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Information precision, transaction costs, and trading volume

Orie E. Barron [a], Jonathan M. Karpoff [b,*]

[a] Pennsylvania State University, University Park, PA 16802, USA
[b] University of Washington, Box 353200, Seattle, WA 98195-3200, USA

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Abstract

Most theoretical models of trade (Pfleiderer, 1984; Grundy and McNichols, 1989; Holthausen and Verrecchia, 1990; Kim and Verrecchia, 1991; Blume et al., 1994) imply that the trading volume prompted by a public announcement is positively related to the announcement's precision. Relying upon this notion, empirical researchers interpret high trading volume as an indication that an announcement is highly informative. We argue that such interpretations are not, in general, correct. In a world with transaction costs, the relation between information precision and trading volume is ambiguous and can be negative. This explains why, in empirical tests using data from actual markets, the relation between announcement precision and trading volume is not monotonically positive, even though in laboratory experiments it is. Our results imply that trading volume reactions to public announcements are most sensitive to announcement precision among low-transaction cost securities and in low-cost trading regimes.

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1. Introduction

Can we tell when a public announcement conveys meaningful information to investors? And just what can be inferred from a trading volume reaction to new

* Corresponding author. Tel.: +1-206-685-4954; fax: +1-206-221-6856.
E-mail address: karpoff@u.washington.edu (J.M. Karpoff).

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information? For nearly 25 years, researchers have had answers to these questions. Beaver (1968), Morse (1981), Bamber (1986), and Bamber and Cheon (1995), for example, all interpret earnings announcements that are accompanied by high trading volume as conveying more information to investors than announcements that generate low trading volume. Supporting such interpretations, several rational expectation models demonstrate that trading volume increases with the precision of investors' information. [1] The notion that high volume accompanies informative announcements has taken roots in both the theoretical and empirical literature. Blume et al. (1994), for example, use it to advance a rationale for using trading volume in technical analysis. Hence, the conventional wisdom holds that meaningful news generates trading volume, and that trading volume is a useful measure of a public announcement's information content.

Unfortunately, however, this conventional wisdom is incorrect. In this paper we demonstrate that one should not expect, as a matter of course, a monotonically positive relation between announcement precision and the corresponding trading volume. As a result, the interpretation of trading volume reactions to public announcements, and our understanding of which types of announcements convey the most information to investors, are more complicated than recognized in most empirical research.

The key to our argument is the cost of trade. Consider as an example Kim and Verrecchia's (1991) model. In this model precise public announcements cause investors to agree more about the asset's value, homogenizing investors' private valuations of the risky asset. Precise public announcements also increase each investor's confidence about his or her private valuation. Bolstered by such confidence, investors become more willing to take speculative positions. In a world of costless trading the net result of these effects is to increase trade. At the extreme, a very precise public announcement could leave investors' valuations differing by only a penny, but each investor would be virtually certain that he or she was correct. Betting on their precise beliefs, investors would take extremely large speculative positions, thereby generating large trading volume.

If transactions are *costly*, however, investors will not dicker over the last penny. Informative announcements will homogenize valuations, but many potential gains from trade will be outweighed by the transaction costs. At the extreme, a very precise and informative announcement will generate *no* trade, because investors' valuations will converge to such an extent that they lie within the bid–ask spread. In general, when transactions are costly, the most precise and informative announcements will trigger the fewest trades.

The effect of transaction costs can explain the available empirical evidence regarding trading volume and information precision. When transaction costs are zero, our model predicts that highly informative public announcements cause investors' beliefs to converge and simultaneously generate large trading volume – the same prediction

[1] See, for examples, Pfleiderer (1984), Grundy and McNichols (1989), Holthausen and Verrecchia (1990), and Kim and Verrecchia (1991).

as in previous models. This is exactly what Gillette et al. (1999) find in an experimental market in which transaction costs are zero.

In actual markets with positive transaction costs, however, our model predicts that trading volume is not monotonically and positively related to information precision and the convergence of investors' beliefs. This result, which other models do not generate, also is consistent with available evidence. Ziebart (1990) and Bamber et al. (1997), for example, find that trading volume is *negatively* related to the convergence in analysts' forecasts around earnings releases. Barron (1995) reports that trading volume is negatively related to convergence in analysts' forecasts in general. Barron et al. (2003) find no significant relation between abnormal trading and a measure of announcement precision that is derived from Barron et al. (1998). And Wasley (1996) finds that trading volume is first increasing, and then decreasing in the precision of management earnings forecasts, with the most precise forecasts generating the lowest trading volume reactions. All of these findings are inconsistent with the conventional notion that trading volume increases with information precision and the convergence of beliefs. They are consistent, however, with our model of trading volume reactions in the presence of transaction costs.

In the next section, we develop our argument in a pure exchange model with transaction costs. The model assumes the same information environment used by Kim and Verrecchia (1991), in which investors have heterogeneous prior private information and receive a common signal from a public announcement. Our general proposition regarding the importance of transaction costs, however, is not limited to this one type of informational setting. To demonstrate that the proposition applies broadly, in Section 3 we examine an informational environment based on the Holthausen and Verrecchia (1990) model. In this framework, investors have homogeneous priors but interpret the public announcement differently. Regardless of one's specific assumptions about investors' information and beliefs, the presence of transaction costs stands conventional wisdom on its head, as trading volume no longer is monotonically related to information precision. In Section 4 we contrast our results to several theoretical papers that also yield non-monotonic relationships between volume and precision, and argue that the transactions cost argument is most consistent with the available evidence. Section 5 concludes the paper with a discussion of our argument's implications for empirical research.

2. Trading volume with differing private information and common signal interpretation

2.1. The basic model

We start with a three-date model of a pure exchange economy in which investors receive both private and public information about an asset's value. At date 1, speculative investors receive endowments of a riskless asset M (i.e., money). Also at date 1, an uncertain quantity $\tilde{q}$ of risky assets, each with uncertain liquidating value $\tilde{u}$, is auctioned to the investors. Uncertainty in $\tilde{q}$ may reflect uncertain order flow based on liquidity-based trades. In the model, it serves as a source of noise. At date 2 the investors receive a public announcement and trade with each other based on this announcement. At date 3, the value of the risky asset is revealed and investors consume their wealth.

To characterize the trading volume equilibrium with transaction costs in as simple a setting as possible, we assume the market consists of only two investors. Further, for ease of notation, we pre-identify one investor as the potential buyer (b) at date 2, and the other as the potential seller (s). Such pre-identification is not essential to our results; when demand-prices differ at date 2, we simply label the lower demand-price as belonging to the potential seller. What is essential is that the investors arrive at date 2 with different priors, regardless of how those priors are reached. [2]

At date 1, each investor i's ($i \in \text{s}, \text{b}$) information set contains both a private element $\tilde{z}_{i1}$ and common element $\tilde{y}_1$:

$$\tilde{z}_{i1} = \tilde{u} + \tilde{e}_{zi}, \tag{1a}$$

$$\tilde{y}_1 = \tilde{u} + \tilde{e}_{y1}. \tag{1b}$$

The private and common signal errors, $\tilde{e}_{zi}$ and $\tilde{e}_{y1}$, are assumed to be independent and normally distributed with mean zero. A signal's precision is the inverse of the signal error's variance. The private and common signals' precisions are $s_i = 1/\text{var}[\tilde{e}_{zi}]$ and $n_1 = 1/\text{var}[\tilde{e}_{y1}]$, respectively. The asset's conditional expected payoff for investor i at date 1 therefore is

$$E_{i1}[\tilde{u}|\tilde{z}_{i1}, \tilde{y}_1] = \tilde{u}_{i1} = \frac{s_{i1}\tilde{z}_{i1} + n_1\tilde{y}_1}{s_{i1} + n_1}. \tag{2}$$

The investor's informedness, defined as the inverse of the conditional variance of $\tilde{u}$, is $K_{it} = s_{i1} + n_1$. This information environment is identical to that assumed by Kim and Verrecchia (1991), and by Barron et al. (1998) in their analysis of how empirical measures of divergence in opinions are related to informedness. For simplicity, Kim and Verrecchia's common date 1 signal, common priors about the asset's liquidating value, and any learning from date 1 transaction prices are collapsed into the common information element $\tilde{y}_1$. [3]

At date 2, investors observe a public announcement (e.g., an earnings announcement) $\tilde{y}_2$, which has precision $n = 1/\text{var}[\tilde{u}|\tilde{y}_2]$. Following the announcement, each investor i's date 2 informedness is $K_{i2} = K_{i1} + n$, and his expectation of $\tilde{u}$ is a weighted average of his or her idiosyncratic prior expectations, $\tilde{u}_{i1}$, and the public signal:

[2] This assumption is similar to an aspect of Karpoff's (1986) model, which pairs potential buyers only with potential sellers. Unlike Karpoff's model, however, we do not require that the amount traded be limited to a single share. Indeed, we seek to characterize the influence of information precision and trading costs on the trading volume.

[3] Unlike Kim and Verrecchia (1991), our model does not generate a typical rational expectations equilibrium in which investors learn from the market price. The advantage of this approach is that it presents our central proposition about trading volume and transaction costs in a simple and transparent setting. (Transaction costs complicate the problem of a rational expectations equilibrium in which investors learn from the market price. This is because there may be many no-trading equilibria that are consistent with multiple prices within a range determined by the transaction cost.)

$$E_{i2}[\tilde{u}|\tilde{u}_{i1},\tilde{y}_2] = \tilde{u}_{i2} = \frac{K_{i1}\tilde{u}_{i1} + n\tilde{y}_2}{K_{i1} + n}. \tag{3}$$

Each investor i maximizes expected date 3 utility of wealth, which is comprised of the riskless asset M and holdings of the risky asset D:

$$E_i U(\widetilde{W}_{3i}) = E_i[-\mathrm{e}^{-r_i^{-1}(D_i\tilde{u}+M_i)}], \tag{4}$$

where r_i is the investor's constant absolute risk tolerance. We assume that $r_i = 1$ for all investors, an assumption that simplifies our expressions without affecting the results. The negative exponential utility function in Eq. (4) is consistent with investor i's demand at date t being a linear function of the asset's price, $\tilde{p}_t$:

$$\widetilde{D}_{it} = K_{it}[\tilde{u}_{it} - \tilde{p}_t]. \tag{5}$$

2.2. Trading volume at date 2 with transaction costs

To examine the effect of transaction costs on trading volume, we introduce a per-share fee, x, for each share bought or sold at date 2. [4] In Appendix A, we show that the investors' resulting desired holdings (gross demand) are

$$\widetilde{D}_{\mathrm{b}2} = K_{\mathrm{b}2}[\tilde{u}_{\mathrm{b}2} - (\tilde{p}_2 + x)], \tag{6a}$$

$$\widetilde{D}_{\mathrm{s}2} = K_{\mathrm{s}2}[\tilde{u}_{\mathrm{s}2} - (\tilde{p}_2 - x)]. \tag{6b}$$

In Eqs. (6a) and (6b), $\tilde{p}_2$ is the date 2 price of the risky asset. When a unique $\tilde{p}_2$ exists, it can be expressed in terms of the seller's demand:

$$\tilde{p}_2 = [\tilde{u}_{\mathrm{s}2} + x] - \frac{\widetilde{D}_{\mathrm{s}2}}{K_{\mathrm{s}2}}. \tag{7}$$

By substituting Eq. (7) into Eq. (6a), the buyer's date 2 demand is

$$\widetilde{D}_{\mathrm{b}2} = K_{\mathrm{b}2}\left[\tilde{u}_{\mathrm{b}2} - \left(\tilde{u}_{\mathrm{s}2} - \frac{\widetilde{D}_{\mathrm{s}2}}{K_{\mathrm{s}2}} + 2x\right)\right]. \tag{8}$$

Since the total quantity of risky assets available for trading is unknown, the quantity $\tilde{q}$ acquired by both investors at date 1 and available for reallocation at date 2 is unknown. The market clearing condition is $\tilde{q} = D_{\mathrm{b}2} + D_{\mathrm{s}2}$. Substituting the expression for the seller's demand ($D_{\mathrm{s}2} = \tilde{q} - D_{\mathrm{b}2}$) into Eq. (8) yields:

$$\widetilde{D}_{\mathrm{b}2} = K_{\mathrm{b}2}\frac{[(\tilde{u}_{\mathrm{b}2} - \tilde{u}_{\mathrm{s}2} - 2x)K_{\mathrm{s}2} + \tilde{q}]}{K_{\mathrm{b}2} + K_{\mathrm{s}2}}. \tag{9}$$

[4] Our main proposition requires that the total transaction cost increases with the number of shares traded. This is consistent with most theoretical models, in which it is typical to assume that transaction costs are proportional to the number of shares traded (e.g., Dumas and Luciano, 1991). It also is consistent with empirical evidence, e.g., Brennan and Chordia (1993). As discussed in Section 3.2, the results change if the transaction cost consists only of a fixed, or lump-sum, component.

Trading volume at date 2 for these two investors is equal to the expected net change in the buyer's (or the seller's) holdings, $|\widetilde{D}_{b2} - \widetilde{D}_{b1}|$. By assumption, investor b is the buyer, so $\widetilde{D}_{b2} - \widetilde{D}_{b1}$ is necessarily non-negative. This (non-essential) assumption allows us to define volume more simply as $\widetilde{D}_{b2} - \widetilde{D}_{b1} (= |\widetilde{D}_{s2} - \widetilde{D}_{s1}|)$. Using a procedure similar to that used to derive Eq. (9), we derive the following expression for $\widetilde{D}_{b1}$:

$$\widetilde{D}_{b1} = K_{b1} \frac{[(\tilde{u}_{b1} - \tilde{u}_{s1})K_{s1} + \tilde{q}]}{K_{b1} + K_{s1}}. \tag{10}$$

$\widetilde{D}_{b1}$ is the amount of the risky asset acquired in period 1 by the investor who will become the buyer in period 2. [5] By assumption, transaction costs arise and affect trading only at date 2. Hence, the expression for $\widetilde{D}_{b1}$ in Eq. (10) does not include a transaction cost term. Including a transaction cost at date 1 complicates our discussion, but does not affect our main conclusions.

The date 2 volume of trade between these two investors is $V_2 = \widetilde{D}_{b2} - \widetilde{D}_{b1}$. Then, substituting from Eqs. (9) and (10):

$$V_2 = \max(W[Y + Z] - X, 0) \tag{11}$$

where

$$W = \frac{(K_{b1} - K_{s1})n}{K_{b1} + K_{s1} + 2n} \quad \text{(reflecting investors' prior information and announcement precision);}$$

$$Y = \tilde{y}_2 - \frac{\tilde{u}_{b1}K_{b1} + \tilde{u}_{s1}K_{s1}}{K_{b1} + K_{s1}} \quad \text{(reflecting the information surprise);}$$

$$Z = \frac{\tilde{q}}{K_{b1} + K_{s1}} \quad \text{(reflecting environmental noise);}$$

and

$$X = (2x)\frac{(K_{b1} + n)(K_{s1} + n)}{K_{b1} + K_{s1} + 2n} \quad \text{(reflecting the effect of transaction costs).}$$

The expression for V_2 is similar to Kim and Verrecchia's (1991, p. 312) expression for trading volume, except Eq. (11) includes the transaction cost term X. Trading volume in Eq. (11) is the Kim and Verrecchia trading volume *less* the friction effect X caused by transaction costs.

The interpretations of the non-transaction cost terms in Eq. (11) are the same as those in Kim and Verrecchia (1991). W, and therefore V_2, is positively related to the extent to which the buyer and seller are differentially informed in the prior period. V_2 also is positively related to Y, which measures the surprise contained in the public

[5] To repeat, our identification of this investor as the date 2 buyer is arbitrary and does not drive the results. If $D_{s2} > D_{b2}$, we would simply redefine investor s as the buyer and switch our notation.

announcement $\tilde{y}_2$, and to Z, which reflects the noise introduced by the uncertain total quantities available for trade.

By assumption, trading volume at date 2 is non-negative. In the absence of transaction costs, this implies that $W[Y+Z]$ is non-negative. Fortunately, this condition is consistent with an intuitive explanation of Eq. (11). When the information surprise is positive ($Y>0$), investor b is the buyer at date 2 because his or her precision is higher ($K_{b1}>K_{s1}$), implying that W also is positive. Conversely, when the information surprise is negative ($Y<0$), investor b is the buyer because his or her precision is lower ($K_{b1}<K_{s1}$), implying that W is negative. Thus, W and Y always have the same sign. Our assumption that trading volume is non-negative therefore rules out only such idiosyncratic situations as when W and Y are negative and $Z>|Y|$.

The variable n reflects the precision of the public signal at date 2. The partial derivative of V_2 with respect to n is

$$\frac{\partial V_2}{\partial n}=\frac{(K_{b1}+K_{s1})(K_{b1}-K_{s1})}{(K_{b1}+K_{s1}+2n)^2}[Y+Z]-(2x)\frac{(K_{b1}+n)^2(K_{s1}+n)^2}{(K_{b1}+K_{s1}+2n)^2}. \tag{12}$$

As discussed above, when $(K_{b1}-K_{s1})>0$, Y also is positive, and when $(K_{b1}-K_{s1})<0$, Y is negative. Then, by the assumption of non-negative trading volume, $Z<|Y|$ and the first term on the right-hand side of (12) is positive. This indicates that, when transaction costs are absent, trading volume increases with the announcement's precision – just as implied by the Kim and Verrecchia (1991) model. The second term on the right-hand side, however, is negative. It increases in magnitude with the size of the transaction cost x. Thus, *with costly trading*, the relation between trading volume and the precision of the public signal is not in general monotonically positive. For some transaction cost and precision levels, the second term in (12) dominates and information precision is negatively related to trading volume.

Inspection of Eq. (12) indicates that the cross-partial derivative, $\partial V_2/\partial n\,\partial x$, is negative. This implies that increased precision in the public announcement leads to lower trading volume particularly when the transaction cost is high. A decrease in transaction cost therefore will have a much larger impact on the trading volume reaction to precise announcements than on imprecise announcements. We discuss the empirical implications of this result in Section 5.

3. Trading volume when investors interpret the signal differently

3.1. A different information environment

Our central proposition is that transaction costs fundamentally change the relation between trading volume and the precision of investors' information. Eq. (12) illustrates the effect of transaction costs within a theoretical framework that is similar to that of Kim and Verrecchia's (1991) model, in which investors' prior expectations and precisions can be heterogeneous and they observe identical signals. The role of transaction costs is not limited to this one type of information environment, however. In this section we illustrate our central proposition in a framework in which investors' prior expectations and precisions are homogeneous and their posterior beliefs differ because they receive different signals. This is the same as the information environment assumed in the Holthausen and Verrecchia (1990) model. [6]

In addition to helping us illustrate the general nature of the role transaction costs play, this alternative information environment has a pedagogic advantage as well. The analytical results are simple enough to illustrate with a numerical example. [7]

3.2. A numerical example

Consider two traders at date 2, s and b. Each has six units of the asset and risk tolerance equal to one. To emphasize that our result does not depend on differential informedness, we assume that the precision of each investor's private information is identical, $K_{s2} = K_{b2} = 0.50$. The investors have homogeneous prior expectations, but each has received different idiosyncratic information, so $\tilde{u}_{s2} \neq \tilde{u}_{b2}$. In creating our example, we use Barron's result (1993, see Appendix D on page 91) that the resulting expected dispersion in investor expectations equals $2\{(1-d)/(\pi K)\}^{1/2}$, where K is the average of the two investors' information precision, $K = K_{s2} = K_{b2}$, and d is the proportion of the investors' total precision that comes from the commonly interpreted portion of investors' information (or consensus), $d = (n_1 + n)/K$. In our example, we let $d = 0.6$ and arbitrarily disperse expectations around a mean price of 14. With $K = 0.5$, the expected dispersion in investor expectations is 1.01, implying $\tilde{u}_{s2} = 13.495$ and $\tilde{u}_{b2} = 14.505$. Eq. (5) therefore implies that the demands are

$$\widetilde{D}_{s2} = 0.5[13.495 - \tilde{p}_t], \tag{13a}$$

$$\widetilde{D}_{b2} = 0.5[14.505 - \tilde{p}_t]. \tag{13b}$$

Since b has a higher reservation price than does s at current holdings, b is the buyer and s the seller. At prices above 13.495, s is willing to sell shares; her transaction supply and investor b's transaction demand are illustrated in Fig. 1. With no transaction costs, the transaction supply and demand intersect at a price of 14 and a quantity of 0.2523 units. (Since our analysis – like many traditional models of trade – involves a bilateral monopoly, we cannot determine the exact prices at which trades occur. We can assert, however, that gains from trade exist, and that in the absence of strategic gaming considerations that could produce a perverse result, investor s will trade 0.2523 units of the asset to investor b.)

With no transaction costs, an increase in investors' informedness increases the volume of trade. Suppose that the investors' precision levels are $K_{s2'} = K_{b2'} = 1.5$ instead

[6] In a different paper, Kim and Verrecchia (1997) examine trading when investors' prior expectations differ *and* heterogeneous information is conveyed to them at the announcement. Our central proposition can be shown to hold in this environment as well.

[7] For a more complete discussion of the role of transaction costs in this information environment, see Barron (1993, pp. 38–51).

of 0.5, i.e., each trader now has increased certainty that his or her conditional valuation of the asset is correct. Continuing to assume that the ratio of the precision of public information to the traders' total information is 0.6 for both traders, the reservation prices change to $\tilde{u}_{s2'} = 13.709$ and $\tilde{u}_{b2'} = 14.291$. Again borrowing from Eq. (5), the new demands are

$$\widetilde{D}_{s2'} = 1.5[13.709 - \tilde{p}_t], \tag{14a}$$

$$\widetilde{D}_{b2'} = 1.5[14.291 - \tilde{p}_t]. \tag{14b}$$

The corresponding transaction demand and supply are illustrated by the dashed lines in Fig. 1. Solving for the quantity traded, we get a trading volume of 0.4369, an amount greater than when $K = 0.5$. This is exactly the effect on trading volume that is implied by the Holthausen and Verrecchia (1990) model. Intuitively, the increased precision causes investors' expectations to be less divergent, because precise information draws all investors' expectations closer to the actual payoff. But the increased precision also causes each investor to become more confident in his or her conditional valuation, encouraging each to take a greater speculative position. This latter effect predominates, and the net effect is to increase trading volume.

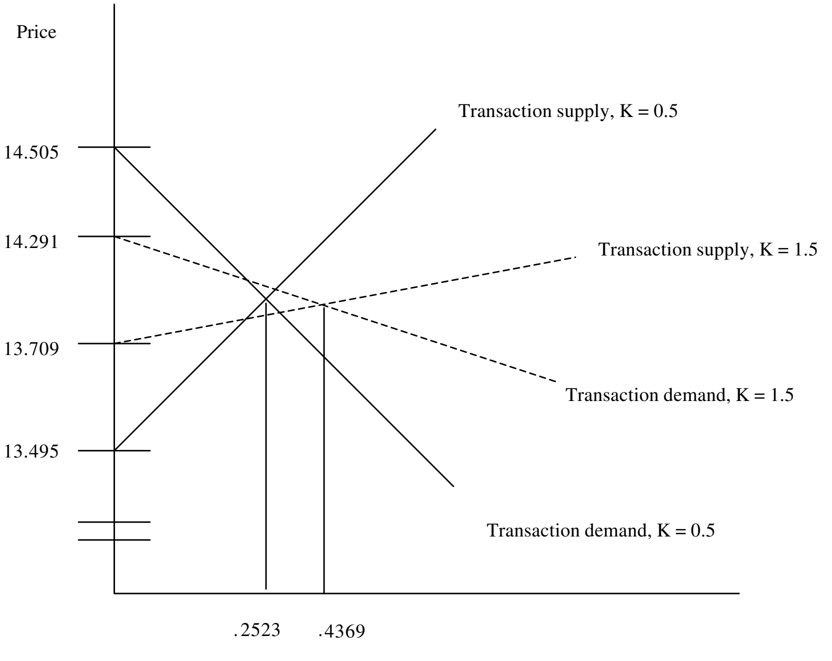

Fig. 1. Illustration of the effect on trading volume of an increase in informedness with zero transaction costs. The solid lines illustrate the transaction supply and demand with low levels of informedness ($K = 0.5$). With an increase in informedness ($K = 1.5$) and no transaction costs, the transaction demand and supply shift as illustrated by the dashed lines. The amount traded *increases* from 0.2523 to 0.4369.

Now consider the effect of a transaction cost imposed on each party of, say 0.25 dollar per unit traded. Eqs. (6a) and (6b) imply that with the original (low) precision levels, the demands, net of transaction costs, become

$$\widetilde{D}_{b2} = 0.5[14.505 - (\tilde{p}_t + 0.25)], \tag{15a}$$

$$\widetilde{D}_{s2} = 0.5[13.495 - (\tilde{p}_t - 0.25)]. \tag{15b}$$

The associated transaction supply and demand curves are illustrated by the solid lines in Fig. 2. With transaction costs, s will transfer only 0.1273 units of the asset to b. The gains from further trade are outweighed by the transaction costs. Thus, compared to the original scenario illustrated in Fig. 1, transaction costs lower the trading volume.

The important point, however, is that transaction costs change the effect of an increase in information precision. Assume positive transaction costs and that the announcement causes an increase in informedness such that $K_{s2'} = K_{b2'} = 1.5$. The demands become

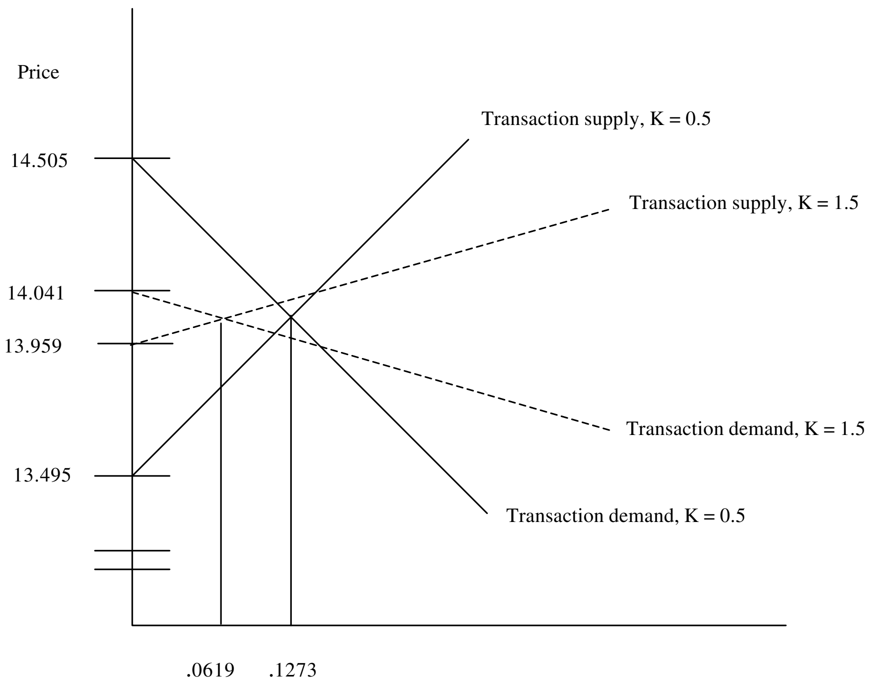

Fig. 2. Illustration of the effect on trading volume of an increase in informedness with positive transaction costs. The solid lines illustrate the transaction supply and demand with a low level of informedness ($K = 0.5$). With an increase in informedness ($K = 1.5$) and transaction cost of 0.25, the transaction demand and supply shift as illustrated by the dashed lines. The amount traded *decreases* from 0.1273 to 0.0619.

$$\widetilde{D}_{s2'} = 1.5[13.709 - (\tilde{p}_t - 0.25)], \tag{16a}$$

$$\widetilde{D}_{b2'} = 1.5[14.291 - (\tilde{p}_t + 0.25)]. \tag{16b}$$

The associated transaction demands are illustrated as dashed lines in Fig. 2. Now the amount traded *decreases* to 0.0619.

The table below summarizes this numerical example. With zero transaction costs, the higher precision increases trading volume, as illustrated in Fig. 1. With positive transaction costs, the higher level of precision decreases trading volume, as illustrated in Fig. 2.

Combined effects of information precision and transaction costs on trading volume

	Zero transaction costs	Positive transaction costs
Low informedness ($K = 0.5$)	Volume = 0.2523	Volume = 0.1273
High informedness ($K = 1.5$)	Volume = 0.4369 (*this is higher than when* $K = 0.5$)	Volume = 0.0619 (*this is lower than when* $K = 0.5$)

The combined effects of information precision and transaction costs are evident by comparing the transaction supply and demand curves in Figs. 1 and 2. Increased precision increases the price elasticity of both the supply and demand. This occurs because each trader becomes more certain about his or her conditional valuation of the asset, and is willing to take larger speculative positions. Without transaction costs, such willingness causes an increase in trade. This is why Holthausen and Verrecchia's (1990) model implies that increased information precision increases trading volume. [8]

With transaction costs, however, the higher precision represented in Fig. 2 is associated with lower trading volume. This is because the higher precision level decreases the difference between the traders' conditional pricing functions, decreasing the differences between both the slopes and intercepts of the transaction supply and demand curves. The highly informative public announcement causes greater consensus among traders about the asset's value and decreases the gain from trade. With a lower gain from any one trade, a positive transaction cost is more likely to become a constraint to trade. In our numerical example some trade occurs, but at a lower volume than without transaction costs.

3.3. Lump-sum transaction costs

Things change somewhat when transaction costs are paid in a lump sum rather than in proportion to the number of units transacted. With a lump-sum transaction cost, the outcome is a bang–bang solution: Either no trading will occur, or the number of

[8] In Holthausen and Verrecchia's words, "[A]gents' demands become more extreme as agents become more knowledgeable" (1990, p. 203). Note that, even though the information environment differs, the intuition applies also to the Kim and Verrecchia (1991) model.

units traded will be the same as if there were no transaction costs. No trades will occur if the total gain from trade is less than the lump-sum transaction cost. If the total gain from trade exceeds the lump-sum cost, the buyer and seller receive smaller surpluses than otherwise, but arrange a trade that equates their marginal values of the asset.

With a lump-sum transaction cost, the effect of information precision on trading volume is indeterminate. The potential gain from trade is represented by the area between the transaction supply and demand curves in Figs. 1 and 2. This gain is affected by the precision of investors' information. If an increase in precision decreases the gain from trade such that it becomes smaller than the lump-sum cost, no trading will occur. In such a case the increased information precision decreases trading volume. If, on the other hand, the increased precision increases the gain from trade, the existence of a lump-sum trading cost has no effect on trades that otherwise would occur. The increased precision also can make possible some trades that previously were prohibited entirely by the lump-sum transaction cost, thus increasing trading volume.

4. Related research

Ours is not the first model in which the relation between volume and precision is not monotonically positive. In models by Grundy and McNichols (1989) and Kim and Verrecchia (1991), for example, the relation is monotonically positive except when investors' idiosyncratic beliefs have identical precisions. In such cases the public announcement's precision does not matter because identical private precisions imply that no trade will occur anyway. This singular result, however, is completely different from ours. We allow heterogeneous precisions and examine the effect on trading volume of marginal changes in the public signal's precision.

A related model that considers information precision, trading volume, and transaction costs is by George et al. (1994). In this model, public announcements cause investors' beliefs to converge, which by itself causes a decrease in trade. The convergence, however, is offset by a decrease in the adverse selection component of the bid–ask spread, which lowers transaction costs. George et al. (1994) conclude that this latter effect dominates, stating that, "Both our model and existing models of volume predict heavy volume in response to events that resolve uncertainty..." (p. 1500).

As we have shown, however, the empirical evidence suggests that "events that (most) resolve uncertainty" often prompt relatively *low* trading volume. (Or more precisely, trading volume is not monotonically and positively related to the precision of the information.) Hence, the George et al. (1994) does not explain the evidence regarding trading volume and precision. [9]

[9] Another difference is that the transaction cost in the George et al. (1994) model depends on the degree of information asymmetry among investors. The transaction cost in our analysis is exogenous. Other researchers, including George et al. (1991) in a different paper, find that most of the bid–ask spread consists of its exogenous components, i.e., order processing and inventory holding costs, and that the adverse selection component contributes only a small portion to the spread. This indicates that an exogenous transaction cost – as used in our analysis – captures a significant share of the actual costs of trade.

Demski and Feltham (1994) also examine theoretically the relation between characteristics of a public announcement and trading volume, and show that trading volume is non-monotonically related to the uncertainty reduction due to the announcement. Such reduction in uncertainty is affected by the announcement's precision, but it also reflects investors' pre-disclosure uncertainty. Accordingly, and as discussed by Demski and Feltham (1994, p. 15), this model does not isolate the relation between trading volume and announcement precision.

The prior result that is closest to ours is Kim and Verrecchia's (1994) prediction that expected trading volume around a public announcement is monotonically *decreasing* in the precision of the information commonly inferred from the announcement. This result arises because the incentives for informed traders to process a common signal into private information decreases with the precision of the common signal. Like our emphasis on transaction costs, Kim and Verrecchia's result recognizes that precise public announcements reduce the marginal (per share) benefits of informed trading. However, they do not examine the relation between trading volume and the total (i.e., both common and private) precision of announcement period information. Furthermore, the prediction that trading volume is monotonically decreasing in the announcement's precision is no more accurate than the more common assertion that volume is monotonically increasing in precision, as it is inconsistent with the results reported by Wasley (1996) and Gillette et al. (1999).

Our argument that transaction costs interrupt the widely accepted positive relation between volume and information precision is so simple that it is obvious once pointed out. We conjecture that this effect has not been discussed previously because it is difficult to incorporate transaction costs into rational expectations models in which investors learn from observing the security price. [10] In this paper we circumvent this modeling problem by analyzing situations that mimic the information environments of well-known rational expectations models, but focusing on trading volume instead of price formation.

5. Conclusions

Previous theoretical models (e.g., Kim and Verrecchia, 1991) predict that trading volume increases with the precision, or information content, of a public announcement. These models reflect the intuition that increased precision makes all traders more confident about their private valuations, encouraging greater speculative positions and higher trading volumes. Empirical researchers rely on this presumed relation between precision and trading volume when they use trading volume data to make inferences about the information content of certain public announcements.

[10] Transaction costs have not been completely ignored, however. For example, Ohlson (1989, p. 265) anticipates our argument with the following admonition: "I believe that any major innovations [in theoretical models of trade] must incorporate trading costs because such costs should place bounds on individuals' trading... With trading costs individuals have to consider the importance of information."

In this paper we show that the relation between information precision and trading volume is sensitive to transaction costs. Increased precision bolsters each investor's confidence in his or her private valuation, but it also homogenizes investors' beliefs and causes their demand-prices to converge. In a world of costless trading, highly precise announcements encourage investors to take extreme positions even though their valuations of the asset differ by small amounts. If trades are costly, however, any potential gains from trade can be swamped by transaction costs. At the extreme, highly precise announcements can cause very little trading because they cause investors' valuations to converge.

In their investigation of price changes and trading volume, Holthausen and Verrecchia (1990) propose that trading volume: (i) increases with an announcement's precision and (ii) decreases with investors' consensus about the information. Verrecchia (1981), demonstrates that, because of investors' heterogeneous risk tolerances, condition (ii) is neither necessary nor sufficient to generate trading volume. One way to think about our analysis is that, because of transaction costs, increases in investor precision (condition (i)) *also* are not sufficient to generate increased trading volume. Thus, care must be taken in deriving inferences from trading volume data about the precision of public announcements.

As pointed out in the introduction, our argument helps reconcile several otherwise puzzling empirical results involving the trading volume reactions to public announcements. Wasley (1996), for example, finds that the trading volume reactions to earnings forecast announcements from managers are not monotonic in the announcement precision. In particular, trading volume first increases, then *decreases* with the announcement precision. Wasley notes that this is inconsistent with the Kim and Verrecchia (1991) model. Our model, however, demonstrates that Wasley's results are consistent with an information environment that is similar to that of Kim and Verrecchia (1991), but when transaction costs are allowed to be positive.

Transaction costs also can explain the apparent discrepancy between empirical and experimental findings regarding the trading volume reactions to public announcements. Using data from an experimental market, Gillette et al. (1999) find that trading volume is positively correlated with the convergence of investors' forecasts following an announcement. Noting that convergence in investors' beliefs is a measure of an announcement's precision, Gillette et al. conclude that this result is consistent with the Kim and Verrecchia (1991) model. Using data from actual security markets, however, Ziebart (1990), Bamber et al. (1997), and Barron (1995), find that trading volume is *negatively* related to convergence in analysts' forecasts. Barron et al. (2003) find a negative relation even after controlling for the potentially confounding effects of changes in consensus.

The apparent discrepancy is attributable to differences in transaction costs. Gillette et al.'s experimental market has zero transaction costs. It yields results that are consistent with the Holthausen and Verrecchia (1990) and Kim and Verrecchia (1991) models because it mimics these models' zero-transaction cost environments. Empirical data from actual markets, however, yield a non-monotonic volume–precision relation because trades are costly in the real world.

Our analysis yields several implications for empirical tests. The fact that transaction costs differ across stocks implies that the sensitivity of trading volume reactions to the precision of public announcements also will differ cross-sectionally. For example, Stoll and Whaley (1983) and others report that transaction costs are inversely related to firm size. This implies that, holding constant the characteristics of the predisclosure information environment, trading volume will be less sensitive to the precision of public announcements regarding small firms (where transaction costs are large) than for public announcements regarding large firms.

A second empirical implication rests on the observation that the per-share cost of trading options typically is lower than that of trading in the underlying securities. When the cost of trading the underlying security is relatively high, a highly precise announcement will tend to generate little trading in the security, but may generate trading in the options market, where transaction costs are smaller. This implies that the ratio of the trading volume reaction in the options market to the trading volume reaction in the underlying asset market should be higher for precise public announcements than for less precise announcements.

Not only do transaction costs vary across firms, but they also vary across investors and have been declining rapidly over time, especially for small investors. Another empirical implication of our analysis is that the sensitivity of trading volume reactions to the precision of public announcements should be increasing over time, as transaction costs have decreased.

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Appendix A. Derivation of Eqs. (6a) and (6b)

This appendix demonstrates that Eqs. (6a) and (6b) represent the investors' gross demands when transaction costs are imposed only on traded units of the asset. Impose a cost x on changes in the investor's holdings at date 2. The buyer maximizes expected utility of wealth, $\widetilde{W}_{b3}$,

$$\widetilde{W}_{b3} = M_b + D_{b1}(\tilde{u} - p_1) + (D_{b2} - D_{b1})(\tilde{u} - (p_2 + x)). \tag{A.1}$$

At date 2, the expectation and variance of date 3 wealth are

$$u_{b3} = E(\widetilde{W}_{b3}) = M_b + D_{b1}(u_{b2} - p_1) + (D_{b2} - D_{b1})(u_{b2} - (p_2 + x)), \tag{A.2}$$

$$\sigma^2_{b3} = \frac{D^2_{b2}}{K_{b2}}. \tag{A.3}$$

With negative exponential utility, investor b maximizes by choice of D_{b2} the following function:

$$\exp\left\{u_{b3} - \frac{1}{2}\sigma_{b3}^2\right\}. \tag{A.4}$$

Substituting from (A.2) and (A.3), the first order condition for a maximum implies

$$u_{b2} - (p_2 + x) - \frac{D_{b2}}{K_{b2}} = 0, \tag{A.5}$$

which, rearranged, is Eq. (6a). A similar derivation holds for the seller, implying Eq. (6b). Thus, our definition of transaction cost is consistent with the costs affecting only the acquisition or sale of the asset.

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