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Price impacts of options volume ☆

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Abstract

The price impacts of signed options volume are investigated with transactions data for options and futures on the German DAX index. We find that signed options and futures trading have a significant contemporaneous price effect, and we investigate the source of the effect. The price impact of options volume has a temporary component, which implies the presence of a liquidity effect. On the other hand, the price impact of futures volume is largely permanent, which implies an information effect. We conclude that futures traders react more quickly to information about the index and that they, not the options traders, provide price discovery in the DAX. We also investigate the relation of options and futures volume and find that signed futures volume leads signed options volume, which suggests that the options traders are the followers not the leaders in price discovery. We investigate whether options or futures volume predict price changes and conclude that they do not.

Keywords: Price impacts; Options volume; Price discovery

1. Introduction

If all information were made public immediately and if quotes immediately adjusted to the information, trading would not convey information about securities' values, because trading would take place at quotes reflecting the information.

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Further, if markets were deep and liquid, trading would not put pressure on prices. Trading affects prices because it conveys information or because it puts pressure on the sources of liquidity. Insofar as trading conveys information, price effects are permanent. Purchases bring about permanent price increases and sales bring about permanent price decreases. Insofar as trading puts pressure on liquidity, price effects are temporary. In the absence of information, prices will revert to their original values after the liquidity shock has passed. If markets are efficient and deep, liquidity shocks will be small.

We investigate the price impacts of options and futures trading in a major stock index—the DAX, which is the German blue chip index of 30 stocks. We find that signed options and futures volumes have a contemporaneous effect on the DAX index price. This result implies that the index market is either not perfectly efficient informationally or not perfectly liquid or both. We let the data tell us the source of the effect by investigating whether the price effects are permanent or temporary. We find that the price effect of signed options volume has a temporary component, which implies the presence of a liquidity effect. On the other hand, the price effect of signed futures volume is largely permanent. We conclude that futures traders possess superior information about the index over and above the information reflected in the quotes, and that they, not the options traders, provide price discovery in the DAX. Since index traders, unlike traders in individual stocks, are unlikely to possess private information about stocks in the index, their informational advantage is more likely to be the speed with which they act on public information.

We also investigate the relation of options and futures volume and find that signed futures volume leads signed options volume, which suggests that the options traders are the followers and not the leaders in price discovery. We investigate whether signed options or futures volume predict price changes and conclude that they do not.

A number of prior studies have examined the price effects of options trading. Early studies, such as Manaster and Rendleman (1982) and Anthony (1988), suggest that the options market leads the stock market. However, the reliability of these results is subject to question because the data frequency is only daily. In this study, data is observed at five minute intervals.

In an excellent paper, Vijh (1990) finds that liquidity, as measured by the price impact of large options trades, is good but that bid–ask spreads in options are large. Vijh examines the price effect of options trading and concludes options trading conveys a small amount of information, but he does not consider lagged volume effects. In this paper, we consider lagged volume effects, which makes it possible to distinguish information and liquidity effects of trading. Stephan and Whaley (1990) find that stock prices lead options prices, which suggests that options are not the path by which new information is incorporated in price. Chan et al. (1993), however, raise some doubt about the findings of Stephan and Whaley by pointing out that the results could also be driven by price discreteness in the options market. These papers focus on the lead–lag relation between options prices and stock prices, whereas in this study we focus on the link between trading and prices.

Easley et al. (1998) (EOS), arguing that options are the instrument of choice for informed traders because they can get more bang for the buck, posit that signed options volume should predict stock price changes. Our analysis is in the spirit of EOS in that we examine the link between signed options volume and stock price change, but we focus on a stock index rather than on individual stocks. EOS conclude that negative options volume (buy puts or sell calls) and positive options volume (sell puts or buy calls) contain information for future stock price changes, consistent with their hypothesis that options traders are informed traders. However, the sign of the relation between stock price changes and signed options volume is counter to the information model. Under the information model, positive options volume should have a positive effect on stock price changes, but EOS find that stock price changes are negatively related to contemporaneous and lag-one positive options volume. Similarly stock prices react positively to negative options volume, rather than negatively as the information model would predict. EOS also find that lagged stock price changes are better at predicting signed options volume than lagged signed options volume is at predicting stock price changes. They conclude that this relation reflects hedging in response to price changes.

Chan et al. (2002) examine the interdependence of signed options volume, signed stock volume, options price changes and stock price changes in 14 stocks over 58 days in 1995. They conclude that options volume is not informative and that stock prices lead options prices, which is consistent with Stephan and Whaley (1991). Like EOS, they also find a counterintuitive negative relation between signed options volume and the contemporaneous stock price change. This could be related to data quality.

Cao et al. (2003) take a different approach to investigating the informational role of options. They investigate options volume prior to takeover announcements. They find that options volume increases and is informative prior to takeovers. Chakravarty et al. (2003) investigate the information share discovered in the options market compared to the stock market using the approach of Hasbrouck (1995).

A number of studies have examined the relation between liquidity or price effects in the stock market and signed trading imbalances in the stock market. Chordia et al. (2002) examine the impact of aggregate stock market imbalances on aggregate liquidity as measured by the aggregate bid-ask spread. Stoll (2000) examines the price impact of trading imbalances in individual stocks.

Our approach to the link between options trading and underlying asset price changes is more agnostic than most of the prior studies. Instead of presuming an informational link, we let the data tell us first whether trading is associated with a price effect and second whether the effect is the result of informed trading or of liquidity effects. We focus on options on the DAX index in 1998. Options on the DAX, which are traded on the Eurex, are ideal for our analysis because they are traded electronically with automatic execution. Consequently time stamps are accurate. Prior studies could not as accurately link options data with stock data. We use the nearby futures contract on the DAX to represent price movements in the index because the futures are also electronically traded on the Eurex and are very active. The underlying index itself is subject to infrequent trading of the component stocks, which can cause price changes in the index to be delayed. Electronic trading of the options and the futures contract also simplifies trade classification since transactions always take place at exactly the best current bid or ask.

Our analysis proceeds as follows. In the next section, an empirical model is specified, variables defined and alternative hypotheses specified. Data are described in Section 3. Empirical evidence on the price effects of signed volume are presented in Section 4. We find there is a contemporaneous price effect. In the case of options that effect has an important temporary component, indicating the presence of a liquidity effect, whereas in the case of futures that effect is permanent, consistent with the information hypothesis. While in the case of options, price effects are correlated with past volume when contemporaneous volume is included in the regression, the effect of lagged volume disappears when contemporaneous volume is excluded. The implication is that signed volume cannot be used to predict future price changes. In Section 5, the relation between signed options and signed futures volume is investigated using a vector autoregression approach. We find that futures volume leads options volume but that options volume does not lead futures volume. This volume transmission suggests, like the results for the price effect analysis, that the futures market, not the options market, is the source of price discovery. The conclusions are in Section 6.

2. Empirical model

We assess the price impact of trading in relation to trading imbalances measured in several ways. The dependent variable is always the five-minute change in the quote midpoint of the nearby DAX futures contract. By using the quote midpoint rather than the transaction price, we minimize the effect of the bid–ask bounce. The independent variables are current and lagged measures of trading imbalance. The imbalance is calculated for options and for futures and is disaggregated in a number of ways.

In order to calculate a trading imbalance, a trade must be signed, that is, it must be identified as a purchase or sale. We define a purchase if the transaction is at the ask, and a sale if the transaction is at the bid. On the automated Eurex system, all trades take place either at the ask or the bid. Hence we are able to sign trades with considerable more accuracy than is the case in US markets.[1]

In the futures contract, a trading imbalance is simply the difference between purchases (trades at the ask) and sales (trades at the bid). In options, puts and calls must be distinguished. Purchase of a call (at the ask) and sale of a put (at the bid)—a synthetic long position—is equivalent to buying the stock. We call this positive volume because the effect on price is expected to be positive. Sale of a call (at the bid) and purchase of a put (at the ask)—a synthetic short position—is equivalent to selling the stock short. We call this negative volume because the effect on price is

[1] Recent studies of the accuracy of trade classification include Lee and Radhakrishna (2000), Odders-White (2000), Finucane (2000), Ellis et al. (2000), and Bessembinder (2003).

expected to be negative. The imbalance is the difference between positive and negative volume.

To assess the price impacts of volume, we estimate a regression of the following form:

$$\Delta P_t = \alpha + \lambda_0 I_t + \sum_{i=1}^{6} \lambda_i I_{t-i} + e_t, \tag{1}$$

where ΔP_t is the change in the quote midpoint in the tth interval, and I_t the imbalance between positive and negative volume in interval t.

The coefficient λ_0 is the Kyle (1985) lambda measure of price impact.[2] On the basis of the current lambda (λ_0) and the lambda coefficients for lagged imbalances, we evaluate three hypotheses about the relation of price change and signed volume: the perfect markets hypothesis, the information hypothesis, and the liquidity hypothesis. The expected signs of the coefficients on current and lag one imbalances under the three hypotheses are specified in the following table (the signs of lag 2–6 are expected to be the same as the lag one sign):

Sign of coefficients in a regression of price change on current and lagged net positive volume

	Lag 0 (λ_0)	Lag 1 (λ_1)
Perfect market	0	0
Information	+	0
Liquidity	+	−

We define a perfect market as one in which all information is immediately made public to all market participants. In such a world, bids and offers would be changed in response to information, but trading would convey no additional information. Further, perfect markets are assumed to be deep and resilient such that there are no temporary price effects associated with illiquidity. In such a world, price change would not bear a systematic relation to volume, and the expected values of both λ_0 and λ_1 would be zero.

Alternatively, signed volume may convey information because certain traders are speedier in acting on public information than those traders setting quotes or because traders possess private information. In the case of an index like the DAX, we do not expect traders to possess private information as they might for individual stocks. More likely, certain traders are quicker to act on public information affecting the entire market. In such a world, net positive volume of speedy traders would have a positive price impact, and λ_0 would be positive. If the price effect of volume is purely informational, the price change would be permanent, which implies that lambdas on lagged volumes would be zero.

[2] Stoll (2000) finds a significant positive λ_0 for estimates based on daily imbalances and daily price changes in individual stocks.

The coefficient λ_0 is also expected to be positive under the liquidity hypothesis because positive volume pushes up prices so that sellers are induced to provide liquidity. The increase in prices is temporary. Prices return to normal as suppliers of liquidity unwind their inventory positions. The temporary nature of the price impact under the liquidity hypothesis implies a negative coefficient on lagged volumes. In other words, the information and liquidity hypotheses are distinguished by the sign of λ_1 (and coefficients on the other lagged values).

While our primary interest is in the price effects of options and futures volume, we also examine whether volume in one market is transmitted to the other. This analysis of volume links provides additional insight into the sources of price effects. Our empirical approach is to estimate a vector autoregressive system for signed volume in the options and index futures markets to determine if volume in one market leads volume in the other. The source of any volume transmission may be the hedging actions of dealers who supply liquidity. For example, a dealer who sells call options at the ask price to public buyers (positive volume in options) may seek to hedge the position by buying futures (positive volume in futures), an activity that leads to positive association of signed volumes. A similar positive association may result if traders in one market simply emulate traders in the other. Finally, a negative association of volumes may arise if arbitragers dominate the two markets. An arbitrager takes a long position in one market (positive volume) and a short position in another (negative volume). Our empirical analysis provides evidence on the extent to which volume is transmitted from one market to the other.

3. Data

The data used in this study come from the Eurex, the world's largest futures exchange as measured by contract volume. The Eurex is a fully electronic market in which traders post electronic bids and offers that automatically execute against incoming market orders. Due to this feature, we can classify all trades correctly as purchases or sales, which is important for the analysis in Section 4. Index contracts on the Eurex are very actively traded. For example, in 1998 roughly 30 million contracts were traded in DAX options. To put this in perspective it is useful to compare this number to the combined volume of equity options for all the 30 stocks in the DAX, which was 30.5 million contracts in 1998. For the DAX futures contract, close to 7 million contracts were traded in 1998. Over the years the trading volume has even increased further. In 2003, for example, 41.5 million and 27.2 million contracts were traded in DAX options and futures, respectively.

The data for the study are collected for each Wednesday in calendar 1998. By choosing Wednesdays we avoid expiration day effects and pricing anomalies associated with Mondays and Fridays. Each day is divided into five-minute intervals. The quote and price at the end of each five-minute interval are retained.

Volume is aggregated within each five-minute interval. In the case of DAX futures, the data are for the nearby futures contract. The futures contract represents a claim on 25 units of the underlying index. In the case of options, volume data are aggregated for all options on the index. Each options contract represents a claim on 10 underlying units of the index. Volume is divided into positive volume (buy volume) and negative volume (sell volume) for each security—futures, call option and put option—and aggregated over the five minute interval. Positive and negative volumes are defined as follows:

- *pfv* Positive futures volume. The total number of contracts in the 5 minute interval traded at the prevailing ask quote.
- *nfv* Negative futures volume. The total number of contracts in the 5 minute interval traded at the prevailing bid quote.
- *pov* $= vc_a + vp_b =$ positive options volume in the 5 minute interval, where vc_a is the number of call option contracts traded at the prevailing ask (volume of calls bought at the ask), and vp_b the number of put option contracts traded at the prevailing bid quote (volume of puts sold at the bid).
- *nov* $= vc_b + vp_a =$ negative options volume in the 5 minute interval, where vc_b is the number of call option contracts traded at the prevailing bid (volume of calls sold at the bid), and vp_a the number of put option contracts traded at the prevailing ask (volume of puts bought at the ask).

We follow EOS (1998) in the definition of positive and negative options volume (*pov* and *nov*).

Descriptive statistics for our sample are shown in Table 1. The midpoint quote changes for the nearby futures contract are symmetric around zero, with a median equal to 0 and a 5% (95%) quantile of -10.75 (10.5). For both puts and calls we find on average more sales than purchases in our data. For calls, on average 4.5 more contracts were sold than purchased per five minute interval, and for puts the average net volume is even more negative with a mean of -16 contracts in a typical interval.

It is interesting to note the wide range for net call and put volume with a difference between the 5% and the 95% quantile of roughly 1,600 (calls) and 1,800 contracts (puts). The data for positive and negative options volume are spread out similarly with a range of around 2,000 contracts between the 5% and the 95% quantile. Finally, both positive and negative futures volume average less than corresponding options volume—about 100 contracts per 5 minute interval, or 250 contracts in options equivalents (since the futures contract size is 2.5 times the option contract size) compared to more than 700 options contracts. The inter-quantile variation is also much less for futures than for options.

In our analysis we aggregate options volume over all options maturities and strike prices. Table 2 provides options trading statistics disaggregated by option maturity. Most of the volume is in the nearby maturity of zero to 30 days. The mean number of trades per 5 minute interval for the nearby maturity is slightly less than 4 trades on the ask side and 4 trades on the bid side for both calls and puts. The median is 3 trades. These means and medians are larger when the maturities are aggregated. For the nearby maturity, call volume averages 179.25 contracts on the ask side and 189.93 contracts on the bid side. Put volume is slightly higher.

Table 1
Descriptive statistics

ΔP is the change in midpoint DAX futures prices over five minute intervals, $vc_a - vc_b$ is the net number of call contracts purchased over five minute intervals, $vp_a - vp_b$ is the analogous number for put options, *pov* is positive options volume (defined as volume of calls purchased plus volume of puts sold), *nov* is negative options volume (defined as volume of calls sold plus volume of puts purchased), *pfv* is positive futures volume (number of futures contracts purchased), *nfv* is negative futures volume (number of futures contracts sold). The sample size is 4,795 observations.

Variable	Mean	Median	Std. dev.	5% Quantile	95% Quantile
ΔP	−0.13	0	6.78	−10.75	10.50
$vc_a - vc_b$	−4.51	−1	599.05	−797	757
$vp_a - vp_b$	−15.94	−3	602.39	−917	865
pov	734.95	527	748.06	53	2,129
nov	723.51	513	744.31	64	2,040
pfv	99.90	85	72.64	15	230
nfv	100.06	84	90.21	14	237

Table 2
Options trading characteristics by type of option and option maturity

Summary data for five-minute data intervals.

	Call options			Put options		
	Days to maturity			Days to maturity		
	0–30	30–60	> 60	0–30	30–60	> 60
Mean per interval						
No. of trades at ask	3.84	1.61	0.67	3.95	2.07	0.73
No. of trades at bid	3.94	1.42	0.60	4.02	1.72	0.69
Volume at ask	179.25	81.52	35.87	198.05	104.09	42.18
Volume at bid	189.93	77.95	34.57	216.98	90.20	47.63
Median per interval						
No. of trades at ask	3	1	0	3	1	0
No. of trades at bid	3	1	0	3	1	0
Volume at ask	75	10	0	90	20	0
Volume at bid	81	5	0	96	10	0
Fraction intervals with zero volume						
At ask	0.12	0.37	0.59	0.12	0.30	0.59
At bid	0.11	0.40	0.62	0.10	0.34	0.61
At both bid and ask	0.02	0.19	0.41	0.02	0.14	0.40

When aggregated over all maturities, the volume figures are larger, as reflected in Table 1. The fraction of intervals with no trade in the nearby option is only 0.02. Since we combine all option maturities and strikes, the fraction of intervals without an option trade is less than 2%—virtually every interval has at least one option trade.

4. Price effects

4.1. Estimation procedure

The estimation of the price impacts of options and futures trading is based on a regression of the following form:

$$\Delta P_t = \alpha + \lambda_0^+ v_t^+ + \lambda_0^- v_t^- + \sum_{i=1}^{6} \lambda_{t-i}^+ v_{t-i}^+ + \sum_{i=1}^{6} \lambda_{t-i}^- v_{t-i}^- + e_t, \tag{2}$$

where ΔP_t is the change in the DAX futures midquote over the 5 minute interval, v_t^+ the positive (buy) volume in 5 minute interval t, and v_t^- the negative (sell) volume in 5 minute interval t.

Note that in estimating (2) all lags are within the day. No lags are taken across days. Three alternative volume variables are used in estimating Eq. (2) (two for options and one for futures)

1. $v_t^+ = vc_{at} - vc_{bt}, \quad v_t^- = vp_{at} - vp_{bt}$ (Net calls purchased, net puts purchased)
2. $v_t^+ = pov_t = vc_{at} + vp_{bt}, \quad v_t^- = nov_t = vc_{bt} + vp_{at}$ (Positive options volume, negative options volume)
3. $v_t^+ = pfv_t, \quad v_t^- = nfv_t$ (Positive futures volume, negative futures volume).

Note also that the total net volume of definition 1 and 2 are the same: net calls purchased minus net puts purchased is the same as positive minus negative options volume [that is, $(vc_{at} - vc_{bt}) - (vp_{at} - vp_{bt}) = (vc_{at} + vp_{bt}) - (vc_{bt} - vp_{at})$]. However, it does matter which pair of variables (plus the respective lags) is used in a regression model, since each pair represents a different restriction on the coefficients. For example, using positive options volume as a variable in the regression is equivalent to imposing the restriction of equal regression coefficients for calls purchased and puts sold. On the other hand, using net calls purchased as a regressor amounts to restricting the coefficients for calls purchased and calls sold to be equal in magnitude, but of opposite sign. The goodness of fit of the two regressions can then serve as an indication for which of the two types of restrictions is more binding.

Since we are using high frequency data, it is important to make sure that there is no systematic component left in the time series of midpoint futures price changes. Using midpoint quotes eliminates the bid–ask bounce automatically; we nevertheless regress the midpoint quote changes on six of its own lags to check if price changes are actually unpredictable from their own history. The results in Table 3 indicate that successive price changes are uncorrelated up to a time span of thirty minutes. None of the individual coefficients for lagged midpoint changes is statistically significant,

Table 3
White noise test for futures price changes

ΔP is the change in midpoint DAX futures prices over successive five minute intervals, and ΔP_{-i} is the ith lag ($i = 1, \ldots, 6$). The coefficients shown in the table are for the regression of midpoint quote changes on a constant and six of its own lags. The sample size is 4,795 observations.

Variable	Coefficient	t-statistic
ΔP_{-1}	0.014	0.96
ΔP_{-2}	–0.018	–1.20
ΔP_{-3}	–0.022	–1.53
ΔP_{-4}	–0.010	0.66
ΔP_{-5}	–0.009	0.64
ΔP_{-6}	0.006	0.42
F-value: 0.985		

and also the F value for the complete regression is far from being significant at conventional levels.

4.2. Main findings

The main findings of the paper are in Table 4. The table presents the results of three regressions in which the price change in the DAX index futures is regressed against current and lagged signed volume defined in the three ways discussed above. Data for all five minute intervals for all Wednesdays in 1998 are pooled in these regressions. In the first regression, net call volume and net put volume are the volume variables. Net calls purchased have a significant contemporaneous positive effect on futures prices. A net purchase of 1,000 call contracts results in an immediate price increase of 3.13 index points. Similarly, a net purchase of puts has a significant negative contemporaneous effect with a coefficient at lag 0 of -2.83.

Besides these contemporaneous effects, net call and net put volume also have an important impact on price changes in later intervals. An increase in net call volume in a five minute interval causes (ceteris paribus) a decrease in the midpoint futures quote by around 0.37 index points in the next interval; that is, about twelve percent of the initial price change is reversed over the next interval. This partial reversal is also observed for net put volume with a coefficient of 0.583 at lag 1, which means that about one fifth of the initial price movement is reversed over the next five minutes. The sum of the lag coefficients on net call volume is -1.03, which implies that about one-third of the contemporaneous price effect of 3.13 is reversed in the subsequent 30 minutes. The sum of the lag coefficients on net put volume is 1.03, which implies that about one-third of the contemporaneous price effect of -2.83 is reversed in the subsequent 30 minutes. In the case of net put volume, even the second lag exhibits a significant positive coefficient, which implies that the reversal continues for at least another five minutes.

Table 4
Price impacts of signed options and futures volume

The dependent variable is the five- minute change in the midpoint quote of the near-term DAX futures contract. The independent variables are alternative volume measures, each stated in 1,000 contracts. Coefficients thus represent the price effect per thousand contracts. The volume measures are as follows: vc_a-vc_b is the net number of call contracts purchased over five minute intervals, vp_a-vp_b is the analogous number for put options, $(vc_{at}+vp_{bt})$ is positive options volume, which is equal to the volume of calls purchased plus volume of puts sold, $(vc_{bt}+vp_{at})$ is negative options volume, which is equal to the volume of calls sold plus volume of puts purchased, *pfv* is positive futures volume (number of futures contracts purchased), *nfv* is negative futures volume (number of futures contracts sold). Numbers below coefficient estimates are *t*-statistics. The sample size is 4,795.

	Regression 1: on net call and net put volume		Regression 2: on positive and negative options volume		Regression 3: on positive and negative futures volume	
	$(vc_{at}-vc_{bt})$	$(vp_{at}-vp_{bt})$	$(vc_{at}+vp_{bt})$	$(vc_{bt}+vp_{at})$	*pfv*	*nfv*
Lag 0	3.13	−2.83	2.82	−3.15	27.46	−19.37
	20.43	18.59	21.70	−24.21	18.45	−16.85
Lag 1	−0.373	0.583	−0.548	0.409	−2.090	−0.961
	−2.38	3.79	−4.08	3.06	−1.36	−0.82
Lag 2	0.024	0.413	−0.267	0.143	0.508	−0.999
	0.15	2.68	−1.98	1.06	0.33	−0.85
Lag 3	−0.249	−0.033	−0.046	0.154	−0.681	−1.280
	−1.58	−0.21	−0.34	1.13	−0.44	−1.09
Lag 4	−0.159	0.065	−0.125	0.106	0.994	0.390
	−1.00	0.41	−0.92	0.78	0.64	0.33
Lag 5	0.092	0.004	−0.103	−0.006	−0.109	−1.550
	0.59	0.02	0.76	−0.04	−0.07	−1.33
Lag 6	−0.365	0.002	−0.233	0.149	−1.040	−1.310
	−2.34	0.16	−1.75	1.11	−0.69	−1.13
Intercept	−0.146		0.207		−0.132	
	−1.62		1.03		−0.56	
Adj R^2	0.1609		0.1607		0.0957	
Sum of lags 1–6	−1.03	1.03	−1.32	0.955	−2.04	−5.71

Similar results are found in regression 2 in which positive and negative options volumes are the right-hand side variables. Positive options volume of 1,000 contracts is associated with a futures price increase of 2.82 index points, and negative options volume is associated with a futures price decrease of −3.15. These magnitudes are comparable to those for net call and net put volume in regression 1. Again, there is evidence of a reversal as the lagged coefficients have signs opposite the contemporaneous coefficient. Lagged positive options volume is significant at lags one and two. Lagged negative options volume is significant at lag 1. The sum of the lag coefficients implies that about $\frac{1}{3}$ of the contemporaneous effect is reversed in a half-hour.[3]

In regression 3, the relation between futures price change and signed futures volume is examined. Whereas lagged signed options volume is statistically significant in regressions 1 and 2, this is not the case for lagged signed futures volume. Here only the contemporaneous coefficient is significant. Positive futures volume is associated with a contemporaneous increase in futures prices of around 27 index points per 1,000 contracts. In an analogous fashion the sale of 1,000 futures contracts leads to a contemporaneous decrease in futures prices of 19 index points over a typical five-minute interval. Coefficients of lagged (positive and negative) futures volume exhibit varying signs and are not statistically significant.

What can one conclude from the regression results in Table 4? First, options and futures trading have a significant contemporaneous price effect. Buying calls or futures pushes DAX futures prices up, and buying puts or selling futures pushes DAX futures prices down. The relation is highly significant. On the basis of these results, the perfect markets hypothesis, which holds that prices and signed volume are unrelated, is rejected in favor of either the information effect or the liquidity effect. Second, on the basis of the negative and significant coefficient on the lagged options volume, we conclude that options trading reflects a liquidity effect, at least in part. The fact that the price effect of options trading is reversed by one third within a half- hour implies that some of the effect is the result of liquidity factors. The balance of the price effect represents informational effects or liquidity shocks that take longer than 30 minutes to reverse. Third, the fact that little of the price effect of futures trading is reversed suggests that the impact of contemporaneous futures volume is largely informational. This is contrary to expectations that options trading would be based on information to a greater degree than would trading in futures. Fourth, the contemporaneous effect of options trading is not as great as that of futures trading. For example, the contemporaneous effect of positive options volume of 1,000 contracts has an effect of 2.82 index points compared with an effect of 27.46 index points for positive futures volume. Part of this difference is due to the fact that the

[3] Our results for the DAX index contrast to those of EOS (1998) for individual stocks. They run separate regressions for positive and for negative volume (their Tables VII and VI)

$$\text{Positive volume} \;\; \Delta P_t = \lambda_0^+ v_t^+ + \sum_{i=1}^{6} \lambda_{t-i}^+ v_{t-i}^+ + e_t,$$

$$\text{Negative volume} \;\; \Delta P_t = \lambda_0^- v_t^- + \sum_{i=1}^{6} \lambda_{t-i}^- v_{t-i}^- + e_t.$$

They find that $\lambda_0^+ < 0$ and $\lambda_0^- > 0$, contrary to the view that options traders are informed investors who push prices up if they buy and push prices down if they sell. Their results may be due to the fact that they run separate regressions for positive and negative options volume, thereby failing to control for potentially offsetting volume effects. Also their data are from 1990, when reporting of trade prices may not have been sufficiently accurate to allow classification into 5 minute intervals. As we do, EOS find that lagged coefficients have opposite signs, implying that lag-one price effects tend to be reversed. Such reversals would not occur if the lag 0 effects were informational.

futures contract size is 25 times the value of the underlying index whereas the option contract size is 10 times the underlying index. But even after adjusting for this difference, the size of the effect of futures trading exceeds that of options trading.

4.3. Prediction

One might be tempted to infer that the significant coefficient on the lag-one net options volume variable in Table 4 implies that price changes can be predicted. However, this need not be the case. In Table 4, the coefficient is estimated conditional on knowing the contemporaneous volume, something that would not be known prior to period zero. To determine if lagged signed volume predicts future returns, we rerun the regressions of Table 4 without the contemporaneous signed volume variable. The results, in Table 5, indicate that lagged volume has no predictive power. None of the lag-one volume variables is significant, and the adjusted R^2 of the regressions is zero. Thus a prediction rule, such as buy calls/sell puts if there is positive options volume this period, would not be profitable without knowing next period's volume. Professional traders may possess such information, but the typical investor does not.

4.4. Correlation of futures and options volume

It is possible that the price effect of options volume is not separate from the price effect of futures volume. If options volume and futures volume are highly correlated, the observed effect of options volume on futures prices may simply reflect the correlation with futures volume. Table 6 shows that the contemporaneous correlation of options and futures volume is not high. The correlation of positive options volume (*pov*) and positive futures volume (*pfv*) is 0.187, and the correlation for the corresponding negative volumes is 0.173. These relatively low correlations make it unlikely that the effect of options trading is simply a substitute for futures trading.

To assess the separate effects of options and futures volume more explicitly, we regress the futures price change on options and futures volume. We focus on *net* positive options volume, *npov*, and *net* positive futures volume, *npfv*. These are defined more precisely as follows:

$$npov = pov - nov,$$

$$npfv = pfv - nfv,$$

npov measures the extent to which positive options volume (buy call or sell put) exceeds negative options volume (sell call, buy put). Similarly *npfv* measures the extent to which positive futures volume (buy futures) exceeds negative futures volume (sell futures). The result of regressing the futures price change on current and lagged values of *npov* and *npfv* are in Table 7. As expected, and consistent with the results in Table 4, these results indicate that contemporaneous options and futures volume have independent effects on the futures price. Positive volume in either

Table 5
Price impacts of lagged signed options and futures volume excluding contemporaneous volume

The dependent variable is the five-minute change in the midpoint quote of the near-term DAX futures contract. The independent variables are alternative lagged volume measures, each stated in 1,000 contracts. Coefficients thus represent the price effect per thousand contracts. The volume measures are as follows: vc_a-vc_b is the net number of call contracts purchased over five minute intervals, vp_a-vp_b is the analogous number for put options, $(vc_{at}+vp_{bt})$ is positive options volume, which is equal to the volume of calls purchased plus volume of puts sold, $(vc_{bt}+vp_{at})$ is negative options volume, which is equal to the volume of calls sold plus volume of puts purchased, *pfv* is positive futures volume (number of futures contracts purchased), *nfv* is negative futures volume (number of futures contracts sold). Numbers below coefficient estimates are *t*-statistics. The sample size is 4,795.

	Regression 1: on net call and net put volume		Regression 2: on positive and negative options volume		Regression 3: on positive and negative futures volume	
	$(vc_{at}-vc_{bt})$	$(vp_{at}-vp_{bt})$	$(vc_{at}+vp_{bt})$	$(vc_{bt}-vp_{at})$	*pfv*	*nfv*
Lag 1	−0.017	0.149	−0.147	0.029	1.500	−1.550
	−0.10	0.89	−1.02	0.20	0.95	−1.28
Lag 2	0.139	0.365	−0.193	0.044	1.340	−0.784
	0.81	2.17	−1.31	0.30	0.83	−0.64
Lag 3	−0.236	−0.075	−0.073	0.071	0.497	−1.840
	−1.37	−0.44	−0.50	0.48	0.31	−1.50
Lag 4	−0.095	0.154	−0.175	0.088	1.610	0.888
	−0.55	0.90	−1.18	0.60	0.99	0.72
Lag 5	0.172	0.049	0.133	−0.005	−0.695	−1.320
	1.00	0.28	0.90	−0.03	−0.43	−1.08
Lag 6	−0.368	−0.031	−0.226	0.109	−1.060	−1.200
	−2.16	−0.18	−1.56	0.75	−0.67	−0.99
Intercept	−0.120		0.126		0.131	
	−1.22		0.59		0.54	
Adj R^2	0.0007		−0.0004		−0.0001	

Table 6
Correlations between contemporaneous volume variables

vc_a-vc_b is the net number of call contracts purchased over five minute intervals, vp_a-vp_b is the analogous number for put options, *pov* is positive options volume (defined as volume of calls purchased plus volume of puts sold), *nov* is negative options volume (defined as volume of calls sold plus volume of puts purchased), *pfv* is positive futures volume (number of futures contracts purchased), *nfv* is negative futures volume (number of futures contracts sold). The sample size is 4,795 observations. All coefficients shown in the table are significant at the 1% level.

	vp_a-vp_b	*pov*	*nov*	*pfv*	*nfv*
vc_a-vc_b	−0.169	0.443	−0.497	0.055	-0.045
vp_a-vp_b	1	−0.503	0.441	−0.020	0.064
pov		1	0.242	0.187	0.085
nov			1	0.127	0.173
pfv				1	0.359

Table 7
Regression of index futures price change on current and lagged net positive options volume (*npov*) and net positive futures volume (*npfv*)

The volume variables are stated in thousands of contracts. The sample size is 4,795. The numbers in parentheses are *t*-statistics.

	Coefficient
Intercept	0.143
	(−1.66)
npov	**2.770**
	(29.06)
$npov_{-1}$	**−0.426**
	(−4.39)
$npov_{-2}$	−0.131
	(−1.34)
$npov_{-3}$	−0.047
	(−0.48)
$npov_{-4}$	−0.001
	(−0.01)
$npov_{-5}$	0.024
	(0.25)
$npov_{-6}$	−0.190
	(−1.94)
npfv	**19.040**
	(20.34)
$npfv_{-1}$	−0.428
	(−0.46)
$npfv_{-2}$	1.540
	(1.63)
$npfv_{-3}$	0.667
	(0.71)
$npfv_{-4}$	−0.042
	(−0.05)
$npfv_{-5}$	0.234
	(0.25)
$npfv_{-6}$	0.933
	(0.99)
Adj R^2	0.228

market pushes up prices. Net positive options volume of 1,000 contracts increases the DAX index price by 2.77 index points, holding constant futures volume. Net positive futures volume of 1,000 contracts increases the DAX index by 19 index points, holding constant options volume. The only significant lag effect is from net options volume one period ago to current price change. The sign is negative, which implies that options price impacts tend to be partially reversed, consistent with Table 4 results. There is no lag effect in futures volume.

In summary the regression results in Table 7 containing both net options and net futures volume are totally consistent with those in Table 4. Both options and futures volume imbalances have price effects. Futures imbalances have a greater price impact and tend not to be reversed. Options imbalances have a lesser price impact and tend to be reversed. These results imply that price discovery tends to take place in the futures market rather than in the options market and that the futures market is very liquid compared to the options market.

5. The volume transmission mechanism

We now investigate if there is a contemporaneous or lead–lag relation between signed options volume and signed futures volume. Volume in the two markets may be related because of index arbitrage, because trading in one market leads to hedging in the other market, or because traders in one market follow the lead in the other market. We discuss these possibilities in turn. We examine the link between options and futures volume by again using as our data *net* positive options volume, *npov*, and *net* positive futures volume, *npfv*.

If index arbitrage were the main volume link between the two markets, one would expect a negative association in signed volume. An arbitrager takes a long position in one market (say buy call, sell put) and a short in the other (sell futures). Thus, a predominance of arbitrage would imply a negative, not positive, contemporaneous correlation of the two net volumes. We calculate the contemporaneous correlation of *npov* and *npfv*, which we find to be $\rho(npov, npfv) = 0.194$. Since the correlation is positive, we rule out arbitrage as the primary link between the markets.

Volume in the two markets would be positively correlated if dealer hedging transmitted volume in one market to the other market. For example, suppose volume occurs first in the options market as the public buys calls at the ask. The options dealer sells calls at the ask and hedges by buying futures at the ask. This process would lead to positive association of volumes contemporaneously and perhaps with a lag if hedging took time. Volume would also be positively associated if investors in one market simply followed the lead of the other market—if, for instance, investors buying calls led to investors buying futures either in the same time period or with some lag.

While one cannot readily distinguish empirically whether hedging or follow the leader behavior is the reason for a positive volume association, it is possible to infer whether one market leads the other in the initiation of volume. If futures markets are the source of price discovery as is implied by the price impact analysis of Table 4, one would expect signed futures volume to lead signed options volume. On the other hand, if options are the source of price discovery, one would expect signed options volume to lead signed futures volume. If one is willing to argue that dealers hedge immediately, one could distinguish the hedging theory from the follow the leader theory. In that case any lagged effects would imply follow the leader behavior. We leave it to the reader to make that judgment and focus our attention on which market leads the other in signed volume.

Table 8
Relation between options volume and futures volume

Results of estimating a two equation vector autoregressive system for net positive futures volume, *npfv*, and *npov*. *npfv*=*pfv*−*nfv*, where *pfv* is positive futures options volume (number of futures contracts purchased) and *nfv* is negative futures volume (number of futures contracts sold). *npov*= *pov*−*nov*, where *pov* is positive options volume (defined as volume of calls purchased plus volume of puts sold), *nov* is negative volume (defined as volume of calls sold plus volume of puts purchased). Subscript $-i$ denotes lag $i(i = 1, \ldots, 6)$. The sample size is 4,795 observations.

	npfv		*npov*	
	Coeff.	*t*-value	Coeff.	*t*-value
Intercept	0.0442	0.03	9.0162	0.69
$npov_{-1}$	−0.0023	−1.42	0.2448	1.71
$npov_{-2}$	−0.0045	−2.96	−0.3024	−2.10
$npov_{-3}$	−0.0029	−1.90	−0.0093	−0.06
$npov_{-4}$	−0.0048	−3.14	0.0051	0.04
$npov_{-5}$	0.0022	1.43	0.2239	1.56
$npov_{-6}$	0.0001	0.08	−0.1079	−0.75
$npfv_{-1}$	0.0717	4.91	0.1296	8.82
$npfv_{-2}$	0.0161	1.10	0.0311	2.09
$npfv_{-3}$	0.0429	2.94	0.0097	0.65
$npfv_{-4}$	0.0005	0.03	−0.0076	−0.50
$npfv_{-5}$	−0.0158	−1.08	0.0049	0.33
$npfv_{-6}$	−0.0045	−0.31	0.0093	0.62

We examine the lead–lag link between volumes in the two markets by estimating a vector autoregressive system for *npov* and *npfv*. The results, in Table 8, indicate that signed futures volume leads signed options volume and that signed options volume does not lead signed futures volume. First, note that *npov* is positively correlated with past *npfv* at lags one and two, holding constant lagged options volume. This implies that futures volume leads options volume by up to 10 minutes. The remaining lag cross-correlations are statistically insignificant. Second, note that net positive futures volume (*npfv*) is not positively correlated with lagged net positive options volume (*npov*), holding constant lagged futures volume. This implies that options volume does not lead futures volume.

We conclude from the volume associations that the options market is not the initiator of volume and is therefore not likely to be the locus of price discovery. Overall, the volume results of Table 8 combined with the price impacts of Table 4 imply that options traders are noise traders. They respond to futures volume, but they are not the source of volume. Their volume has price effects, but the price effects are reversed, unlike futures volume effects, which are permanent.

6. Conclusions

We examine the relation between signed options and futures volume in DAX and the price change in the DAX index futures. In a perfectly efficient market in which all information is public and where markets are deep and liquid, trading of options or futures would have no price effect. We conclude that the market is not perfectly efficient in this sense. Trading has price effects. Positive options volume (buy calls and sell puts, or calls bought minus calls sold) has a contemporaneous positive price effect. Positive futures volume has contemporaneous positive price effect. Negative volume has the corresponding negative price effect. While signed options volume does have the predicted contemporaneous price effect, that effect is partially reversed within one-half hour, which implies at least part of the effect is due to trading pressure, not information trading. The price impact of contemporaneous signed futures volume is not reversed, suggesting that futures volume, unlike options volume, is wholly informational. Signed options volume is positively correlated with lagged signed futures volume, but signed futures volume is not correlated with lagged signed options volume, which suggests that the price discovery transmission mechanism in the DAX market is more likely to be from futures to options than from options to futures. We also show that neither options volume nor futures volume can be used to predict price changes in the next interval. Overall, our results suggest that, in the DAX index market, options traders are the followers, not the leaders, in price discovery.

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