns of Table 8 display significant positive relationships between mispricing and absolute idiosyncratic volatility consistent with our previous results. The last two columns of Table 8 also show that (1) the very first period (1980–1990) was characterized by a higher level of mispricing than the two following periods – at least when measuring mispricing in terms of values (column 7) - and (2) the association between mispricing and absolute idiosyncratic volatility does not significantly differ between the three time periods (insignificant interaction terms).

5. Understanding the mixed results in the existing literature

This second part of our paper investigates the interaction between market volatility, idiosyncratic volatility, and R-squared and the consequences for the association between idiosyncratic volatility and equity mispricing. Our findings contribute to a deeper understanding of the reasons for the mixed results in the previous literature.

Table 9 displays correlations between market volatility, idiosyncratic volatility, and R-squared from a regression of stock returns on the returns of the market index. Market volatility is the standard deviation of daily market returns. Table 9 shows (1) that market volatility and absolute idiosyncratic volatility are positively correlated, (2) that market volatility and R-squared are positively correlated, and (3) that absolute idiosyncratic volatility and R-squared are negatively correlated.[15] Thus, absolute idiosyncratic volatility tends to be higher when markets are more volatile. At the same time, the part of volatility explained by the market model - R-squared - also increases with market volatility. These results indicate that markets tend to become more volatile because of both an increase in systematic as well as an increase in idiosyncratic risk. The negative correlation between absolute idiosyncratic volatility and R-squared indicates that although both are increasing in market volatility, the increase in the latter is – in this simple correlation display – associated with a decrease in the former. The implications of this negative correlation are important once we move to a relative measure of idiosyncratic volatility at a later stage (Table 12).

[15] We provide the cross-sectional correlations over the entire period. We cannot calculate the time-series average of the cross-sectional correlations since only one value of market volatility is obtained for all sample firms within each year.

Table 8
Robustness checks.
Columns [1] and [2] report results using the rank of idiosyncratic volatility. Columns [3] and [4] report results after excluding the most illiquid stocks. In each year, stocks are classified into decile groups by scaled trading volume, which is computed by the average over the year of the daily trading volume scaled by the number of outstanding shares. The regressions are conducted after excluding the lowest decile group (i.e., the most illiquid stocks). Columns [5] and [6] report results showing the non-linear relationship between idiosyncratic volatility and mispricing. Columns [7] and [8] report results showing the interacted effects of time and idiosyncratic volatility on mispricing. *Mispricing index* = the index that combines the yearly ranks of the four individual mispricing measures. The individual mispricing measures are: *Mispricing1* = the mispricing measure based on the Ohlson (1995) model; *Mispricing2* = the mispricing measure based on the Rhodes-Kropf et al. (2005) model; *Mispricing3* = the mispricing measure based on the Berger and Ofek (1995) model; *Mispricing4* = the mispricing measure based on the industry-adjusted market-to-book ratio. *Abs(alpha4)* = the absolute value of alpha obtained from the four-factor model. *IV* = idiosyncratic volatility. *IV_Rank* = the rank of idiosyncratic volatility ranging from 0 to 1. *Time 1* (*Time 2*) = a time indicator that takes a value of 1 for years from 1980 to 1990 (1991 to 2001) and a value of 0 otherwise. *Size* = the log of one plus total assets. *Leverage* = the ratio of long-term debt to total assets. *Profitability* = return on assets. *Age* = the log of one plus firm age. *Diversification* = a diversification dummy that takes one if the firm operates in multi-segments and zero otherwise. *Dividend* = a dividend-payer dummy. *Sales growth* = sales growth rate in the past three years. *Skewness* = the scaled measure of the third moment of the residual obtained by the regression of daily return on market return and industry return. Industry and year dummies are included. Industry and year dummies are included. Refer to the Appendix for detailed variable definitions. We use Thompson (2011) standard errors that cluster on firm and time, and *t*-statistics are shown in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	Ranks of idiosyncratic volatility		Excluding the most illiquid stocks		Non-linear relationship		Time	
Dependent variable:	*Mispricing index* [1]	*Abs(alpha4)* [2]	*Mispricing index* [3]	*Abs(alpha4)* [4]	*Mispricing index* [5]	*Abs(alpha4)* [6]	*Mispricing index* [7]	*Abs(alpha4)* [8]
IV_Rank	0.0481***	0.2002***						
	(4.26)	(13.38)						
IV			0.1167***	0.4777***	0.2276***	0.7545***	0.1401***	0.4801***
			(4.31)	(13.43)	(5.71)	(9.91)	(3.49)	(4.20)
IV^2					−0.1187***	−0.4164***		
					(−2.64)	(−4.67)		
*IV*Time1*							0.0245	−0.0053
							(0.34)	(−0.05)
*IV*Time2*							−0.0173	0.0433
							(−0.39)	(0.38)
Time1							0.0278***	−0.0053
							(3.45)	(−0.75)
Tmie2							0.0005	0.0029
							(0.06)	(0.41)
Size	0.0002	0.0010	−0.0013	−0.0046***	−0.0046*	−0.0017*	−0.0014	−0.0025**
	(0.07)	(1.09)	(−0.55)	(−4.24)	(−1.94)	(−1.68)	(−0.62)	(−2.00)
Leverage	−0.2265***	−0.0024	−0.2210***	0.0183***	−0.2119***	0.0153**	−0.2227***	0.0185***
	(−14.15)	(−0.38)	(−13.66)	(2.73)	(−14.31)	(2.53)	(−14.42)	(2.87)
Profitability	0.1718***	0.0244**	0.1793***	0.0558***	0.1769***	0.0611***	0.1687***	0.0565***
	(6.93)	(1.99)	(7.28)	(3.51)	(7.42)	(4.03)	(6.49)	(3.34)
Age	−0.0105***	−0.0009	−0.0115***	−0.0027***	−0.0115***	−0.0014	−0.0102***	−0.0028***
	(−4.04)	(−0.99)	(−4.34)	(−3.11)	(−4.49)	(−1.58)	(−4.00)	(−3.55)
Diversification	−0.0156***	0.0005	−0.0172***	−0.0002	−0.0159***	−0.0003	−0.0163***	0.0012
	(−3.61)	(0.42)	(−3.81)	(−0.13)	(−3.69)	(−0.22)	(−3.71)	(0.88)
Dividend	−0.0062	−0.0026	−0.0062	−0.0117***	−0.0051	−0.0075***	−0.0070*	−0.0148***
	(−1.56)	(−1.04)	(−1.44)	(−4.80)	(−1.29)	(−3.27)	(−1.73)	(−5.36)
Sales growth	0.0117***	0.0040***	0.0122***	0.0042***	0.0104***	0.0041***	0.0115***	0.0047***
	(9.51)	(4.31)	(9.90)	(4.79)	(8.95)	(4.78)	(9.77)	(4.80)
Skewness	0.0069***	0.0082***	0.0068***	0.0056***	0.0064***	0.0062***	0.0057***	0.0055***
	(6.59)	(5.17)	(6.28)	(4.25)	(6.26)	(4.80)	(5.85)	(4.85)
Constant	0.6843***	0.0411**	0.7652***	0.1734***	0.7993***	0.1536***	0.6325***	0.1318***
	(9.37)	(2.00)	(12.27)	(9.24)	(11.75)	(7.05)	(10.07)	(4.50)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	No	No
N	39,259	39,259	35,345	35,345	39,247	39,259	39,259	39,259
R^2	0.145	0.259	0.145	0.270	0.150	0.278	0.142	0.256

Table 9
Correlations among market volatility, idiosyncratic volatility, and R-squared.
This table reports the cross-sectional correlation coefficients among market volatility, idiosyncratic volatility, and R-squared. *Market volatility* = the standard deviation of daily market returns. *IV* = idiosyncratic volatility. R^2 = R-squared measured using a regression of stock returns on the returns of the market index. Refer to the Appendix for detailed variable definitions. *** denotes statistical significance at the 1% level.

	Market volatility	*IV*
IV	0.2851***	
	[0.000]	
R^2	0.2884***	−0.2304***
	[0.000]	[0.000]

We elaborate on the correlations in Table 9 by showing the average values of absolute idiosyncratic volatility and R-squared for quintiles of market volatility in Fig. 2. Firms are classified into quintile sub-samples by market volatility, the standard deviation of daily market returns. The bars in the graphs represent the average values of market volatility, idiosyncratic volatility, and R-squared for each sub-sample group. Per construction, market volatility is increasing monotonically. However, this is not the case for absolute idiosyncratic volatility and R-squared. The increase in absolute idiosyncratic volatility seems to follow a U-shaped relationship (but with a tall right-hand side of the U) while the increase in R-squared primarily reflects a low R-squared for the first quintile of market volatility and a high R-squared for the last quintile of market volatility.

Given the associations between market volatility, absolute idiosyncratic volatility, and R-squared displayed in Table 9 and Fig. 2, we want to investigate two specific associations between idiosyncratic volatility and mispricing. First, we want to investigate the association between absolute idiosyncratic volatility and mispricing once we control for market volatility (Tables 10 and 11). Second,

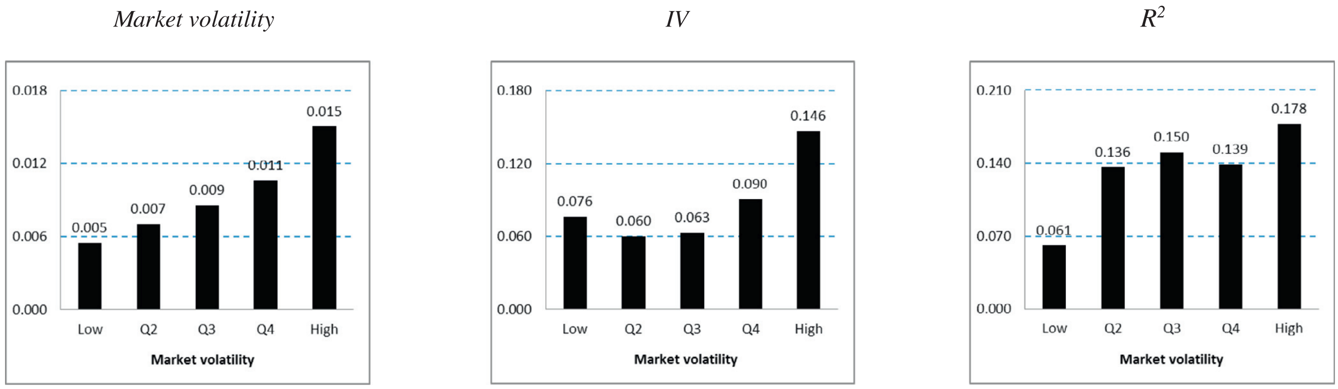

Fig. 2. Average values for IV and R^2 by market volatility.
Firms are classified into quintile sub-samples by market volatility, the standard deviation of daily market returns. The bars in the graphs represent the average values of market volatility, idiosyncratic volatility, and R-squared for each sub-sample group. *IV* = idiosyncratic volatility. R^2 = R-squared measured using a regression of stock returns on the returns of the market index. Refer to the Appendix for detailed variable definitions.

Table 10
High market volatility and the effect of idiosyncratic volatility on mispricing.
This table reports the coefficient estimates of the regressions of equity mispricing on market volatility, idiosyncratic volatility, and other firm characteristics. *Mispricing index* = the index that combines the yearly ranks of the four individual mispricing measures. The individual mispricing measures are: *Mispricing1* = the mispricing measure based on the Ohlson (1995) model; *Mispricing2* = the mispricing measure based on the Rhodes-Kropf et al. (2005) model; *Mispricing3* = the mispricing measure based on the Berger and Ofek (1995) model; *Mispricing4* = the mispricing measure based on the industry-adjusted market-to-book ratio. *Abs(alpha4)* = the absolute value of alpha obtained from the four-factor model. *High market volatility* = a dummy that takes a value of 1 if the standard deviation of market return is higher than the median value in the sample period or a value of 0 otherwise. *IV* = idiosyncratic volatility. *Size* = the log of one plus total assets. *Leverage* = the ratio of long-term debt to total assets. *Profitability* = return on assets. *Age* = the log of one plus firm age. *Diversification* = a diversification dummy that takes one if the firm operates in multi-segments and zero otherwise. *Dividend* = a dividend-payer dummy. *Sales growth* = sales growth rate in the past three years. *Skewness* = the scaled measure of the third moment of the residual obtained by the regression of daily return on market return and industry return. Industry and year dummies are included. Industry and year dummies are included. Refer to the Appendix for detailed variable definitions. We use Thompson (2011) standard errors that cluster on firm and time, and *t*-statistics are shown in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable:	*Mispricing index* [1]	*Abs(alpha4)* [2]	*Mispricing index* [3]	*Abs(alpha4)* [4]	*Mispricing index* [5]	*Abs(alpha4)* [6]
High market volatility	0.0731***	0.0580***	0.0751***	0.0654***	0.0804***	0.0682***
	(9.65)	(14.01)	(10.64)	(15.87)	(9.94)	(10.88)
IV			0.1319***	0.4712***	0.1921***	0.5036***
			(5.80)	(12.75)	(7.14)	(11.99)
*High market volatility * IV*					−0.0765**	−0.0410
					(−1.98)	(−0.74)
Size	−0.0029	−0.0119***	−0.0007	−0.0040***	−0.0005	−0.0038***
	(−1.26)	(−11.03)	(−0.29)	(−3.83)	(−0.19)	(−3.74)
Leverage	−0.2223***	0.0151*	−0.2214***	0.0183***	−0.2223***	0.0178***
	(−14.17)	(1.92)	(−14.20)	(2.81)	(−14.18)	(2.71)
Profitability	0.1518***	−0.0590***	0.1828***	0.0519***	0.1828***	0.0519***
	(5.92)	(−5.18)	(7.35)	(3.31)	(7.33)	(3.32)
Age	−0.0119***	−0.0070***	−0.0107***	−0.0025***	−0.0106***	−0.0025***
	(−4.73)	(−6.66)	(−4.19)	(−3.16)	(−4.18)	(−3.13)
Diversification	−0.0160***	−0.0009	−0.0159***	−0.0006	−0.0157***	−0.0005
	(−3.68)	(−0.65)	(−3.65)	(−0.42)	(−3.62)	(−0.36)
Dividend	−0.0113***	−0.0236***	−0.0083**	−0.0128***	−0.0078*	−0.0125***
	(−2.72)	(−8.98)	(−2.04)	(−5.16)	(−1.92)	(−5.29)
Sales growth	0.0125***	0.0076***	0.0117***	0.0047***	0.0118***	0.0047***
	(9.68)	(8.08)	(9.72)	(5.53)	(9.87)	(5.57)
Skewness	0.0073***	0.0096***	0.0061***	0.0054***	0.0062***	0.0055***
	(7.08)	(5.36)	(5.86)	(4.51)	(5.90)	(4.58)
Constant	0.7012***	0.3570***	0.6452***	0.1571***	0.6369***	0.1526***
	(10.75)	(15.15)	(9.58)	(7.09)	(9.45)	(7.51)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	39,259	39,259	39,259	39,259	39,259	39,259
R^2	0.143	0.181	0.145	0.268	0.146	0.268

we want to investigate the association between a relative measure of idiosyncratic volatility and mispricing (Table 12).

Table 10 (columns 1–2) shows that high market volatility on its own is associated with more mispricing. High market volatility is a dummy that takes a value of 1 if the standard deviation of market return is higher than the median value in the sample period or a value of 0 otherwise. Furthermore, Table 10 (columns 3–4) show that high absolute idiosyncratic volatility is associated with more mispricing even when controlling for market volatility in spite of the positive correlation between market volatility and absolute idiosyncratic volatility. Finally, Table 10 (columns 5–6) show that absolute idiosyncratic volatility has a non-constant “impact” on mispricing dependent on the level of market volatility when mispricing is measured in values but not in returns. We elaborate on this non-constant “impact” in Table 11.

Table 11
Low vs. high market volatility.
This table reports the coefficient estimates of the regressions of equity mispricing on idiosyncratic volatility and other firm characteristics. The sample is divided into the low and high market volatility periods if the standard deviation of market return is lower and higher, respectively, than the median value in the sample period. *Mispricing index* = the index that combines the yearly ranks of the four individual mispricing measures. The individual mispricing measures are: *Mispricing1* = the mispricing measure based on the Ohlson (1995) model; *Mispricing2* = the mispricing measure based on the Rhodes-Kropf et al. (2005) model; *Mispricing3* = the mispricing measure based on the Berger and Ofek (1995) model; *Mispricing4* = the mispricing measure based on the industry-adjusted market-to-book ratio. *Abs(alpha4)* = the absolute value of alpha obtained from the four-factor model. *IV* = idiosyncratic volatility. *Size* = the log of one plus total assets. *Leverage* = the ratio of long-term debt to total assets. *Profitability* = return on assets. *Age* = the log of one plus firm age. *Diversification* = a diversification dummy that takes one if the firm operates in multi-segments and zero otherwise. *Dividend* = a dividend-payer dummy. *Sales growth* = sales growth rate in the past three years. *Skewness* = the scaled measure of the third moment of the residual obtained by the regression of daily return on market return and industry return. Industry and year dummies are included. Industry and year dummies are included. Refer to the Appendix for detailed variable definitions. We use Thompson (2011) standard errors that cluster on firm and time, and *t*-statistics are shown in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable:	Low market volatility periods *Mispricing index* [1]	High market volatility periods *Mispricing index* [2]	Coefficient difference tests High – Low [3]	Low market volatility periods *Abs(alpha4)* [4]	High market volatility periods *Abs(alpha4)* [5]	Coefficient difference tests High – Low [6]
IV	0.1842***	0.1147***	−0.0695**	0.4974***	0.4622***	−0.0352
	(8.35)	(4.63)	(−2.10)	(10.67)	(10.18)	(−0.54)
Size	−0.0048*	0.0033	0.0081**	−0.0039***	−0.0038**	0.0001
	(−1.78)	(1.15)	(2.06)	(−5.87)	(−2.13)	(0.05)
Leverage	−0.1843***	−0.2474***	−0.0631**	0.0236***	0.0128	−0.0108
	(−10.20)	(−14.01)	(−2.50)	(4.38)	(1.22)	(−0.92)
Profitability	0.2473***	0.1520***	−0.0953**	0.0264	0.0686***	0.0422
	(6.88)	(5.83)	(−2.15)	(1.28)	(3.54)	(1.49)
Age	−0.0099***	−0.0109***	−0.0010	−0.0023**	−0.0026**	−0.0003
	(−3.60)	(−3.57)	(−0.24)	(−2.55)	(−2.16)	(−0.20)
Diversification	−0.0113**	−0.0187***	−0.0074	−0.0011	−0.0002	0.0009
	(−2.42)	(−3.83)	(−1.10)	(−0.87)	(−0.08)	(0.32)
Dividend	−0.0110**	−0.0064	0.0046	−0.0131***	−0.0118***	0.0013
	(−2.28)	(−1.40)	(0.69)	(−4.73)	(−3.21)	(0.28)
Sales growth	0.0102***	0.0122***	0.0020	0.0051***	0.0047***	−0.0004
	(5.45)	(8.28)	(0.84)	(9.92)	(3.53)	(−0.28)
Skewness	0.0070***	0.0052***	−0.0018	0.0034***	0.0075***	0.0041*
	(4.53)	(3.34)	(−0.82)	(3.18)	(3.73)	(1.80)
Constant	0.7557***	0.6635***	−0.0922	0.1577***	0.2296***	0.0719**
	(8.42)	(6.35)	(−0.67)	(14.89)	(6.63)	(1.99)
Industry dummies	Yes	Yes		Yes	Yes	
Year dummies	Yes	Yes		Yes	Yes	
N	18,412	20,847		18,412	20,847	
R^2	0.136	0.161		0.210	0.276	

Thus, Table 11 shows that the association between absolute idiosyncratic volatility and mispricing is stronger during low market volatility periods than during high market volatility periods. However, this is only the case when we measure mispricing in terms of values but not when we measure mispricing in terms of returns.[16] The conclusion of Tables 10 and 11 is that (1) market volatility is positively associated with mispricing but in such way that absolute idiosyncratic volatility is also and independently associated with mispricing, and 2) the "impact" of one unit of absolute idiosyncratic volatility on mispricing varies according to the level of market volatility when mispricing is measured in levels. The non-constant "impact" of absolute idiosyncratic volatility on mispricing illustrated above is a factor that is relevant to take into account when trying to understand diverging findings across time and geographical areas in the existing literature.

Throughout this paper, we have used an absolute measure of idiosyncratic volatility. However, some previous studies (e.g., Durnev et al., 2003, 2004; Ferreira and Laux, 2007; Kelly, 2014) have used a relative measure of idiosyncratic volatility. We construct a relative measure of idiosyncratic volatility and show that the results are very different from our previous results.

Following past studies, we compute each stock's relative idiosyncratic volatility for each year t using the following logistic transformation.

$$\Psi_{i,t} = \ln\left(\frac{1-R^2_{i,t}}{R^2_{i,t}}\right) = \ln\left(\frac{\sigma^2_{ie,t}}{\sigma^2_{i,t}-\sigma^2_{ie,t}}\right). \tag{8}$$

Logistic relative idiosyncratic volatility ($\Psi_{i,t}$) measures the ratio of unexplained variance to explained variance. We replicate Table 3 but instead of using our previous absolute version of idiosyncratic volatility, we use the above relative version of idiosyncratic volatility. Table 12 reports the results.

Table 12 shows a significant *negative* relation between relative idiosyncratic volatility and mispricing based on values (and an insignificant relation for mispricing based on returns). Not being aware of the associations between market volatility, idiosyncratic volatility, and R-squared as shown in Table 9, but using a relative measure of idiosyncratic volatility could lead to the faulty conclusion that idiosyncratic volatility is associated with informed trad-

[16] One could argue that, almost by construction, an interaction effect does not exist in the case of alphas (Table 10, column 6). When we try to explain returns by alpha, the market, and a noise term (= the market model) –all measured over the same year, then there cannot be an interaction effect between absolute idiosyncratic volatility and mispricing because the "noise" (= absolute idiosyncratic volatility) is simply the residual from the market model. The noise term cannot be correlated with the market (and therefore an interaction effect cannot exist) because instead beta simply adjusts either lower or higher. Since an interaction effect cannot exist in the case of alphas, Table 11 shows no difference in the coefficients for the alpha models. The mispricing index is comprised of comparisons of accounting and market value measures. Thus, it is a more static measure of mispricing than the contemporaneous measure based on alphas. It turns out that the two independent contributions to mispricing (i.e., the market volatility and the absolute idiosyncratic volatility) exaggerate the mispricing index when both measures are high. Thus, Table 10, column 5, shows a negative interaction effect that reduces the combined mispricing from the two contributions.

Table 12
Relative idiosyncratic volatility.
This table reports the alternative regressions of mispricing on the relative idiosyncratic volatility measure and other firm characteristics. *Mispricing1* = the mispricing measure based on the Ohlson (1995) model. *Mispricing2* = the mispricing measure based on the Rhodes-Kropf et al. (2005) model. *Mispricing3* = the mispricing measure based on the Berger and Ofek (1995) model. *Mispricing4* = the mispricing measure based on the industry-adjusted market-to-book ratio. *Mispricing index* = the index that combines the yearly ranks of the four individual mispricing measures. *Abs(alpha1), Abs(alpha3)*, and *Abs(alpha4)* = the absolute value of alpha obtained from the one-, three-, and four-factor models, respectively. *Relative IV* = the log of the ratio of unexplained variance to explained variance. *Size* = the log of one plus total assets. *Leverage* = the ratio of long-term debt to total assets. *Profitability* = return on assets. *Age* = the log of one plus firm age. *Diversification* = a diversification dummy that takes one if the firm operates in multi-segments and zero otherwise. *Dividend* = a dividend-payer dummy. *Sales growth* = sales growth rate in the past three years. *Skewness* = the scaled measure of the third moment of the residual obtained by the regression of daily return on market return and industry return. Industry and year dummies are included. Industry and year dummies are included. Refer to the Appendix for detailed variable definitions. We use Thompson (2011) standard errors that cluster on firm and time, and *t*-statistics are shown in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable:	*Mispricing1* [1]	*Mispricing2* [2]	*Mispricing3* [3]	*Mispricing4* [4]	*Mispricing index* [5]	*Abs(alpha1)* [6]	*Abs(alpha3)* [7]	*Abs(alpha4)* [8]
Relative IV	−0.0361***	−0.0146***	−0.0105**	−0.0230***	−0.0088***	0.0010	0.0003	0.0005
	(−4.57)	(−5.36)	(−2.39)	(−9.05)	(−6.26)	(0.41)	(0.15)	(0.20)
Size	0.0027	−0.0082***	−0.0031	−0.0188***	−0.0072***	−0.0123***	−0.0113***	−0.0117***
	(0.34)	(−2.80)	(−0.65)	(−5.65)	(−3.31)	(−10.55)	(−12.03)	(−9.95)
Leverage	−0.2557***	−0.2604***	−0.2950***	−0.3235***	−0.2131***	0.0154**	0.0161**	0.0144**
	(−4.98)	(−9.12)	(−8.57)	(−12.15)	(−14.41)	(1.99)	(2.40)	(2.08)
Profitability	−1.1309***	0.2319***	−0.2332***	0.6753***	0.1409***	−0.0639***	−0.0639***	−0.0582***
	(−13.85)	(7.13)	(−3.10)	(13.85)	(5.74)	(−3.41)	(−4.53)	(−4.87)
Age	−0.0383***	−0.0142***	−0.0217***	−0.0188***	−0.0131***	−0.0074***	−0.0071***	−0.0069***
	(−4.07)	(−4.42)	(−2.95)	(−4.68)	(−5.20)	(−6.35)	(−5.84)	(−5.72)
Diversification	−0.0044	−0.0249***	−0.0039	−0.0364***	−0.0161***	0.0005	−0.0012	−0.0009
	(−0.41)	(−4.30)	(−0.34)	(−5.45)	(−3.73)	(0.28)	(−0.89)	(−0.62)
Dividend	−0.0257*	−0.0244***	−0.0213*	0.0033	−0.0101**	−0.0228***	−0.0233***	−0.0236***
	(−1.95)	(−3.80)	(−1.96)	(0.50)	(−2.46)	(−9.91)	(−8.24)	(−9.31)
Sales growth	0.0134**	0.0228***	0.0248***	0.0242***	0.0116***	0.0080***	0.0081***	0.0077***
	(2.21)	(10.65)	(5.77)	(8.60)	(9.28)	(8.76)	(7.87)	(9.21)
Skewness	0.0290***	0.0128***	0.0136***	0.0105***	0.0075***	0.0117***	0.0098***	0.0096***
	(4.86)	(8.08)	(5.00)	(5.59)	(7.50)	(3.48)	(4.84)	(5.36)
Constant	0.9873***	0.7901***	1.1779***	1.1019***	0.8684***	0.4262***	0.4037***	0.4099***
	(5.28)	(9.16)	(9.36)	(11.42)	(13.66)	(15.68)	(20.35)	(17.56)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	39,247	39,247	39,247	39,247	39,247	39,247	39,247	39,247
R^2	0.182	0.151	0.124	0.220	0.146	0.187	0.178	0.181

ing. We deem it relevant to speculate that some previous findings may have been affected by a lack of such awareness.

Absolute idiosyncratic volatility is generally increasing in market volatility (Table 9 and Fig. 2). In additional tests (not tabulated), we find that the correlation between market volatility and relative idiosyncratic volatility is negative and statistically significant. This negative correlation reflects that market volatility – which is positively correlated with R-squared, which again is highly negatively correlated with relative idiosyncratic volatility – increases more than the absolute idiosyncratic volatility. These associations lead us to conclude that relative idiosyncratic volatility appears to be a dubious and imprecise measure that is probably ill-chosen for use in investigating the relationship between mispricing and idiosyncratic volatility.

Finally, the coefficient on relative idiosyncratic volatility in the alpha regressions in Table 12 is not significant. This is not surprising, given that relative idiosyncratic volatility is measured as the ratio of unexplained variance to explained variance. Since the numerator and denominator have independent and roughly equal effects on alpha, and if R-squared can be roughly approximated by market volatility, the coefficient on relative idiosyncratic volatility in the alpha regressions becomes insignificant.

6. Conclusion

Past studies have argued that idiosyncratic volatility may reflect informed arbitrageurs' trading or uninformed noise traders' frenzy. In this paper, we revisit the alternative interpretations of idiosyncratic volatility in two ways. *First*, we show that absolute idiosyncratic volatility displays a positive and robust relationship to multiple measures of mispricing based on accounting information and abnormal stock returns. Thus, we find that larger values of absolute idiosyncratic volatility reflect an increasing role of noise traders. *Second*, we show that the interaction between market volatility, idiosyncratic volatility, and R−squared is an important aspect for understanding the mixed results in the existing literature. Hence, this interaction causes (1) the "impact" of absolute idiosyncratic volatility on mispricing to be non-constant and (2) the relationship between idiosyncratic volatility and mispricing to reverse when a relative version of idiosyncratic volatility is used.

Our findings contribute to the existing literature by showing strong and robust support for the noise trading hypothesis and by deepening our understanding for the reasons behind the lack of consensus in the existing literature.

Appendix. Variable definitions

Variables	Descriptions
Idiosyncratic volatility	
R^2	R-squared measured using a regression of stock returns on the returns of the market index, $r_{i,d,t} = \alpha_{i,t} + \beta_{i,t} r_{m,d,t} + e_{i,d,t}$, where $r_{i,d,t}$ is the excess return for stock *i* on day *d* in year *t*, and $r_{m,d,t}$ is the value-weighted excess market index return on the day *d* in year *t*.
σ_e^2	Absolute idiosyncratic volatility. From the regression, $r_{i,d,t} = \alpha_0 + \beta_1 r_{m,d,t} + e_{i,d,t}$, idiosyncratic variance is defined as $\sigma_{ie,t}^2 = \sigma_{i,t}^2 - (\sigma_{im,t}^2/\sigma_{m,t}^2)$, where $\sigma_{i,t}^2 = \mathrm{Var}(r_{i,d,t})$, $\sigma_{m,t}^2 = \mathrm{Var}(r_{m,d,t})$, and $\sigma_{im,t} = \mathrm{Cov}(r_{i,d,t}, r_{m,d,t})$.
σ_e^2/σ^2	Relative idiosyncratic volatility that is the ratio of idiosyncratic volatility to total volatility or equivalently one minus R-squared.
Ψ	Logistic relative idiosyncratic volatility. $\Psi_{it} = \ln(\frac{1-R_{i,t}^2}{R_{i,t}^2}) = \ln(\frac{\sigma_{ie,t}^2}{\sigma_{i,t}^2 - \sigma_{ie,t}^2})$.
Mispricing	
Mispricing1	The absolute value of excess value based on the Ohlson's (1995) residual income value approach. $Mispricing1_{it} = \ln[Price_{i,t} / I(Value)_{i,t}]$, where $Price_{it}$ is the stock price at the end of June of each year from CRSP, and $I(Value)_{it}$ is intrinsic value using the residual income model (Ohlson, 1995) and median values of analysts' forecasts issued in June, as in Frankel and Lee (1998).
Mispricing2	The absolute value of the excess value based on the Rhodes-Kropf et al. (2005). Fundamental value (*Value*) is estimated by decomposing the market-to-book into two components: a measure of price to fundamentals (ln(*Market*/*Value*)), and a measure of fundamentals to book value (ln(*Value*/*Book*)). The first component captures the part of book-to-market associated with mispricing. This component is further decomposed into firm-specific and industry-specific mispricing. We use the firm-specific mispricing component based on Model III of Rhodes-Kropf et al. (2005) that also accounts for net income and leverage effects. $\ln(Market_{i,t}) = \alpha_{0j,t} + \alpha_{1j,t} \ln(Book_{i,t}) + \alpha_{2j,t} \ln(Net\ Income)^+_{i,t} + \alpha_{3j,t} I_{(<0)} \ln(Net\ Income)^+_{i,t} + \alpha_{4j,t} \ln(Leverage_{i,t}) + \varepsilon_{i,t}$, where *Market* is firm's market value, *Book* is book value, $Net\ Income^+$ is absolute value of net income, $I_{(<0)}$ is an indicator function for negative net income observations, and *Leverage* is the leverage ratio.
Mispricing3	The absolute value of excess value based on the Berger and Ofek (1995) approach. $Mispricing2_{it} = \ln[Capital_{i,t} / I(Capital)_{i,t}]$, where $Capital_{i,t}$ is total capital that is market value of equity plus book value of debt, $I(Capital_{i,t})$ is the imputed value derived as the product of firm sales and the median capital to size ratio in the firm's industry.
Mispricing4	The absolute value of the industry-adjusted market-to-book ratio. $Mispricing4_{it} = \ln[MB_{i,t} / Median(MB)_{j,t}]$, where, $MB_{i,t}$ is the market to book ratio for firm *i* at time *t*, and $Median(MB_{j,t})$ is the *j*th industry median of MB_t.
Mispricing index	The mispricing index that is constructed each year for each observation $i = 1,\ldots,N$ as: $Mispricing\ index_i = (1/N)(1/K)\sum_k^K Rank_k(Mispricing_{i,k})$, where $Rank_k(Mispricing_{i,k})$ is the rank function which assigns a rank for each observation from least misvalued (rank of one) to most misvalued (rank of *N*). $Mispricing_{i,k}$ is the *k*th measure of mispricing for firm *i* in our sample, and *K* represents the dimensions of mispricing measures. The denominator, *K*, averages the ranks by the number of mispricing values available for each firm in the sample in a particular year. Finally, dividing by *N*, we scale the mispricing index from 0 (least mispriced) to 1 (most mispriced).
Abs(alpha1)	The absolute value of alpha obtained from the one-factor model. $r_{i,d,t} = \alpha_0 + \beta_1\ r_{m,d,t} + e_{d,t}$, where $r_{i,d,t}$ is the excess return for stock *i* on day *d* in year *t*, and $r_{m,d,t}$ is the value-weighted excess market index return on the day *d* in year *t*.
Abs(alpha3)	The absolute value of alpha obtained from the three-factor model. $r_{i,d,t} = \alpha_0 + \beta_1\ r_{m,d,t} + \beta_2\ SMB_{d,t} + \beta_3\ HML_{d,t} + e_{d,t}$, where *SMB* (small minus big) is the difference each day between the return on small and big firms, while *HML* (high minus low) is the daily difference of the returns on a portfolio of high book-to-market and low book-to-market firms.
Abs(alpha4)	The absolute value of alpha obtained from the four-factor model. $r_{i,d,t} = \alpha_0 + \beta_1\ r_{m,d,t} + \beta_2\ SMB_{d,t} + \beta_3\ HML_{d,t} + \beta_4\ UMD_{d,t} + e_{d,t}$, where *UMD* (up minus down) is the momentum factor computed on a daily basis as the return differential between a portfolio of winners and a portfolio of losers.
Firm characteristics	
Size	Log of one plus total assets.
Leverage	The ratio of long-term debt to total assets.
Profitability	Return on assets. The ratio of net income to total assets.
Age	The log of one plus firm age, where the firm age is counted as the number of years since the stock inclusion in the CRSP database.
Diversification	Diversification dummy that equals one if a firm operates in multi-segments and zero otherwise.
Dividend	Dividend-payer dummy that equals one if a firm pays dividends and zero otherwise.
Scaled trading Volume	The average over the year of the daily trading volume scaled by the number of outstanding shares. $Scaled\ trading\ volume_{i,t} = (1/D_{i,t})\sum_{d=1}^{D_{i,t}}(Volume_{i,d,t}/Share_{i,d,t})$, where $D_{i,t}$ is the number of days for which data are available for stock *i* at year *t*. $Volume_{i,d,t}$ and $Share_{i,d,t}$ are the firm *i*'s trading volume and the number of common shares on day *d* at year *t*, respectively.

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