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Does an electronic stock exchange need an upstairs market?[☆]

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Abstract

We examine the Paris Bourse, whose electronic limit order market closely resembles the downstairs markets envisioned by theorists, to test several theoretical predictions regarding upstairs trading. We present direct evidence in support of the Grossman (J. Business (1992) 509) prediction that upstairs brokers lower execution costs by tapping into unexpressed liquidity, as actual execution costs upstairs are on average only 20% (35%) as large as they would be if block trades were executed against displayed (displayed and hidden) liquidity in the downstairs limit order book. Consistent with prior analyses, the Paris data also support the Seppi (J. Finance (1990) 73) hypothesis that upstairs brokers certify trades as uninformed. We also find that participants in stocks with less restrictive crossing rules agree to outside-the-quote executions for more difficult trades and at times when downstairs liquidity is lacking. These likely represent trades that could not have been otherwise completed, suggesting that

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market quality can be enhanced by allowing participants more flexibility to execute blocks at prices outside the quotes.

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1. Introduction

Glosten (1994) emphasizes the efficiencies that result from consolidating financial market trading in a centralized electronic limit order book. A computerized market has relatively low operating costs, the book's price and time priority rules create incentives for liquidity providers to bid aggressively for market orders, and the consolidation of trading ensures that each order is exposed to all other displayed orders. Despite these efficiencies, virtually every stock market is accompanied by a parallel upstairs market, where larger traders employ the services of brokerage firms to locate counterparties and negotiate trade terms. This paper provides empirical description of the upstairs market and tests of theoretical models of upstairs trading using data from the Paris Bourse. The Bourse is particularly well suited to this endeavor because the downstairs market in Paris is an electronic limit order mechanism similar to that envisioned by theoreticians, because of cross-sectional variation in the crossing rules that govern upstairs executions and because of the richness of the dataset made available by the Bourse. (See Biais et al., 1995, for description of the Paris limit order market.)

Theoretical analyses of upstairs trading focus on two issues that are of particular importance to larger traders: order exposure and trades' information content. Prices are likely to move adversely if the existence of a large unexecuted order becomes widely known, as other traders may front run the order or simply infer information about future price movements from its presence. A large limit order, in particular, provides free trading options and risks being picked off if market conditions change. Grossman (1992) argues that the trading preferences of many large investors are not expressed publicly and that a role of the upstairs broker is as a repository of information on large investors' unexpressed trading interests. Given that some trading interest is not reflected in the limit order book, a large market order sent to the downstairs market will walk the book, bypassing uncommitted liquidity, thus increasing execution costs. An upstairs broker who receives a large customer order can tap the pool of unexpressed trading interest, while minimizing the degree to which the customer's order is exposed. To partially mitigate such risks the Paris Bourse allows limit order traders to hide a portion of their trading interest. (See Harris, 1996, for more detail.) The hidden portion of the limit order is not displayed to other market participants but is executed if a market order exhausts the displayed liquidity at the same price.

A second branch of research on upstairs markets considers the role of upstairs brokers in certifying trades' information content. Easley and O'Hara (1987) demonstrate that an investor trading on private information regarding security values will prefer to trade larger quantities. Their model implies that liquidity providers will charge more to complete larger orders. Large traders who transact for liquidity rather than informational motives therefore have incentives to identify themselves as such. Seppi (1990) describes mechanisms by which an upstairs broker can distinguish between informed and uninformed traders. This allows the broker to screen informed traders from the upstairs market, lowering adverse selection costs for large liquidity traders.

This paper extends our understanding of the role of upstairs markets, focusing in particular on the Paris Bourse, where the upstairs market competes with an electronic limit order market. The Paris market is well suited for studying upstairs trading, particularly as compared with the New York Stock Exchange. Theoretical analyses of upstairs trading typically compare the benefits of a negotiated upstairs market with a pure limit order book in the downstairs market. The NYSE floor, however, does not fit the theoretical model of a limit order book and could replicate some benefits of upstairs trading. In particular, NYSE floor brokers can work client orders without fully revealing them. Chakravarty (2001) argues that NYSE specialists and floor brokers can sometimes deduce the identity of trade initiators, thereby lowering the risk of adverse selection.[1] Further, the NYSE specialist, being positioned at the center of a trading crowd on the exchange floor, has information on the hidden liquidity on the floor and unexpressed liquidity upstairs.[2] While these features likely increase the appeal of the NYSE trading floor to investors, they interfere with clean tests of upstairs trading models, as the distinction between upstairs and downstairs markets is not clear. We therefore test theories of upstairs markets in an electronic limit order market that closely resembles the downstairs markets described by theorists.

Prior empirical work has focused mainly on the Seppi (1990) prediction regarding the informational role of the block broker. Madhavan and Cheng (1997) study upstairs trading in the floor-based NYSE, while two recent papers, Smith et al. (2001) and Booth et al. (2001), study upstairs trading in the Toronto Stock Exchange (TSE) and the Helsinki Stock Exchange (HSE), respectively, where the downstairs market is electronic. These studies find that upstairs brokers lower adverse selection costs by effectively screening information-motivated trades, thus providing support for the certification role of the upstairs broker. Booth et al. (2001) also report that most price discovery occurs in the downstairs, not the upstairs market.[3]

Our paper is distinguished from these studies and earlier work partly because the downstairs market in Paris more closely resembles that envisioned in the theory

[1] Benveniste et al. (1992) argue that the long-standing professional relationships between the floor traders and specialists result in information exchange, which can mitigate adverse selection costs.

[2] In addition, Venkataraman (2001) suggests that the trading rules in a floor-based market structure allow large traders to selectively participate in block trades and better control the risk of order exposure. Hence, large traders are more likely to express their interests in the downstairs market in a floor-based market structure.

[3] This finding could be interpreted as an affirmative answer to a variation of the question posed in the title of this paper: "Does an upstairs market need an electronic stock exchange?"

papers, but mainly because we test hypotheses that the prior papers could or did not.[4] Most notably, we present the first direct empirical evidence regarding the Grossman (1992) prediction that the upstairs broker lowers execution cost by tapping into pools of unexpressed liquidity. While prior empirical work supports the Seppi (1990) prediction, the Grossman prediction remained untested due to the lack of an empirical proxy for liquidity beyond the inside quotes. We are able to recreate the downstairs limit order book, including both liquidity that is publicly displayed and liquidity that is committed to the limit order book but was not displayed to market participants. We compare actual execution costs in the upstairs market with costs that would have been incurred if the same trades had been routed to the downstairs limit order book.

We are also able to exploit variation in the crossing rules that were in effect on the Paris Bourse during our sample period to present evidence on their relevance. Upstairs trades in most Paris Bourse stocks must be executed at prices at or within the best bid-offer (BBO) quotes in the downstairs market at the time of the trade. However, for a subset of liquid stocks (called eligible stocks), the Paris Bourse allows block trades to be executed at prices away from the BBO. Allowing outside-the-quote executions could open the upstairs market in a broader set of circumstances. We examine the factors that govern when the option to complete trades outside the quotes is used, and we study the quality of these executions. An investigation of the effects of different crossing rules is particularly useful in the wake of market decimalization in the United States. The NYSE generally requires upstairs trades to be executed at prices that match or improve on the downstairs quotes. This requirement has become more restrictive in the wake of decimalization, which has substantially tightened bid–ask spreads.

Finally, we investigate the popular view that an automated execution system is inherently less expensive than a trading mechanism with human intermediation. To do so, we implement econometric techniques that control for self-selection bias in traders' choice between upstairs and electronic trading and that measure the inherent cost of completing trades in each market. The results indicate that a randomly selected order would incur higher execution costs in the upstairs market than in the electronic market. However, due to traders' efficient selection, average execution costs for large trades routed upstairs are smaller than for trades routed downstairs.

We analyze 92,170 block trades in a broad cross-section of 225 Paris stocks. The upstairs market at the Paris Bourse is an important source of liquidity for large transactions, as almost 67% of the block trading volume is facilitated upstairs. The option to complete upstairs trades in eligible stocks at prices outside the quotes is exercised for larger trades, when the downstairs spread is unusually narrow and when there is relatively little depth in the limit order book. This suggests that more flexible crossing rules allow some trades to be completed that otherwise would not.

[4] Even the electronic market at the TSE differs from a pure auction market, because of the presence of a designated market maker. In contrast, the liquid stocks at the Paris Bourse do not have a designated market maker.

Overall trading costs for those block trades completed upstairs are lower than for block trades completed downstairs, even though selectivity-adjusted estimates indicate higher fixed costs in the upstairs market. This reflects the strong support in the Paris data for the Seppi (1990) prediction that upstairs brokers screen on the basis of information content: Upstairs trades contain less information than downstairs trades, despite being larger. The data also support the notion that traders strategically choose across the upstairs and downstairs markets to minimize expected execution costs.

The empirical results strongly support the Grossman (1992) prediction that upstairs brokers are able to tap into unexpressed liquidity. Execution costs for upstairs trades are much lower than would be expected if the trade were executed against the displayed and undisplayed liquidity in downstairs limit order book. Our reconstruction of the downstairs limit order book is imperfect. The measurement error arises because the available data do not report on cancellations of limit orders before the end of the trading day. As a consequence, our measures of downstairs liquidity are overstated and our tests are biased against finding support for the Grossman (1992) hypothesis. Despite this limitation, we find that on average trades are executed upstairs at a cost only 35% as large as if they had been executed against both the displayed and the hidden liquidity in the downstairs limit order book. Eighty-one percent of sample trades were completed at a lower cost upstairs than they would have incurred downstairs. Another 3% of sample trades could not have been completed downstairs, due to insufficient liquidity in the book at any price. Despite the bias against the Grossman hypothesis, 84% of sample trades received better executions upstairs than they would have if they had been executed against the estimated downstairs limit order book.

This paper is organized as follows. Section 2 describes market structure at the Paris Bourse, reviews the related literature, and provides testable predictions regarding upstairs trading. Section 3 presents the sample and descriptive statistics about block trading in Paris. Section 4 reports on average trade execution costs in the Paris upstairs and downstairs markets. Section 5 presents the results of testing the Grossman (1992) hypothesis that upstairs brokers reduce trading costs by tapping pools of unexpressed liquidity. Section 6 investigates the effect of varying crossing rules at the Paris Bourse. Section 7 presents evidence on the execution cost of a typical order in both markets, after controlling for selection bias in the data. Section 8 summarizes results and discusses policy implications for electronic stock exchanges.

2. The related literature and testable predictions on block trading at the Paris Bourse

2.1. The literature on block trading and hybrid markets

Theoretical papers model the benefits and costs of upstairs intermediation. Grossman (1992) suggests that upstairs brokers have knowledge on the states of nature that are likely to induce customers to trade. One such state would be the opportunity to trade with a block initiator who wishes to trade for liquidity rather than information-based reasons. Grossman also emphasizes that potential block traders may prefer to not quantify or publicly reveal their trading interest. The upstairs broker has information on the unexpressed trading interests of these customers, and accessing this unexpressed demand increases the effective liquidity of the upstairs market, thus reducing execution costs to the block initiator.

Seppi (1990) focuses on the certification of trades, suggesting that the upstairs broker screens informed traders from the upstairs market.[5] Liquidity providers can therefore charge a smaller information premium, which lowers the execution cost. Barclay and Warner (1993) and Hansch et al. (1999) extend this reasoning. They note that negotiation and repeat transactions allow dealers to assess whether traders possess private information. Uninformed customers find it in their interest to interact with dealers and receive prices better than implied by the quotes or the limit order book. Informed customers, in contrast, choose to remain anonymous and trade at quoted prices.[6]

The insights provided by Seppi and Grossman are related, but distinct. The ability of the upstairs broker to tap into pools of unexpressed liquidity can reduce the cost of trading for any order, informed or not, implying that the Grossman reasoning could be empirically supported even if the Seppi hypothesis were not. However, the hypotheses are not competing, in the sense that they could both be correct, a conclusion supported by our empirical results.

Though the benefits of trading in the upstairs market could be significant, the search process in the upstairs market is costly. In Keim and Madhavan (1996), the cost of upstairs facilitation is an increasing function of the number of counterparties located. In Burdett and O'Hara (1987), a cost of upstairs trading is information leakage in the downstairs market. Each block trader can select the upstairs or downstairs market based on expected costs and benefits.

Vishwanathan and Wang (2002) note that an important distinction arises in the nature of price quotations across dealer markets and limit order books. Upstairs dealers can quote an array of prices at which they are willing to complete orders of various sizes. Quotations for orders of a given size therefore need not affect revenues from executing orders of a different size. In contrast, because larger orders walk up the limit order book, revenues from executing large orders submitted to the limit order book depend on limit prices for smaller orders as well. This distinction leads to differences in pricing schedules across market structures and allows Vishwanathan and Wang (2002) to obtain two important results: Risk averse liquidity demanders will, conditional on the presence of enough competing dealers, prefer a hybrid

[5] For example, the broker could require the trader to make a no-bagging commitment to not trade again for a specified interval. This commitment is not costly to a liquidity trader who has revealed its full trading program, but can be costly to a strategic informed trader.

[6] Several authors have considered relations between order execution costs and order size within a single market structure. Among these, Hansch et al. (1998, 1999) and Reiss and Werner (1995, 1998) focus on the London Stock Exchange's dealership market, with each reporting that large orders on average receive better executions than midsize or small orders. This result is consistent with the reasoning that larger orders tend to be certified as originating with uninformed traders.

market with both a limit order book and competing upstairs dealers to either a pure limit order or a pure dealer market, and large orders submitted to the hybrid market will tend to receive better executions in the upstairs dealer market.

Parlour and Seppi (2003) present a model in which a limit order market competes with a hybrid market consisting of a limit order book and a single, strategic, specialist. They note that the hybrid structure provides more flexibility. While the limit order book gives executions that depend entirely on the orders in the book, the specialist in the hybrid structure can elect to give price improvement, i.e., to execute trades at better prices. This insight is similar to the Grossman (1992) observation that upstairs dealers can tap into pools of unexpressed liquidity.

Rhodes-Kropf (2002) provides a formal model of price improvement in dealer markets. He notes that, while a certification that a trader is uninformed (as in Seppi, 1990) is one reason that dealers may elect to execute trades at prices better than implied by posted liquidity schedules, market power could also provide an explanation. Dealers with a degree of market power will post less favorable price schedules than competitive dealers. However, customers who also possess some market power could be able to negotiate trades at prices within those schedules. Rhodes-Kropf goes on to note that, if market power is the only reason for price improvement, then the information content of price-improved trades should not differ from that of trades completed at the quotes. We are able to distinguish between explanations by measuring the price impact of trades in the upstairs and downstairs markets.

2.2. The upstairs market in Paris

In a typical Paris upstairs transaction, an institutional investor submits a large order to a member firm (upstairs broker) with whom the block initiator ordinarily has a long-standing relationship. The broker generally has discretion to send the order to the downstairs market to execute against standing limit orders, act as a dealer (i.e., principal) and execute the block against his own inventory, or act as a broker (i.e., agent) and search for counterparties.

The upstairs broker deals with numerous institutional investors on a daily basis and typically has some information on their current holdings and latent trading interest. The block broker contacts potential counterparties and negotiates the transaction price. The identity of the block initiator is not revealed during the search process, though counterparties are informed of the block size. All upstairs transactions are reported immediately to the Paris Bourse, which publishes a majority of the transactions with no delay. Block trades in which a member firm acts a dealer could be made public with delay to enable the member firm to reverse its position. Although some principal trades are made public with a delay, the Base de Donnees de Marche (BDM) database that we use indicates actual trade times. Upon publication of the transaction by the system the public learns the details of the transaction, except whether the member firm acted as a dealer or a broker. Appendix A provides more detail as to rules in effect on the Bourse during our sample period.

Some upstairs trades in stocks listed on the Paris Bourse are completed in London, not Paris, and are not included in our database. Jacquillat and Gresse (1995) estimate the London market share of French stocks at 8.4% in 1993, while Demarchi and Foucault (1999) report similar numbers for 1998. As a consequence, our results understate the importance of upstairs trading for Paris-listed stocks.[7]

2.3. Testable predictions on block trading

The theoretical analyses of block trading provide several testable implications. These are stated in terms of trades' information content; observed empirically as permanent (on average) price changes around trades, in terms of the liquidity costs of trading; observed empirically as execution prices that are inferior (on average) to the post-trade value of the stock, and in terms of the total cost of executing trades.

These analyses support the following testable hypotheses:

Hypothesis I: Total execution costs for those trades routed to the upstairs market are lower than for similar trades completed in the downstairs market.

Hypothesis II: *Total execution costs for upstairs trades are lower in part because upstairs brokers can tap into unexpressed and uncommitted liquidity that is known only to market intermediaries.*

Hypothesis III: *Upstairs markets are used primarily by those traders who can certify that their trades are uninformed.*

Hypothesis IV: *Upstairs trades incur higher fixed execution costs to compensate dealers for search and negotiation expenses.*

We provide empirical tests of Hypotheses I through IV. In addition, we provide evidence regarding the importance of variation in crossing rules and on the inherent cost of executing trades in the upstairs and electronic markets.

3. Sample selection and descriptive statistics

3.1. Sample selection

As our objective is to investigate the significance of an upstairs market across a broad cross-section of firms, we focus on firms comprising the SBF-250 index at the beginning of our April 1997 to March 1998 sample period. SBF-250 represents all

[7] Pagano (1997) argues that the reported trading volumes in the London dealer market and the French auction market are not directly comparable, noting, "A direct customer trade with a London exchange member generates a cascade of inter-dealer transactions, by which the dealer rebalances his inventories – an effect not present in an auction market when two customers' orders are crossed" (p. 6). Inventory rebalancing trades are likely to be particularly important for block transactions that leave dealers with large inventory imbalances. In contrast to the evidence reported by Jacquillat and Gresse (1995) and Demarchi and Foucault (1999), Friederich and Tonks (2001) report that the London market share of liquid French firms averaged between 40% and 50% during the 1990s.

sectors of the French economy and includes all component firms of the CAC40 and SBF-120 indexes. Trade, quote, and order data are obtained from the BDM database made available by the Paris Bourse.[8] To remain in the sample, a firm must trade in the continuous (not batch) downstairs auction market, so that downstairs prices are available to calculate trades' price effects (deletes 13 firms); trade common equity with voting rights (deletes five firms); and have normal trade and quote data during the sample period (deletes seven firms). The remaining 225 stocks are further divided into trading activity quintiles based on the average trading volume and market depth during the sample period.

Ideally, analyses of upstairs markets would be conducted using order level data on the entire trading programs of all institutional investors. In practice, however, publicly available data sets (e.g., NYSE's Trade and Quote (TAQ), SBF-Paris Bourse's BDM, TSE's Order and Trade) have broad coverage but do not provide data on the orders that underlie trades or on trading intentions. We follow Madhavan and Cheng (1997), Smith et al. (2001), and Booth et al. (2001) in using trades as the basic unit of observation.[9]

A large marketable order to buy (sell) sent downstairs can exhaust the depth on the inside quote and walk up (down) the limit order book. Such a large order will be reported as multiple trades at different prices but occurring at the same time in the BDM database. Following Biais et al. (1995), Piwowar (1997), and Venkataraman (2001), we classify these simultaneous trades as one large trade. The block trade size is the sum of the trade sizes of all simultaneously reported trades, and the block transactions price is calculated as the size weighted average of the simultaneous reported trade prices. We analyze large transactions that occur during regular market trading hours, when traders can choose between the upstairs and downstairs markets.

3.2. Definition of a block trade

Studies of block trading on the New York Stock Exchange typically define a block trade as any trade for 10,000 shares or more. In our view, however, the definition of a block trade should vary depending on share price and trading activity in the stock. Share price variation is particularly relevant for this study. Fig. 1 reports on the distribution of share prices for NYSE (all common stocks) and Paris Bourse (the 225 stocks in this study). On April 1, 1997 the average stock price at the Paris Bourse is FF 800 (or U.S. $142), compared with $41 on the NYSE. Also, stock prices are more

[8] We use a series of filters to delete trades and quotes that have a high likelihood of reflecting errors. Trades are omitted if trade price is non-positive, involves a price change (since the prior trade) greater than absolute value of 25%, occurs on a day when change in overnight price is greater than 15%, or occurs on the day of stock split. Quotes are deleted if bid or ask is non-positive, bid–ask spread is negative, change in bid or ask price is greater than absolute value of 10%, and bid or ask depth is non-positive.

[9] A notable exception is Keim and Madhavan (1996), who use a non public data set obtained from Dimensional Fund Advisors (DFA) that includes orders. However, their data set reflects orders by only a single institutional trader, who specializes in small-capitalization stocks. It is difficult to know the extent to which analyses based on proprietary data sets that reflect a small slice of overall trading can be generalized beyond the specific sample.

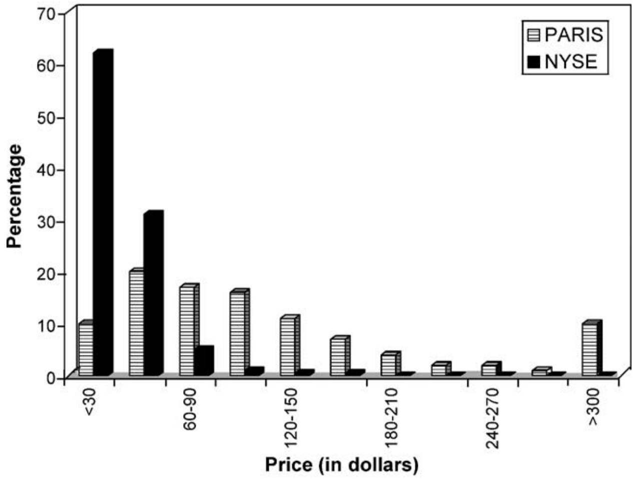

Fig. 1. The distribution of share prices for all common stocks at the NYSE and the 225 sample stocks at the Paris Bourse on April 1, 1997.

widely dispersed at the Paris Bourse than the NYSE. (See Angel, 1997, for additional description of diverse stock price distributions across world markets.) Because traders are likely to be concerned about the dollar (or franc) size of the transaction, it is reasonable to suggest that the block size in shares at the Paris Bourse should be smaller than the NYSE on average and should vary across stocks. We therefore follow Gemmill (1996), Reiss and Werner (1998), and Hansch et al. (1998), who each defined a stock-specific block size in their studies of London markets.

The Paris Bourse defines a normal block size (NBS) for those stocks that are eligible for special block trading rules, including 80 stocks in our sample. We use the Bourse definition of NBS for these 80 stocks. For the remaining sample stocks, we follow the Bourse methodology and use measures of market depth and trading volume to assess the normal trading activity in a stock. Also, we require that the block size should be at least FF 500,000, an economically significant amount. Specifically, for firm I in month M, we define block size as $NBS_{I,M} = MAX\ [NBS_1, NBS_2, NBS_3]$, where $NBS_1 = 7.5 *$ (average depth of the inside quotes in the limit order book), $NBS_2 = 2.5\%$ of average daily downstairs trading volume, and $NBS_3 =$ FF 500,000. The NBS for a calendar quarter is the average value of $NBS_{I,M}$ for the preceding quarter.[10] We define as block transactions those with size greater than or equal to the computed NBS of the firm.

[10] As a check, we compare computed measures of NBS with the block sizes provided by the Paris Bourse for the 80 sample stocks that are eligible for special block trading rules, and find a correlation of 0.86. The Bourse ensures that any change in trading activity is permanent before announcing a change in block size. In the same spirit, we minimize the effect of temporary abnormal trading activity by identifying stocks in which the absolute change in NBS from one quarter to the next is greater than 100% (14 observations). If the change is the result of a stock split, then we change the NBS on the day on which the split is effective (three occasions). If the increase in NBS is the result of abnormal trading behavior in a single month, then we retain the NBS from the previous quarter (eight occasions).

Also, as the NBS measures variations in trading activity across firms, we group firms into trading activity quintiles based on NBS. The average block size is 1.45 million French francs, or about $290,000. Computed block sizes vary substantially across activity quintiles, from an average 0.5 million francs for the least active to 4.3 million francs for the most active.

3.3. Descriptive statistic on Paris block trading

Table 1 presents sample summary statistics. Sample firms are classified into activity quintiles. The average stock price and market capitalization of the sample on

Table 1
Sample summary statistics and the distribution of block trading volume
The Paris Bourse sample consists of the component firms of the SBF-250 index that trade common stock in the continuous auction market on April 1, 1997. The sample period is from April 1997 to March 1998 and the data source is the Base de Donnees de Marche (BDM) database. The firms are classified into activity quintiles based on normal block size (NBS), a measure of the trading activity in the stock during the sample period. Only block trades executed during regular market hours are included in the analysis. Reported are the average market price and market capitalization of the sample of firms on April 1, 1997. For upstairs and downstairs block trades, the table reports the total number of trades, the mean and median trade size, the cumulative trading volume, and the percentage of the trades and cumulative trading volume executed in the upstairs market during the entire sample period.

Activity quintile	Stock price (in FF)	Market size (in FF millions)	Trades		Trade size (in FF)		Cumulative Volume	
			Number	Percent	Mean	Median	(in FF millions)	(Percent of all volume)
Full sample	799	13,554						
Downstairs			61,082		2,871,875	1,835,000	175,420	
Upstairs			31,088	33.7	11,491,550	5,047,500	357,249	67.1
Most active quintile	800	48,670						
Downstairs			26,342		4,414,975	3,055,000	116,300	
Upstairs			20,323	43.6	14,709,025	7,452,000	298,931	72.0
Quintile 4	1,184	8,903						
Downstairs			17,741		2,063,000	1,487,500	36,600	
Upstairs			5,617	24.0	6,036,575	2,542,500	33,907	48.1
Quintile 3	1,016	5,334						
Downstairs			11,680		1,401,825	988,575	16,373	
Upstairs			2,967	20.3	5,436,975	1,800,000	16,132	49.6
Quintile 2	604	3,252						
Downstairs			3,795		1,192,025	856,350	4,524	
Upstairs			1,453	27.7	3,921,725	1,542,000	5,698	55.7
Least active quintile	391	1,614						
Downstairs			1,524		1,065,700	734,200	1,624	
Upstairs			728	32.3	3,544,550	1,269,450	2,580	61.4

April 1, 1997 is FF 799 and FF 13,544 million, respectively. Average market capitalization increases monotonically from FF 1,614 million for the least active quintile to FF 48,670 million for the most active quintile.

The sample includes 92,170 block trades. Of these, 31,088 (33.7%) were facilitated in the upstairs market. The average size of a block trade in the upstairs market is FF 11.5 million, compared with FF 2.9 million for block trades in the downstairs market. The substantial difference between mean and median trade sizes indicates that some trades in both markets are very large. As expected, the number of trades, the average trade size, and trading volume tend to increase across activity quintiles.

The upstairs market at the Paris Bourse is a significant source of liquidity for large transactions, with almost 67% of cumulative block trading volume facilitated upstairs. By comparison, Hasbrouck et al. (1993) report that 27% of block volume in all NYSE-listed stocks is facilitated upstairs, while Madhavan and Cheng (1997) find that 20% of the block volume in the Dow Jones Industrial Average (DJIA) index stocks is facilitated in the upstairs market. The greater percentage of block volume facilitated upstairs at the Paris Bourse as compared with the NYSE is consistent with the conjecture that the upstairs market will play a more significant role at an electronic stock exchange than when the downstairs market includes a trading floor.[11]

Results in Panel A of Table 2 indicate that large trades are more likely to be facilitated in the upstairs market. Here, we classify block trades as small if ($NBS \leqslant$ trade size $< 2 * NBS$), medium if ($2 * NBS \leqslant$ trades size $< 5 * NBS$), and large if (trade size $\geqslant 5 * NBS$). For small block trades, only 19% of the trades and cumulative trading volume is facilitated in the upstairs market. However, for large block trades, almost 80% of the trades and 87% of cumulative block volume are facilitated upstairs. Finding that large trades are more likely to be routed upstairs in Paris is broadly consistent with the results reported by Smith et al. (2001) for the Toronto Stock Exchange.

Results in Panel B of Table 2 indicate that firms with less activity in the downstairs market have a higher level of upstairs participation. In this analysis, trades are first classified into trade size (in FF) quintiles. We calculate the upstairs participation rate for each firm and report the median upstairs participation rate by activity quintiles. Results indicate that within a trade size quintile, the upstairs participation rate increases for less active firms. For example, in trade size quintile 3, the upstairs participation rate increases from 19.9% for firms in the most active quintile to 57.1% for firms in the least active quintile.

4. Trading costs in the upstairs and downstairs markets

We next present evidence on trading costs for a broad cross-section of stocks in the broker-facilitated upstairs and electronic downstairs markets at the Paris Bourse. Comparisons of upstairs and downstairs trading costs have been presented for

[11] In a result not reported in the tables, we find blocks are bought and sold with similar frequency in Paris. This finding contrasts with results for the U.S. market (e.g., Kraus and Stoll, 1972; Chan and Lakonishok, 1995) where blocks are sold with a higher frequency.

Table 2
Firm activity, trade size and upstairs participation rates
Presents the upstairs market participation rate for 225 firms at the Paris Bourse for the period April 1997 to March 1998. The firms are classified into activity quintiles based on normal block size (NBS), a measure of the trading activity in the stock during the sample period. In Panel A, trades are classified as small if (NBS $\leqslant$ Trade size $< 2 * \text{NBS}$), medium if ($2 * \text{NBS} \leqslant$ Trade size $< 5 * \text{NBS}$), and large if (trade size $\geqslant 5 * \text{NBS}$). Reported are the median percentage of trades and cumulative trading volume facilitated upstairs by trade sizes categories. In Panel B, trades are also classified into trade size (in FF) quintiles, producing a 5×5 classification. Reported is the median percentage of trades facilitated in the upstairs market by classification.

Trade size	Number of trades			Cumulative trading volume		
	Small	Medium	Large	Small	Medium	Large
Panel A: Trade size and upstairs participation rates (in percent)						
Full sample	18.5	42.6	80.0	19.7	45.2	87.3
Most active quintile	30.7	66.3	90.9	35.2	70.9	96.2
Quintile 4	13.7	35.0	72.4	14.5	37.3	77.3
Quintile 3	15.9	35.8	69.4	16.8	37.5	80.1
Quintile 2	14.9	40.0	80.0	16.3	37.8	86.7
Least active quintile	21.9	52.4	88.9	25.5	53.0	90.0

Firm activity	Overall	Trade size (in FF) quintiles				
		Small	2	3	4	Large
Panel B: Firm activity and upstairs participation rates (in percent)						
Most active quintile	41.7	0.0	13.1	19.9	34.4	74.4
Quintile 4	22.2	9.8	14.5	27.3	47.7	77.7
Quintile 3	28.1	11.9	24.7	37.1	61.5	86.8
Quintile 2	32.2	15.6	32.0	50.0	75.0	100.0
Least active quintile	38.6	26.3	50.0	57.1	100.0	100.0

narrow cross-sections of stocks in prior papers. These include Madhavan and Cheng (1997), who focus on the 30 liquid DJIA index firms, and Booth et al. (2001), who study only the 20 most active Helsinki stocks.

4.1. Empirical measures of price effects

Kraus and Stoll (1972) first delineated measures of temporary and permanent price changes around a block trade and their interpretation as liquidity costs and informational effects, respectively.[12] Fig. 2 provides a graphic representation of the price effects of a block buy order. The temporary component, $\tau(Q)$, represents compensation to liquidity providers (i.e., counterparties) and can be measured by the

[12] Some empirical studies in microstructure, such as Huang and Stoll (1996) and Bessembinder and Kaufman (1997), have defined the permanent and temporary components of trades as price impact and realized spreads, respectively.

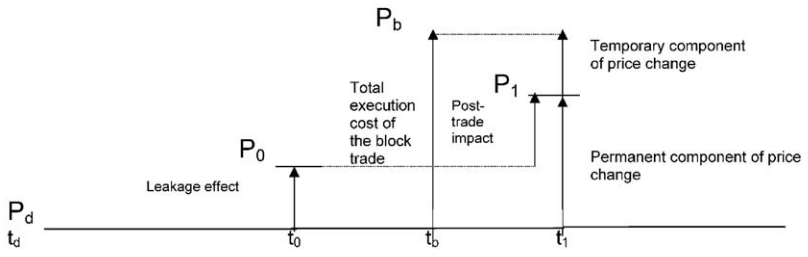

Fig. 2. Liquidity and information effects of a block buy. The facilitation process is initiated at time $= t_{\rm d}$ in the upstairs market. The leakage of information of the block size could move the security value in the downstairs market. The security value just before the block trade (time $= t_0$) is P_0. The block of size $= Q$ is executed in the upstairs market at (time $= t_{\rm b}$) at price $= P_{\rm b}$. The liquidity effect of the block results in a price reversal and moves prices to P_1. Temporary component of price change $\tau(Q)$: $\ln(P_{\rm b}) - \ln(P_1)$. Post-trade impact $\pi(Q)$: $\ln(P_1) - \ln(P_0)$. Leakage effect $L(Q)$: $\ln(P_0) - \ln(P_{\rm d})$. Permanent component of price change $P(Q)$: $\ln(P_1) - \ln(P_{\rm d})$. Total execution cost of the block trade $T(Q)$: $\ln(P_{\rm b}) - \ln(P_{\rm d})$.

price reversal after the block trade:

$$\tau(Q) = \ln(P_{\rm b}) - \ln(P_1), \tag{1}$$

where $P_{\rm b}$ is the block trade price and P_1 is a measure of post-trade value.[13]

The permanent component, $P(Q)$, can be divided into post-trade impact and pre-trade leakage. The post-trade impact, $\pi(Q)$, represents the change in the market's perception of a security's value after the announcement of the block trade:

$$\pi(Q) = \ln(P_1) - \ln(P_0), \tag{2}$$

where P_0 is the pre-trade value of the security, proxied by the last quote midpoint before the announcement of the block trade. The leakage effect $L(Q)$ represents price movements in the downstairs market while the block is being facilitated (or shopped) in the upstairs market:

$$L(Q) = \ln(P_0) - \ln(P_{\rm d}), \tag{3}$$

where $P_{\rm d}$ is the security value when the upstairs broker initiates the search process.[14] The total execution cost $T(Q)$ to the block initiator is the sum of the liquidity and

[13] We examine the sensitivity of results to four different proxies for P_1: (1) the midpoint of the first quote reported 30 minutes after the trade, (2) the midpoint of the first quote reported after 12:00 noon the next trading day, (3) the midpoint of the closing quotes on the next trading day, and (4) the midpoint of the closing quote on the third trading day after the trade. Because some principal trades are reported with delays of up to a day, results based on measures (3) and (4) are arguably more valid. In actuality, the empirical results are similar across all four measures, and we report only results obtained while using the midpoint of the closing quotes on the next trading day.

[14] We consider three proxies for $P_{\rm d}$: (1) the midpoint of the quotes 30 minutes before the trade, (2) the midpoint of the closing quotes the day before the block trade (t_{-1}), and (3) the midpoint of the closing quotes three days before the block trade. We report results using (2). Demarchi and Thomas (1996) survey the member firms at the Paris Bourse and find that most block orders are facilitated within a day. Although $L(Q)$ traditionally (e.g., Keim and Madhavan, 1996) has been interpreted as measuring pre-trade information leakage, an alternate perspective is that $L(Q)$ could be positive because traders following momentum strategies will buy after price increases, and vice versa.

information effects:

$$T(Q) = P(Q) + \tau(Q) = \ln(P_{\rm b}) - \ln(P_{\rm d}). \quad (4)$$

All measures are expected to be positive for a block buy and negative for a block sell. We adjust each measure for overall market movements by subtracting the SBF-120 index's market return from the stock's return.

4.2. Execution costs in the upstairs and downstairs market

Table 3 presents several execution cost measures for seller- and buyer-initiated block trades. These estimates are consistent with Hypothesis I, in that total execution costs are lower in the upstairs market; Hypothesis III, in that permanent price impacts are lower in the upstairs market; and Hypothesis IV, as temporary price effects reflecting search and negotiation costs are greater in the upstairs markets.

For seller-initiated trades (Panel A), the average total execution cost is 43 basis points (bp) in the upstairs market and 52 bp in the downstairs market. Separating total trading costs into permanent and temporary price effects reveals that the information content of an upstairs trade is significantly lower than that of a downstairs trade, in each activity quintile. On average, a seller-initiated trade has no effect on prices in the upstairs market and permanently lowers prices by 35 bp in the downstairs market. However, compensation to counterparties (measured by the temporary price effect) is larger in the upstairs market (48 bp) than in the downstairs market (17 bp). In both markets, average trading costs are lower for stocks with higher activity.

For a buyer-initiated trade (Panel B), the benefit of facilitating a trade in the upstairs market is significantly larger. Average execution costs are 56 bp in the upstairs market compared with 90 bp in the downstairs market. Execution costs in the upstairs market are lower by at least 30 bp in each activity quintile, except quintile 4. The cost advantage in the upstairs market for buy orders again originates from a lower adverse selection component. The permanent price effect is significantly lower in the upstairs market (54 bp) relative to the downstairs market (128 bp), and this finding holds across activity quintiles.[15]

To summarize, a block trade initiator incurs lower trading costs in the upstairs market than in the downstairs market (Hypothesis I). This result holds across most activity quintiles, and the execution cost advantage of the upstairs market is significantly larger for a buyer-initiated trade. An analysis of the components of execution costs provides strong support of the certification role of the upstairs broker (Seppi, 1990). While trades in both markets contain information, the adverse selection component of execution costs is significantly lower in the upstairs market

[15] Counterparties to upstairs block buys receive insignificant compensation for their services, while counterparties to block buys in the downstairs market lose money on average (–37.6 bp), as the stock price tends to increase after a block buy. The possibility that counterparties take losses on block transactions is addressed by Burdett and O'Hara (1987). They note that the counterparty could be a risk-averse investor with a strong desire to transact, who would prefer the certainty of a small loss to the uncertain cost of demanding liquidity in the market.

Table 3

Price effects of seller- and buyer-initiated block trades

Presents the components of price effects for seller- and buyer-initiated block trades in the upstairs and the downstairs market for 225 firms at the Paris Bourse between April 1997 and March 1998. All price effects are adjusted for market movements in the SBF 120 index. The adjustment is made by subtracting the relevant market index return from the stock's return. The trades are classified into market buys and sells using the Lee and Ready (1991) algorithm. The firms are classified into activity quintiles based on normal block size (NBS), a measure of the trading activity in the stock during the sample period. The price effects are stated in percentage basis points.

Activity quintile		Leakage price effect (L_{-1})	Post trade impact (P_{+1})	Permanent effect ($P_{-1,+1}$)	Temporary effect (T_{+1})	Total trading cost (PE_{-1})
Panel A: Price effects of seller-initiated block trades						
Overall	Downstairs	–5	–30[a]	–35[a]	–17[a]	–52[a]
	Upstairs	–4	10	6	–48[a]	–43[a]
Most active	Downstairs	–23[b]	1	–22[b]	–21[a]	–43[a]
	Upstairs	–7[c]	1	–7	–21[a]	–28[b]
Quintile 4	Downstairs	–8	–22[b]	–30[b]	–15[c]	–44[a]
	Upstairs	7	–6	1	–22[b]	–21[c]
Quintile 3	Downstairs	0	–37[a]	–37[a]	–9	–46[a]
	Upstairs	–9	14	5	–57[a]	–51[a]
Quintile 2	Downstairs	13	–34[b]	–21[b]	–25[c]	–45[a]
	Upstairs	0	32[b]	32[b]	–85[a]	–53[a]
Least active	Downstairs	–8	–63[a]	–72[a]	–15	–86[a]
	Upstairs	–9	9	0	–62[c]	–62[a]
Panel B: Price effects of buyer-initiated block trades						
Overall	Downstairs	41[a]	86[a]	128[a]	–38[a]	90[a]
	Upstairs	20[a]	34[a]	54[a]	2	56[a]
Most active	Downstairs	52[a]	45[a]	97[a]	–25[a]	72[a]
	Upstairs	17[a]	2	18[b]	18[a]	36[a]
Quintile 4	Downstairs	38[a]	69[a]	106[a]	–30[a]	76[a]
	Upstairs	30[a]	20[b]	50[a]	17	66[a]
Quintile 3	Downstairs	42[a]	73[a]	115[a]	–24[b]	90[a]
	Upstairs	28[a]	28[b]	56[a]	3	59[a]
Quintile 2	Downstairs	54[a]	93[a]	147[a]	–30[b]	118[a]
	Upstairs	21	39[b]	59[a]	6	65[a]
Least active	Downstairs	18	163[a]	181[a]	–86[a]	96[a]
	Upstairs	4	88[a]	93[a]	–40	53[a]

[a] P-value <0.01.

[b] $0.01 < P$-value <0.05.

[c] $0.05 < P$-value <0.10.

relative to the downstairs market (Hypothesis III). Liquidity-motivated traders are able to use the services of an upstairs broker to obtain lower trading costs. In addition, counterparties also may prefer to provide liquidity in the upstairs market, as the lower risk of adverse selection provides greater compensation to them even while providing lower execution costs to block initiators (Hypothesis IV).

The results obtained here concerning the lower information content of upstairs block trades can be contrasted with those of Madhavan and Cheng (1997). Their results indicate only slightly lower information content for upstairs NYSE trades, and in some subsamples their results indicate larger information content for upstairs trades. The lack of strong support for the certification hypothesis in NYSE data, contrasted with the strong support in the Paris data presented here and in the TSE data analyzed by Smith et al. (2001), support the contention that theories of upstairs trading can best be tested when the downstairs market is an electronic stock exchange.

5. The role of unexpressed liquidity in reducing upstairs trading costs

We next provide evidence regarding the Grossman (1992) argument (Hypothesis II) that trade execution costs are lower in upstairs markets because brokers have, or are able to obtain, information about liquidity that has not been publicly displayed or committed. To do so, we reconstruct from the BDM data estimates of the limit order book at the time of each upstairs trade and assess the cost that the upstairs trade would have incurred if it had been routed downstairs to walk the limit order book. As noted in Section 1, limit order traders in Paris can specify that a portion of their order be hidden rather than publicly displayed. The hidden portion of the limit order is executed if a market order exhausts the displayed liquidity at the same price. Hidden limit orders represent liquidity that has been committed, but not displayed. We therefore construct two estimates of the costs that would have been incurred had the upstairs trade been routed to the limit order book, one based on displayed orders, and one based on both displayed and hidden orders. The former measure would have been known to market participants at the time of trade execution and would have placed an upper bound on execution costs in the limit order book. The second measure is an estimate of the actual cost the trade would have incurred in the limit order book, but this cost could not have been known with precision at the time of the trades.

Our reconstruction of the limit order book is described in detail in Appendix B. One point should be noted here. Our estimates of liquidity in the downstairs market are overstated, because the available data do not allow us to identify instances in which a limit order is cancelled, until the end of the trading day. (Such errors never carry over to the following day, however.) As a consequence, our estimates of trading costs had the orders been routed to the limit order book are understated, and our results are biased against the Grossman hypothesis. Two additional biases also affect reported results. We exclude from the analysis upstairs trades executed at the midpoint, because we are unsure whether these should be executed against the buy or sell side of the limit order book. These trades, if included, would surely have also supported the Grossman hypothesis. Finally, we exclude from the average cost estimates those upstairs trades that could not have been executed downstairs due to the lack of sufficient limit order depth at any price. That these excluded trades were

Table 4
Execution costs upstairs compared to costs that would have incurred downstairs
Presents average execution costs of block trades for sample firms in the upstairs market and the execution costs for the same trades had they been routed downstairs to be executed against both displayed and hidden liquidity (in Panel A) and against displayed liquidity (in Panel B) in the limit order book (LOB). The limit order book at the time of upstairs trade is reconstructed using order data from the Base de Donnees de Marche (BDM) database. The execution cost measures, in basis points, compare the block transaction price with the quote midpoint at the time of the trade. The difference in executions costs (and corresponding *P*-values) across markets is reported in the last column. The table also reports statistics on the number of upstairs trades analyzed, the normal block size (NBS), and the depth in the limit order book as a measure of NBS and upstairs trade size. The analysis is presented by buyer- and seller-initiated upstairs trades and by instances in which the upstairs executions costs are less than, equal to, and greater than executions costs against the limit order book.

Trade	Number of upstairs trades	Block size in shares	LOB depth/ NBS	LOB depth/ upstairs trade size	Execution cost upstairs	Execution cost downstairs	Difference in execution costs
Panel A: Depth in the limit order book is defined as total (displayed plus hidden) depth							
All trades							
Mean	25,932	6,538	29	14	20	58	38[a]
Median	25,932	5,000	21	10	11	34	19[a]
Buyer-initiated trade							
Mean	11,893	6,571	28	14	19	52	33[a]
Median	11,893	5,000	22	10	11	32	17[a]
Seller-initiated trade							
Mean	14,039	6,510	30	14	20	62	42[a]
Median	14,039	5,000	22	10	11	36	21[a]
Cost upstairs > cost downstairs							
Mean	2,524	6,940	34	18	55	25	–30[a]
Median	2,524	5,000	28	14	35	19	–11[a]
Cost upstairs = cost downstairs							
Mean	1,782	5,714	58	27	18	18	0
Median	1,782	3,300	29	18	11	11	0
Cost upstairs < cost downstairs							
Mean	21,626	6,559	26	13	16	65	49[a]
Median	21,626	5,000	21	9	9	39	25[a]
Panel B: Depth in the limit order book is defined as displayed depth							
All trades							
Mean	24,712	6,675	16	8	19	93	74[a]
Median	24,712	5,000	13	6	10	53	37[a]
Buyer-initiated trade							
Mean	11,365	6,713	15	8	19	86	67[a]
Median	11,365	5,000	13	6	11	51	35[a]

Table 4 (*continued*)

Trade	Number of upstairs trades	Block size in shares	LOB depth/ NBS	LOB depth/ upstairs trade size	Execution cost upstairs	Execution cost downstairs	Difference in execution costs
Seller-initiated trade							
Mean	13,347	6,643	17	9	19	98	79[a]
Median	13,347	5,000	14	6	10	55	39[a]
Cost upstairs > cost downstairs							
Mean	1,336	7,171	19	11	71	34	–37[a]
Median	1,336	5,000	17	9	48	27	–14[a]
Cost upstairs = cost downstairs							
Mean	391	5,444	63	24	15	15	0
Median	391	3,000	20	14	10	10	0
Cost upstairs < cost downstairs							
Mean	22,985	6,667	15	8	16	98	81[a]
Median	22,985	5,000	13	6	10	56	41[a]

[a] Significant at the 1% level.

actually completed upstairs also supports the Grossman hypothesis. Despite these biases, the Grossman hypothesis is strongly supported by the data.

Table 4 provides estimates of average trade execution costs. The execution cost measure reported compares the block transaction price with the quote midpoint at the time of the trade and is similar to the effective spread measure in the literature (e.g., Huang and Stoll, 1996). Results are reported for trades executed upstairs and for the same trades had they been routed downstairs to walk the limit order book.

Those trades that could have fully executed against the limit order book (displayed and hidden) paid average execution costs of 20 bp in the upstairs market. Had these trades been routed downstairs to be executed against the displayed and hidden liquidity, they would have paid an average execution cost of 58 bp. This 38 basis-point differential is highly significant from a statistical perspective and large in economic terms. These results verify that Grossman (1992) was correct in hypothesizing that upstairs brokers are able to reduce execution costs by matching larger orders with liquidity that has not been committed or displayed publicly. Average cost savings are similar for buy orders (33 bp) and for sell orders (42 bp).

Panel B of Table 4 reports results obtained when the analysis is repeated while focusing only on displayed liquidity in the downstairs market. Displayed liquidity would have been known to market participants at the time of the trade and so provide an upper bound on downstairs execution costs. Those trades that could have executed against displayed liquidity downstairs paid an average upstairs cost of 19 bp. Had the same orders been routed to the limit order book to be executed against displayed liquidity (without triggering hidden limit orders), the average execution costs would have been 93 bp.

Table 5

Percentage of upstairs trades that support Grossman (1992) hypothesis

Reports the number and percentage of upstairs trades in support of, against, and neither for nor against the Grossman hypothesis for the full sample and for sub samples formed by firm activity or by firm eligibility for the special rules of block trading. The limit order book (LOB) at the time of the upstairs trade is reconstructed using order data from the Base de Donnees de Marche (BDM) database. An upstairs trade supports the Grossman hypothesis if the execution costs in the upstairs market (UP) is lower than if the same trade were executed against the total or displayed liquidity in the limit order book (DN), or if the trade could not have been executed against the limit order book.

Firm groups	Number of upstairs trades	Evidence on Grossman (1992) prediction on the role of upstairs markets				
		In support			Neither	Against
		Insufficient depth in the LOB	Sufficient depth cost-UP < cost-DN	Total	cost-UP = cost-DN	cost-UP > cost-DN
All firms						
Total depth	26,785	853	21,626	22,479	1,782	2,524
Percent	100	3	81	84	7	9
Displayed depth	26,785	2,073	22,985	25,058	391	1,336
Percent	100	8	86	94	1	5
Firms eligible for special block trading rules						
Total depth	22,671	376	18,446	18,822	1,477	2,372
Percent	100	2	81	83	7	10
Displayed depth	22,671	954	20,095	21,049	339	1,283
Percent	100	4	89	93	1	6
Firms ineligible for special block trading rules						
Total depth	4,114	477	3,180	3,657	305	152
Percent	100	12	77	89	7	4
Displayed depth	4,114	1,119	2,890	4,009	52	53
Percent	100	27	70	97	1	1
Most active quintile						
Total depth	17,713	227	14,507	14,734	976	2,003
Percent	100	1	82	83	6	11
Displayed depth	17,713	568	15,831	16,399	199	1,115
Percent	100	3	89	93	1	6
Activity quintile 4						
Total depth	4,748	197	3,787	3,984	456	344
Percent	100	4	80	84	10	7
Displayed depth	4,748	488	4,009	4,497	131	156
Percent	100	10	84	95	3	3
Activity quintile 3						
Total depth	2,513	165	2,006	2,171	220	122
Percent	100	7	80	86	9	5
Displayed depth	2,513	419	2,006	2,425	41	47
Percent	100	17	80	96	2	2

Table 5 (*continued*)

Firm groups	Number of upstairs trades	Evidence on Grossman (1992) prediction on the role of upstairs markets				
		In support			Neither	Against
		Insufficient depth in the LOB	Sufficient depth cost-UP < cost-DN	Total	cost-UP = cost-DN	cost-UP > cost-DN
Activity quintile 2						
Total depth	1,181	153	898	1,051	90	40
Percent	100	13	76	89	8	3
Displayed depth	1,181	372	783	1,155	15	11
Percent	100	31	66	98	1	1
Least activity quintile						
Total depth	594	111	428	539	40	15
Percent	100	19	72	91	7	3
Displayed depth	594	226	356	582	5	7
Percent	100	38	60	98	1	1

One apparent puzzle is that 1,336 sample trades (out of 24,712 considered) on Panel B of Table 4 were executed upstairs (at an average cost of 71 bp) even though they could have been executed against displayed downstairs liquidity at a lower cost (on average, 34 bp). Likely, this reflects the upward bias in our estimates of displayed liquidity.

Beyond supporting the Grossman hypothesis, Table 4 allows other interesting conclusions. First, the limit order book does have sufficient depth to execute most upstairs trades. On average the book can accommodate at some price 29 times the normal block size and 14 times the upstairs trade size. The limit order book is a viable, though typically more expensive, source of liquidity for block transactions. Second, comparing average limit order book execution costs that are based on displayed liquidity (93 bp) with costs based on both displayed and hidden liquidity (58 bp), it appears that on average about two-thirds of the liquidity committed to the limit order books is publicly displayed. Additional analysis of limit order traders' decisions to display or hide their trading interest appears warranted.

Table 5 reports on a number of upstairs trades for which the Grossman hypothesis is supported, for the full sample and for subsamples. Among all trades considered, 81% (21,626 of 26,785) were completed at a lower cost upstairs than if they had been executed against both displayed and hidden liquidity in the downstairs market. Another 3% (853 trades) could not have been executed downstairs at all, as a result of a lack of limit orders at any price. Thus 84% of upstairs trades were completed on terms that support the Grossman hypothesis, despite the biases mentioned earlier. Seven percent (1,782 trades) were completed upstairs at prices identical to what they would have received downstairs, while 9% (2,524 trades) of the total trades would apparently have received better executions downstairs than they received upstairs. This reflects both that brokers could not have been sure of the downstairs execution (as some liquidity was hidden) and the biases mentioned earlier.

The percentages of trades that were executed at a price supporting the Grossman hypothesis is highest (91%) for the least active quintile of stocks and is lowest (83%) for the most active quintile of stocks. Thus, while the data support the Grossman hypothesis for all stocks, the results suggest that the ability to tap into pools of unexpressed liquidity could be most important for stocks in which trading activity and downstairs liquidity is less.

The results presented here can also be interpreted in light of traders' reluctance to let others know their trading intentions. The Paris Bourse allows traders to use hidden limit orders to avoid conveying too much information about their trading intentions to other market participants. Since hidden orders are used we can infer that traders find them valuable. However, hidden limit orders are not a complete substitute for communicating one's trading interest to upstairs brokers. If traders were willing to commit all of their trading interest in the form of hidden limit orders, then there would no longer be a need for upstairs brokers, or, equivalently, we would have found that upstairs trades paid the same or higher average costs as trades executed against the displayed and the hidden liquidity in the limit order book.

6. Crossing rules and execution costs

We next evaluate the effect of variation in crossing rules on execution costs.[16] An exchange's crossing (or interaction) rules stipulate the allowable price range for upstairs trades and whether downstairs orders that offer superior prices for smaller quantities will be allowed to participate in the transaction. At the NYSE, for example, upstairs trades must typically be completed at prices at or within the downstairs BBO, and downstairs participants are allowed to take a portion of the block.[17] At the TSE, upstairs trades need to be executed at or within the best bid-offer quotes in the downstairs market at the time the order is received by the upstairs broker. As Smith et al. (2001) note, this obligation leads upstairs market makers in Toronto to submit most orders immediately to the downstairs markets.

While the same crossing rules apply to all stocks at the NYSE and TSE, the crossing rules in effect at the Paris Bourse during our sample period varied depending on typical trading activity. For the majority of stocks listed on the Paris Bourse, upstairs trades need to be completed at or within the BBO quotes in the

[16] In another analysis of the effect of market rules, Gemmill (1996) examines changes in London Stock Exchange rules regarding the rapidity with which block trades must be reported to the market. He does not find a significant relation between block trade execution quality and reporting rules for block trades.

[17] NYSE rule 127 does allow for blocks to be completed at prices outside the downstairs BBO after "exploring crowd interest." However, this process is costly, and Hasbrouck et al. (1993) report that less than one-half of 1% of NYSE share volume occurs under Rule 127. Madhavan and Cheng (1997) note that NYSE crossing rules provide incentives for upstairs NYSE participants to complete the negotiated transaction as a "clean cross" on a regional stock exchange rather than the NYSE floor.

downstairs market at the time of the trade.[18] However, for a subset of active stocks (called eligible stocks), the Paris Bourse allowed block trades to be executed at prices away from the BBO at the time of the trade. However, trades in eligible stocks must still be completed within the weighted average spread computed by the Paris Bourse. The weighted average bid is the weighted average price of executing a market sell (buy) order of order size equal to the NBS against the limit order book. Hence, it takes depth away from the inside quotes into account and is an empirical measure of the displayed block liquidity in the book. Appendix A provides more detail regarding crossing rules on the Paris Bourse. We exploit the existence of variation in crossing rules to present evidence on their relevance.

Panel A in Table 6 reports locations of transaction prices for upstairs trades relative to the bid–ask quotes at the time of the cross. For each firm, we calculate the percentage of buyer- and seller-initiated trades that are executed outside the relevant quote, at the quote, and between the quote and the midpoint. For eligible firms ($N=80$) and non-eligible firms ($N=145$) in our sample, Panel A reports the median percentage of trades executed and the median trade size, in each location category. Also reported is the average quoted depth, the inside spread, the total execution cost, and, for eligible firms, the weighted average spread in the downstairs market at the time of the trade. As in Section 5, the execution cost measure reported compares the block transaction price with the quote midpoint at the time of the trade.

For *eligible* firms, about 10% of upstairs trades occur outside the quotes, and these trades pay execution costs that are about 40 to 50 bp higher than for upstairs trades executed at or within the quotes.[19] However, trades completed outside the quotes are larger than average and occur when downstairs spreads and depths are unusually small. For example, buyer-initiated trades completed above the ask price occur when the downstairs spread is 0.13% and the quoted depth is 11% of the NBS, compared with a spread of 0.27% and depth that is 16% of NBS when buyer-initiated trades are completed below the ask price. These statistics are consistent with the reasoning that those block trades completed outside the quotes might not otherwise have been completed at all.

We next turn to a detailed analysis of the decision to execute a trade in an eligible stock outside the quotes. We consider all 23,634 upstairs trades in eligible stocks. For these trades, we estimate a pooled time-series cross-sectional probit model with firm-specific indicator variables. The dependent variable equals one if the trade is completed outside the quote and zero otherwise. Explanatory variables include the quoted spread at the time of the trade, trade size relative to the NBS, a buy order dummy, a first hour of trade dummy, a last hour of trade dummy, and a measure of the imbalance in the downstairs market, defined as in Handa et al. (2004) as $\text{Imb}_t=$ ((weighted average quote on the same side–quote midpoint)/weighted average

[18] The Bourse does allow an exception for very large blocks (called structural blocks), which can be executed at prices away from the quotes, provided the trade size exceeds an amount as determined by an SBF-Paris Bourse Instruction.

[19] Only a miniscule proportion of upstairs trades in non-eligible firms are executed away from the inside quotes.

Table 6

Crossing rules and execution costs

Panel A reports the locations of transaction prices for upstairs trades relative to the bid-ask quotes at the time of the cross for eligible and non-eligible stocks. The Paris Bourse allows block trades in eligible stocks to be executed at prices away from the best bid-offer at the time of the trade. For both firm types, reported are the cross-sectional median percentage of trades executed and the median trade size [normalized by normal block size (NBS)], in each location category. For a buyer- (seller-) initiated trade, location categories are above (below) the ask (bid) price, at the ask (bid) price, and between the ask (bid) price and quote midpoint. For eligible firms, the average quoted spreads (in percent), quoted depth (normalized by NBS), and weighted average spread (in percent) at the time of the upstairs trade, as well as actual execution cost (%) are reported. Panel B reports the results of probit analysis of all block trades in eligible firms. The dependent variable equals one for trades completed outside the quotes.

Trade	Cross-sectional medians of firm-specific means							
	Eligible firms ($n = 80$ firms) $n = 23,637$ trades						Non-eligible firms ($n = 145$ firms) $n = 4,474$ trades	
Panel A: Location of the upstairs transaction relative to the quotes								
	Percentage of trades executed	Quoted spread (in percent)	Quoted depth/NBS	Weighted average spread (in percent)	Execution cost upstairs (in percent)	Trade size/NBS	Percentage of trades executed	Trade size/NBS
Seller-initiated trades								
Below the bid price	9.3	0.141	0.121	0.721	0.690	5.4	0.0	21.6
At the bid price	51.8	0.175	0.170	0.621	0.175	3.5	42.3	4.1
Above the bid price	40.2	0.263	0.154	0.766	0.113	3.5	57.1	3.9
Buyer-initiated trades								
Above the ask price	10.4	0.125	0.107	0.624	0.582	3.9	0.0	170.7
At the ask price	53.5	0.177	0.181	0.586	0.177	3.5	42.9	3.4
Below the ask price	35.0	0.269	0.159	0.745	0.117	3.6	58.3	3.8

Panel B: Probit analysis of the decision to execute away from the inside quotes
Dependent variable = one if upstairs trade is executed outside quotes and zero otherwise

Constant	Bid–ask spread	Order imbalance	Trade size/NBS	Buy order dummy	First hour dummy	Last hour dummy
−1.452[a]	−1.233[a]	0.841[a]	0.007[a]	0.014	−0.453[a]	−0.145[a]

[a] P-value < 0.01.

spread). The imbalance variable takes a value closer to zero (one) when there is more (less) downstairs trading interest on the side of the initiating order.

Block initiators are likely to be more receptive to executions outside the quotes when downstairs liquidity is lacking, implying a positive coefficient estimate on the imbalance measure and a negative coefficient on the spread width. Larger trades and buy orders are generally more difficult to facilitate, so we also anticipate positive coefficients on these variables. If traders wait to observe market conditions after the open, we anticipate a negative coefficient on the first hour of trading indicator. Finally, if traders place a premium on completing the transaction before the market close, we anticipate a positive coefficient on the last hour of trading indicator.

Results of estimating probit model are reported in Panel B of Table 6. Each coefficient estimate is of the anticipated sign (except for the last hour indicator) and all are statistically significant (except for the buy order dummy). Market participants are more likely to agree to having a block trade executed at a price outside the quotes when the inside spread is narrow, when there is relatively little liquidity in the downstairs book on the side of the initiated trade, for large trades, and for buy orders. They are less likely to complete block trades outside the quotes during the first and last hours of trading. This last result could reflect the possibility of trading during after-hours crossing sessions. On balance, these results are consistent with market participants agreeing to outside-the-quote executions for more difficult trades completed during more difficult market conditions and with the notion that these trades might not have been completed at all in the absence of the option to take the price outside the quotes.

The NYSE effectively requires all upstairs trades to be completed at prices at or within the best downstairs quotes. The recent (January 2001) reduction in the NYSE tick size to one cent has narrowed the inside bid–ask spread and reduced the depth of the NYSE quotes (see, for example, Bessembinder, 2003). In short, decimalization has made the requirement to complete upstairs-facilitated trades at or within the quotes more restrictive. Our analysis of cross-sectional variation in crossing rules suggests that market quality could be improved by allowing upstairs initiators to agree to prices outside the quotes. Consistent with this view, the Euronext market (which was created by the September 2000 merger of the Paris, Brussels, and Amsterdam stock markets) now allows block trades in all stocks to be executed outside the quotes.[20]

7. Transaction costs and self-selection of trading venue

Since trade initiators presumably select the market (upstairs or downstairs) they expect to provide the lowest cost execution for their trade, the observed execution cost measures must be interpreted as conditional on self-selection of venue. In this section we present an analysis of unconditional execution costs, i.e., costs for orders

[20] See section 4403/2B of "Harmonized Market Rules, Book I," which is available at www.euronext.com.

selected at random, to measure the inherent cost of completing trades in the upstairs market and in the electronic limit order market. This allows investigation of the common perception that execution costs are lower in an electronic market and validation of the intuition that traders do strategically select the market to route their order. The technique to correct for self-selection of trading venue involves two stages (see Maddala, 1983, and Greene, 2000, for general discussions, and Madhavan and Cheng, 1997, for a similar implementation that uses data from the NYSE trading floor). In the first stage, the block initiator's choice process is modeled as a structured probit. In the second stage, execution costs in each market are estimated while correcting for the selection bias.

7.1. Determinants of the choice of the trading venue

The block initiator will route his order to the market with the lowest expected execution cost. This will depend in part on liquidity in the limit order book. We use as empirical proxies for liquidity the bid–ask spread and a measure of order imbalance (as defined in Section 6). Other variables that likely affect the choice of the trading venue are the block size (normalized by the NBS), return volatility (when slower upstairs executions could prove more costly), and the (inverse) stock price. A dummy variable that denotes buyer-initiated trades is also included.

The choice of market is modeled as a structured probit, in which the dependent variable is an indicator variable that equals one for an upstairs trade and zero for a downstairs trade. We expect that a block initiator will more likely route the order to the upstairs market for larger order sizes, during periods of wider downstairs spreads, during larger order imbalances, and when volatility is lower. If buyer-initiated trades are more likely to be initiated by an informed trader, as implied by Burdett and O'Hara (1987) and Saar (2001), then the probability of an upstairs execution will be lower for a buyer-initiated trade.

To control for firm-specific effects and allow valid inference, we estimate the first-stage probit and the second-stage regressions simultaneously, using maximum likelihood estimation (MLE), on a firm-by-firm basis. Panel A of Table 7 reports median coefficient estimates from the Probit model for the 115 firms with more than 30 block trades in which the MLE routine converged. All average coefficient estimates are of the predicted sign and are statistically significant. The likelihood of routing a order to the upstairs market is higher during periods of wider spreads, larger order imbalance, and lower volatility; for larger orders; and for a seller-initiated trade.

7.2. The endogenous switching regression model

Trading costs in the upstairs and downstairs markets can be modeled as

$$\mathrm{E}[\tau_i^{\mathrm{u}} | U_i = 1] = \beta_{\mathrm{u}} * X_i + \alpha_{\mathrm{u}} * [\phi(\gamma * Z_i)/\Phi(\gamma * Z_i)], \quad (5)$$

$$\mathrm{E}[\tau_i^{\mathrm{d}} | U_i = 0] = \beta_{\mathrm{d}} * X_i + \alpha_{\mathrm{d}} * [-\phi(\gamma * Z_i)/(1 - \Phi(\gamma * Z_i))], \quad (6)$$

Table 7
Liquidity effects of a random trade after controlling for selection bias
Panel A presents the median coefficient estimates from the probit model of the likelihood that an order is routed to the upstairs market. The model is estimated on a firm-by-firm basis. The dependent variable is an indicator variable that equals one for an upstairs trade and zero otherwise. The explanatory variables include liquidity measures, such as the bid–ask spread and the order imbalance at the time of order execution, and order characteristics such as the order size and buy/sell indicator, besides the stock volatility and the stock price. The trades are classified into market buys and sells using the Lee and Ready (1991) algorithm. Panel B presents the median coefficient estimates of the endogenous switching regression model of the temporary price effects of block trades that is specified as follows:

$$E[\tau_i^{u}|U_i = 1] = \beta_u * X_i + \alpha_u * [\phi(\gamma * Z_i)/\Phi(\gamma * Z_i)];\ \text{and}$$

$$E[\tau_i^{d}|U_i = 0] = \beta_d * X_i + \alpha_d * [-\phi(\gamma * Z_i)/(1 - \Phi(\gamma * Z_i))];$$

where $X_{i,t} = (1, Q_{i,t}/\text{NBS}_i, \text{DMKTORD}_t, \text{DMKTORD}*Q_{i,t}/\text{NBS}_i)$. Q_t is the order size, NBS_i is the firm's normal block size (NBS), DMKTORD equals one for a buyer-initiated trade and zero otherwise, and $\gamma * Z_i$ denotes the estimated value of the continuous response variable from the first-stage probit model. To allow valid inference, the two models are estimated simultaneously using a maximum likelihood estimator approach, on a firm-by-firm basis. Panel C presents the median difference in execution costs in the two markets for a random buy or sell order using the selectivity-corrected parameter estimates (β) and average order characteristics (X_i) for each firm as follows:

$$E[\tau_i^{u} - \tau_i^{d}] = (\beta_u - \beta_d) * X_i$$

Panel A: Probit analysis of the choice of the trading venue

	Constant	Bid–ask spread	Order imbalance	Buy order	Order size/NBS	Volatility (hourly)	Price (inverse)
	–0.743	0.488[a]	0.395[a]	–0.199[a]	0.281[a]	–1021.51[a]	–24.43

Panel B: Selectivity adjusted analysis of liquidity effect in both markets
Temporary price effect

	Constant	Order size/NBS (Q)	Buy order	Buy order * Q	Covariance (sigma)
Upstairs market	34.59[a]	–0.07	–1.68	–1.49	–15.28[c]
Downstairs market	0.65	0.84	–25.69[a]	–0.09	37.20[b]
Upstairs–downstairs	31.56[a]	–2.19	27.28	0.04	–47.84[b]

Panel C: Execution cost of a random order (in basis points)
Temporary price effect

	Sell order	Buy order
Upstairs–downstairs	41.27[b]	63.63[a]

[a] P-value < 0.01.
[b] $-0.01 < P$-value < 0.05.
[c] $-0.05 < P$-value < 0.10.

where ϕ (.) denotes the standard normal density function, Φ (.) denotes the cumulative standard normal distribution, Z's are the explanatory variables used in the probit estimation of trading venue, γ's represent coefficient estimates from the probit model, and X's represent the variables affecting expected liquidity costs. Eqs. (5) and (6) estimate execution costs conditional on traders' self-selection of trading venue in both markets. The role of the second terms in brackets on the right-hand side of Eqs. (5) and (6) is to correct for selection bias. These selectivity bias adjustment variables are simply non-linear combinations of the variables used to predict choice of trading venue. As a result of the selectivity correction, the first term on right-hand side of Eqs. (5) and (6) measures the (unconditional) execution costs of a random order submitted to each market, i.e., of an order that is not certified as informed or uninformed and that does not strategically time variations in liquidity across markets. If traders strategically select their execution market, then execution costs conditional on selection of a market will be lower than the unconditional execution costs. That is, we expect $\alpha_u < 0$ and $\alpha_d > 0$.

Because theory suggests that order size affects execution costs, we include order size, Q_i (normalized by the NBS), as an explanatory variable. The asymmetric effects of buyer- versus seller-initiated orders are captured by an indicator variable that equals one for buyer-initiated trades. Also, we include the product of the buyer-initiated indicator variable and order size to allow for differences in marginal effects of order size across buyer- and seller-initiated trades. The slope coefficients in Eqs. (5) and (6) estimate the marginal effects of characteristics of random orders submitted to each market.

The results of the regression analysis are presented in Panel B of Table 7. The dependent variable is the temporary price effect, $\tau(Q)$, in basis points. As predicted by theory, the estimate of α_u is significantly negative while the estimate of α_d is significantly positive, empirically confirming that traders strategically select the market that provides lower execution costs.

The intercept term in the upstairs market regression is statistically and economically significant (34.5 bp), and the difference between the intercepts in the upstairs and downstairs market is positive. This result provides direct support for Hypothesis IV that the upstairs market incurs higher fixed costs, reflecting the need for screening, search, and negotiation. Somewhat surprisingly, the marginal effect of order size on execution costs is not statistically significant in either market. In the upstairs market, this likely reflects that trader reputation, rather than order size, is the determinant of execution costs.

Finally, we estimate the difference in execution costs for a random order in the upstairs and downstairs market using the selectivity-corrected parameter estimates (β's) from Table 7, as

$$E[\tau_i^u - \tau_i^d] = (\beta_u - \beta_d) * X_i. \quad (7)$$

We evaluate Eq. (7) based on an order with average characteristics for each firm. In Panel C of Table 7 we report cross-sectional median estimates indicating that, for a random seller- (buyer-) initiated order, liquidity costs are lower in the downstairs markets by 41 (64) basis points. Estimates of this cost differential are little altered when we evaluate Eq. (7) for larger or smaller trade sizes, because coefficient estimates on trade size are close to zero.[21]

This analysis confirms that traders self-select to the market that will provide the better execution cost for their trades and indicates that the liquidity cost of executing a typical block order is lower in the downstairs market than in the upstairs market. This provides support for those who argue that an electronic trading process is inherently less expensive than a trading process with human intervention. Glosten (1994), for example, argues that the electronic limit order book is ''inevitable'', unless alternative market structures can provide tangible benefits to overcome their greater costs. Based on the estimates obtained here, the Paris upstairs market is a viable alternative for those traders who gain at least 41 (64) bp by reacting strategically to time variation in relative liquidity across the upstairs and downstairs markets, or by credibly signaling that their sell (buy) orders do not reflect private information.

8. Conclusions and discussion

This paper studies an upstairs market operating in parallel with an electronic stock exchange, using data on 92,170 block trades completed at the Paris Bourse. The answer to the question posed in the title of this paper is clearly yes. Despite the lower operating costs of the electronic market, the upstairs market is efficient for many large traders, and over two-thirds of the block-sized trades in our sample are completed in the upstairs market. While our analysis confirms the certification role of block brokers predicted by Seppi (1990), we also provide strong empirical support for the Grossman (1992) hypothesis that upstairs brokers reduce trading costs by tapping pools of unexpressed liquidity.

We argue that Paris provides an excellent setting to test the implications of upstairs intermediation models, because its electronic limit order market closely resembles the downstairs markets envisioned by theorists. We find strong support for the predictions that: (1) upstairs brokers lower the risk of adverse selection by certifying block orders as uninformed, (2) upstairs brokers are able to tap into pools of hidden or unexpressed liquidity, (3) traders strategically choose across the upstairs and downstairs markets to minimize expected execution costs, and (4) trades are more likely to be routed upstairs if they are large or are in stocks with less overall trading activity. Of these, result (2) is the most novel and arguably the most important. We document that upstairs trades pay execution costs averaging only about 20% of what they would have paid if the same trade had been executed against displayed liquidity in the limit order book and about 35% of what they would have paid if executed against both the displayed and the hidden liquidity in the limit order book.

[21] When we run the model using permanent price effects as the dependent variable, the estimated permanent effects are greater upstairs for sells and greater downstairs for buys, but the differences are not statistically significant. This supports our priors that permanent price effects should be the same upstairs and downstairs for a random order, i.e., in the absence of any certification effect.

We investigate the effect of variations in crossing rules at the Paris Bourse on execution costs. For eligible stocks, market participants agree to outside-the-quote execution mainly for more difficult trades and at times when downstairs liquidity is lacking. These outside-the-quote executions likely represent trades that could likely not have been otherwise completed, suggesting that market quality can be enhanced by allowing participants more flexibility to execute blocks at prices outside the quotes. Consistent with this reasoning, the Euronext market has recently adopted rules that allow large block trades in all Paris stocks to be executed outside the quotes. These findings are particularly relevant to U.S. markets because quoted spreads and depths have decreased substantially in the wake of decimalization.

The upstairs market in Paris completes two-thirds of block trading volume, compared with 20% on the NYSE. A likely explanation is that the NYSE floor allows large traders to execute customized strategies through a floor broker, while avoiding the risks of order exposure. If orders submitted to electronic markets do not allow block initiators to limit order exposure and trade strategically, then order flow is likely to migrate to alternative trading venues such as the upstairs market.

To compete with broker-intermediated markets, the next generation of electronic trading systems need to include features that better meet the needs of large traders. Hidden limit orders are useful, but insufficient. To allow large investors to manage order exposure in an electronic exchange, a wider range of order types that include state contingent exposure and execution algorithms need to be made available. The NYSE's recently introduced "Conversion and Parity" orders (see NYSE (2003)), which are intended to be "smart" orders for large lots of stocks that are executed gradually through the day, contingent on market conditions, comprise a step in this direction.

Appendix A

The trading rules described below were in effect in Paris during our sample period and are outlined in the manual titled "The Organization and Operation of the Regulated Market Operated by SBF-Paris Bourse," dated March 30, 1998, which is published by SBF-Bourse de Paris. We also held extensive discussions with exchange officials for additional clarifications on the trading rules and the Base de Donnees de Marche (BDM) data set.

A.1. Crossing rules

During our sample period, the Paris Bourse had two distinct sets of rules for block trading. Upstairs trades in most Paris Bourse stocks must be executed at prices at or within the best bid-offer (BBO) quotes in the downstairs market at the time of the trade (Articles N.4.1.17 and N.4.2.6). However, the Paris Bourse classified certain stocks as being eligible for the special rules of block trading (Article N.4.2.8). For these eligible stocks, the Bourse specified a normal block size (NBS) and continuously disseminated the weighted average spread (WAS). The weighted average bid (ask) gives the weighted average price of executing a market sell (buy) order of order size equal to the NBS against displayed liquidity in the limit order book.

An upstairs trade in an eligible stock with size greater than the NBS can be executed at prices at or within the WAS (Articles N.4.2.9, N.4.2.10, and N.4.2.13). During our sample period, upstairs trades in the non eligible stocks cannot trade through the book.

A.2. Reporting rules

An upstairs trade could involve a member firm as a dealer (principal) or broker (cross-trade). All upstairs trades have to be reported immediately to the Paris Bourse (Article N.4.2.15). Cross-trades and ordinary principal trades are published with no delay (Article N.4.2.17). Principal block trades that are less than five times the NBS are published at the end of a two-hour period commenced upon notification. Structural block trades that are at least five times larger than the standard block size are published at the opening of the next trading session.

The BDM data set provides the time at which an upstairs trade is reported to the exchange and not the time at which an upstairs trade is publicly published. While the data set does not distinguish between principal and cross-trades, exchange officials informed us that the majority of upstairs trades are cross-trades and are published with no delay. However, to account for delayed reporting, we use the midpoint of closing quotes on the next trading day to calculate our measures of trades' permanent and temporary price impacts.

Appendix B

The Base de Donnees de Marche (BDM) database contains information on all orders for all stocks. The order data includes the firm symbol; date and time of order submission; a buy or sell indicator; the total size of the order (in shares); the displayed size (in shares); an order type indicator for identifying marketable, market, open or limit orders; a limit price in case of a limit order; an order validity indicator that indicates when the order will expire (day-order, fill or kill, good until canceled); a date variable that denotes the specific date on which the order will expire; and a "putthru" indicator to identify orders that were executed in the upstairs market. In addition, each order contains fields that allow tracking of any modification made within the day, except that the data set does not record cancellations. The data also provide information on the status of the order at the end of each trading day. All orders for stocks traded with monthly settlement automatically expire on the last day of the settlement cycle (typically around the 24th of each month), and all order for stocks traded in the cash market automatically expire on the last day of the current month.

The book is empty before 8:30 a.m. on the first trading day (day 0) of a new settlement cycle. We accumulate orders that arrive between 8:30 a.m. and 10:00 a.m.

The opening call auction is around 10 a.m. If a call auction occurs, the trade file will contain multiple trades executed at the same time and at the same price.[22] Using the clearing price and size information from the trade file, we clear buy and sell orders in the book that executed at the open. The first quote of the day is used to cross check that the clearing is accurate.

During regular trading hours we add newly arrived limit orders to the book, and we clear orders from the book after trades, as follows:

- If the initiating order fully exhausts a limit order, the limit order is deleted from the limit order book (LOB). If the limit order is partially executed, its size is reduced by the part executed. If the initiating order is large enough to walk up the book, orders that are completely executed are deleted, and the size of orders that are partially executed are reduced. The trade file has information on the number of shares executed at each price level which we use to clear the orders on the opposite side of the book.
- If a market order to buy (sell) is not fully executed, then the unexecuted portion remains in the book as a buy limit order at the ask (bid) price.

The main limitation of the BDM data is lack of information on order cancellations. Therefore, the depth in the LOB may be overstated. However, the end-of-the-day order status variable allows us to identify canceled orders as of the end of the trading day, so the effect of not observing order cancellations will never accumulate across days.

We are able in some instances to infer when an order has been canceled. If an order at the inside quote is canceled, it will generate a quote revision, but we will not observe a new order in the order file. We use quote updates that occur in the absence of trades or new orders to identify some cases in which orders are canceled. Similarly, a downstairs trade will always generate a quote update. We cross check that our constructed LOB generates the same quote update. If there is a discrepancy, it results from an order cancellation. We can sometimes identify and delete an order to make the constructed limit order book consistent with the quote file.

Modifications of orders are handled by adding the modified order to the book, while deleting the order modified. Identification of linked orders is facilitated by the order status variable flagged as code M and by linking order reference codes. If the order being modified cannot be unambiguously identified, then we do not delete any order, and the effect again is to overstate depth until the end of the trading day.

Despite the imperfections that may cause us to sometimes overestimate limit order book depth during the trading day, the BDM database contains end-of-day state variables that allow accurate assessment of the end-of-day (and beginning-of-next-day) limit order book. For orders that are partially executed, we move the remaining shares (i.e., part of the order not executed) to the next day. Any order that did not take part in trading on day 0 and is still valid simply remains in the book the following day.

[22] This differs from what we would observe when a large marketable order walks up the book. We would then observe multiple trades at the same time but at different prices.

Upstairs trades do not clear orders from the limit order book. For upstairs trades that are buyer-(seller-) initiated we calculate the weighted average price on the sell (buy) side of the limit order book against both the total shares and the displayed shares. The weights are the percentage of shares executed against total or displayed depth at each price level as the trade walks up or down the LOB. This is the price at which this upstairs trade would have executed if it had been sent downstairs.

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