Crossing Network Trading and the Liquidity of a Dealer Market: Cream-Skimming or Risk Sharing?[♣]

Carole Gresse
Université de Paris-Nanterre & CEREG
e-mail: carolegresse@hotmail.com
http://www.carolegresse.com

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Finally, results and conclusions in the paper have been achieved in total independence from any public or private institution and wholly reflect the opinion of the author. All errors are mine. Suggestions are welcome.

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Abstract

This article investigates the relationship between the trading activity of a crossing network (CN) and the liquidity of a traditional dealer market (DM) by comparing data from the SEAQ quote-driven segment of the London Stock Exchange (LSE) and internal data from the POSIT crossing network over two 6-months' periods. This exploratory study, which is the first one to use internal CN data, provide new insights into market competition between traditional exchanges and alternative trading systems in Europe, and opens further research leads. Based on a cross-sectional analysis in a sample of UK mid and small cap stocks, the findings support that CN-trading does not significantly increase adverse selection and inventory risk on the central market. It appears that the competition between market makers strengthens with the CN activity, and CN-trading gives dealers a risk sharing opportunity that leads them to improve quotes.

Crossing Network Trading and the Liquidity of a Dealer Market: Cream-Skimming or Risk Sharing?

During the last decades, new electronic trading systems, designated by the SEC as *Alternative Trading Systems* (ATS),[1] have developed all around the world, in response to the need expressed by institutional investors as well as broker-dealers[2] for alternative systems that would help reduce the cost of trading. These ATSs divide in two categories: Electronic Communication Networks (ECNs), which work as anonymous electronic order books, and Crossing Networks (CNs), which cross unpriced buying and selling interests. Like ECNs, CNs generally promise anonymity and lower transaction costs, but the main difference with ECNs is that participants do not enter the prices at which they wish to trade, so that no price discovery takes place in a CN. Instead, at designated cross times, interested buyers and sellers are matched and the price at which the trades execute is taken from an exchange. This price can be the central market mid-quote, or, in some cases, the preceding closing price or the volume-weighted average price over some period. In a CN, trades execute with no market impact, yet execution is not guaranteed. In such, CN address the needs of a certain type of traders, ready to sacrifice immediacy and execution guarantees so as to obtain low-cost execution.

ECNs have gained substantial market share in trading volumes in the US, since the opening of Instinet[3] in the 70s, and now account for approximately 40% of the NASDAQ trading volume.[4] As for CNs, the main ones currently operating in North America are the Reuters' Instinet Crossing Network, ITG's POSIT[5] and the New York Stock Exchange's after-hours Crossing Network, the most prominent being POSIT. POSIT developed quickly in the United States. 35 millions of shares are presently traded daily on this system, which represents around 2,5% of volumes. The competition coming from these new trading facilities have changed the structure of financial markets, and probably also the role of intermediaries on these markets. The implications for liquidity are of much interest for academics, regulators and investors. Several articles have already addressed this issue by using ECN data, but no work has been done yet with CN data. This paper focuses and provides new evidence on the consequences of the trading activity of a CN, by testing market data from the London Stock Exchange dealer market segment (SEAQ[6]) and private data from the POSIT European crossing network.

To this goal, the London Stock Exchange is an interesting case of investigation because, conversely to the situation in the US, ECNs have not developed in Europe, where only CNs have emerged. For that reason, the impact of CN-trading can be tested independently from the potential effect of other ATSs.

The very first attempt to create crossing facilities in Europe took place in the UK, in the 80s, with the crossing system ARIEL, which, at that time, failed in attracting and executing substantial order flow. Ever since, two London-based crossing networks have emerged on European stock markets. First, after being already operating in the North-American and Australian markets, POSIT was adapted to Europe and launched there on the 18th of November 1998 by ITG Europe.[7] It is now working for eleven European countries.[8] A second CN followed in March 2000. A team of institutional investors, led by Barclays Global Investors and Merrill Lynch Investments Managers, created E-crossnet. Up to now, E-crossnet has not really succeeded in reaching a critical mass and the rate of execution in its system has kept quite low from its start, so that POSIT has remained the biggest CN on the European market. At the current date, the main part of the POSIT order flow is related to UK mid and small caps.

As a consequence, since 1998, institutional investors and broker-dealers have several venues to trade within the UK stock market: they can either submit an order to the central market of the London Stock Exchange (LSE) or submit it to a CN. In the former case, they incur the bid-ask spread but get higher execution guarantee. In the latter case, their probability of execution is little but they are provided anonymity, they incur no adverse selection cost as their orders are not visible from the rest of the market, and, if executed, they trade at the mid-quote with no market impact.

The objective of this paper is to analyse the effects on the liquidity of a dealership market of CN submitted and crossed order flow, by using both private data from a CN and public market data from SEAQ, over two 6 months' periods. These data are particularly well-adapted to the aim of the research, as the SEAQ trading platform is a nearly pure quote-driven market where the POSIT crossing network attracts the major part of multilateral crossing. The paper is organised as follows. Section 1 sets the theoretical framework of the study and derives a series of testable hypotheses about the impact of CN trading activity on the liquidity of a DM. Section 2 provides information on the organisation of the SEAQ market segment and the workings of the POSIT crossing network. After describing the data and the samples in Section 3, stylised facts about market activity, CN order flow and CN-traded stocks are reported in Section 4. Finally, the testable hypotheses developed in section 1 are tested: methodology and results are presented in section 5. Section 6 concludes.

1. Theoretical findings on market competition with a CN and testable hypotheses

The emergence of ATSs has given rise to a stream of research around the trade-off between the benefits of competition and the potential costs of order flow fragmentation that ATSs may cause. The debate[9] began with Hamilton (1979), who pointed out the two opposite effects of multi-market trading and the deviation of a part of the order flow from the central market. Either multi-system trading increases *competition* among liquidity providers and thus reduces bid-ask spreads, or, conversely, the *fragmentation* of the order flow between several locations lowers economies of scale and probabilities of execution, resulting in higher volatility and spreads.

1.1. The potential benefits and costs of multi-system trading

A common argument in favour of multi-system trading is that increased competition could reduce the market power of price-setting agents and thus result in better execution conditions, as mentioned by Easley, Kiefer and O'Hara (1996). Giving the opportunity to trade at mid-quote, CNs such as POSIT, contribute to reduce the average cost of trading, increase the competition between liquidity providers, as market makers[10] or limit order traders, resulting in lower bid-ask spreads. A substantial number of papers provide empirical evidence on the gains from the competition between ATSs and traditional markets as well as on the cost savings institutional investors may get from trading on ECNs or CNs (Barclay, Hendershott and McCormick (2002), Næs et Ødegaard (2001), and Conrad, Johnson and Wahal (2002), Huang (2002), Weston (2001)).

At the opposite, some authors argue that trading at multiple locations is potentially detrimental to liquidity. With the fragmentation of the order flow, each trading system will have fewer people willing to trade, making it more difficult to find a counterparty. Mendelson (1987) demonstrates that trading in a security market possesses a network externality, which means that a security market is more valuable to customers as more customers engage in trading at that location. The dispersal of orders between several trading locations lowers the probability of execution at each location and therefore reduces liquidity.

Under information asymmetry, Chowdry and Nanda (1991) show that informed trading, and thus adverse selection costs, increase with the number of markets listing an asset.

Moreover, when a new market opens for a stock, it may skim the least informed and consequently more profitable orders, and then harm the liquidity of the primary market. Barclay, Hendershott and McCormick (2002) highlight that such is not the case for ECNs competing with NASDAQ: the more informed orders spill onto the ECNs and market makers' preferencing and internalisation agreements allow them to retain the less informed order flow. At the opposite, Easley, Kiefer and O'Hara (1996) and Bessembinder and Kaufman (1997) show that US regional exchanges attract mostly uninformed orders in the NYSE stocks.

However, most of these theoretical predictions and empirical findings on adverse selection costs assume that price discovery is active at all trading locations and that trades have market impact on every market. Hence, they cannot fully apply to the case of a CN competing with another market. No price discovery is taking place in a CN, where transaction prices are derived from another market without producing market impact. Because of this specific feature, potential competition or fragmentation effects induced by a CN may slightly differ from those caused by trading systems with pricing mechanisms, like ECNs.

To address the particular case of CNs, Hendershott and Mendelson (2000) model the inter-market competition between a CN and a competitive dealership market (DM). Their theoretical predictions are widely discussed in the next paragraphs and will serve as a basis to the testable hypotheses investigated in section 5.

1.2. Theoretical findings on multi-market competition involving a CN

Hendershott and Mendelson (2000) and Dönges and Heinemann (2001) specifically study the case of a CN operating next to a DM. They show that, when traders assign the same value to trading, it is very unlikely that both markets co-exist. Conversely, when the value assigned to order execution differs across investors, the CN and the DM should co-exist: traders with high trading value cluster on the DM while traders with low trading value choose the CN. The consequences of this double-market situation on liquidity are widely discussed in Hendershott and Mendelson (2000).

Their model shows that the effects of CN-trading on a DM are ambiguous. On the one hand, traders who exclusively use the CN can provide a counterbalancing effect that reduces adverse selection and inventory costs for market makers on the central market. On the other hand, the CN may fragment the market: traders who use the DM as a "market of last resort", i.e. submit orders to the CN first and then go to the DM if not executed, can induce dealers to widen their spread.

They consider a population of traders compounded of:

– informed traders with short-lived private information,
– informed traders with long-lived private information
– uninformed traders with different preferences for liquidity.

There are two trading venues: a DM, where orders are charged the half-spread but executed with certainty, and a CN, where execution is risky but provided at mid-quote. Thus, traders have four possible strategies:

– do not trade,
– trade exclusively in the CN and do nothing if the order fails to execute,
– trade opportunistically in the CN, in other words, submit an order to the CN and if it fails to execute, trade in the DM,
– trade only in the DM without first attempting to trade in the CN.

The game results in multiple equilibria, all characterised by the following structure.

1. By hypothesis, the informed traders' decisions are driven by the longevity of their information:

– short-lived information forces trading in the DM exclusively;
– long-lived information leads to opportunistic trading in the CN.

2. Any liquidity trader, according to the value they assign to their trades, will choose from the following strategies:

– uninformed traders with very low preference for liquidity do not trade at all;
– low-preference-liquidity traders trade exclusively in the CN;
– medium-preference-liquidity traders use the CN opportunistically;
– high-preference-liquidity traders trade immediately in the DM.

From there, the global effect of CN-trading on the DM in equilibrium is unclear. On the one hand, additional liquidity trading in the CN produces positive risk-sharing effects. On the other hand, opportunistic CN-trading induces negative cream-skimming effects.

The positive risk-sharing effects on the dealers' spread

1. Dealers’ inventory costs are reduced because the expected dealer imbalance is decreased due to long-lived information trading in the CN.

2. The CN attracts both new low-liquidity-preference traders who would not otherwise trade and liquidity traders who would otherwise go directly to the DM: in case of long-lived private information, a part of the adverse selection risk is then born by these CN liquidity traders.

The negative cream-skimming effects on the dealers' spread

1. Allowing liquidity traders to use the CN opportunistically rather than go directly to the DM tends to widen dealers' spreads. The CN is then skimming off a part of the uninformed trades, which cannot be used anymore by dealers to compensate their losses on informed trades. Actually, the traders that strategically use the DM as a "market of last resort", either informed or uninformed, make the DM riskier and force dealers to quote larger spreads.

2. If CN-trading leads to higher dealer spreads, then the lower-liquidity-preference traders, many of whom would not trade with the DM as the only option, are made better off because they get a lower-cost trading opportunity. However, the higher-liquidity-preference traders are made worse off: they still trade in the DM, but now at higher cost. In whole, the CN can either improve or harm social welfare.

1.3. Dealer trading in the CN

Hendershott and Mendelson (2000) clearly demonstrate that the CN may create an interesting risk-sharing benefit for dealers. In their model, this benefit comes from pooling customer orders in the CN and not from inter-dealer trading or dealer trading in the CN, yet the CN structure can also be viewed as an ideal mechanism for facilitating inter-dealer trading or dealer principal trading.

As shown in Reiss and Werner (1998), inter-dealer trading, by producing risk-sharing benefits, reduces dealers' costs and consequently allow them to improve their spreads. Therefore, another role of the CN, that has not been modelled in previous literature, might consist of providing dealers with a mean to trade at low cost after executing customers' demand. If the CN actually plays the role of a risk-sharing tool, its activity could then result in lower spreads on the DM.

A series of hypotheses ensuing from all these theoretical predictions about the implications of CN-trading for market liquidity, are now developed in the next subsection.

1.4. Testable hypotheses

Four groups of testable hypotheses are derived from the theoretical literature, and more specifically from Hendershott and Mendelson's model. The first group of hypotheses concerns the consequences of CN opportunistic trading with respect to the harmful impact of CN unexecuted order flow. Then, follows two categories of hypotheses on the risk-sharing effects: the first one focusing on the trade-off between the so-called cream-skimming effect and the potential risk sharing effect due to new liquidity trading in the CN, the second one addressing the issue of dealer trading in the CN. Finally, the last set of hypotheses aims at defining tests of the net global effect of CN-trading on the competitiveness of prices and transaction costs.

1.4.1. The cream-skimming effect due to opportunistic trading in the CN

As pointed out by Hendershott and Mendelson (2000), when patient liquidity traders and fundamental informed traders are present in the market, they will use the CN opportunistically: they will first submit orders to the CN, and use the DM as a "market of last resort", if CN orders get no execution. As a result, the CN first skims off liquidity trades from the central market; secondly, the unexecuted opportunistic CN order flow makes the DM riskier when coming back to the dealers after crossing hours, and increases market making costs at the end of the trading session. For this reason, hypotheses H1 and H2, related to the cream-skimming effect, are based upon the impact of the POSIT unexecuted order flow.

Hypotheses H1 and H2

H1. ***Crossing activity makes the DM riskier at the end of the trading day because unexecuted opportunistic CN orders come back to dealers after the crosses.***

If H1 holds, the volatility of closing prices per unit of traded volume would increase with the CN unexecuted order flow.

H2. ***Unexecuted order flow coming back from the CN to the central market for execution, creates temporary tension on liquidity, either because it increases adverse selection, as demonstrated in Hendershott and Mendelson (2000), or because it suddenly generates abnormal inventory costs for market makers.***

Provided H2, quoted spreads would widen with the amount of unexecuted CN order flow, and closing spreads would widen more than intra-day spreads.

1.4.2. Risk-sharing effect due to new liquidity trading in the CN vs cream-skimming effect

The cream-skimming effect may nevertheless be offset by a positive risk sharing effect induced by new liquidity trading attracted into the CN. On the one hand, the CN may skim off uninformed trading from the DM, and thus increase adverse selection costs on the central market; but, on the other hand, it can also attract new liquidity traders, who would not trade out of the CN because trading in the DM would be too costly for them. These new liquidity-motivated orders help to absorb long-lived information-based orders in the CN, which reduces market-making costs on the DM and creates a risk sharing effect. Hypotheses H3a and H3b focus on this alternative.

Hypotheses H3

H3a. ***The fragmentation of the order flow between the central market and the CN creates additional adverse selection costs on the DM, because the CN skims off opportunistic liquidity trading from the DM, where the proportion of informed trading gets higher.***

Under H3a, intra-day quoted spreads would increase with the share of order flow submitted to POSIT.

H3b. ***The fragmentation of the order flow between the central market and the CN lowers adverse selection and inventory risk on the DM because the CN attracts new liquidity traders whose orders help absorb the opportunistic informed order flow.***

If intra-day quoted spreads decrease in the share of order flow submitted to POSIT, H3b is accepted and H3a is rejected: the risk-sharing effect can then be considered dominant over the cream-skimming effect.

1.4.3. The risk-sharing effect due to dealer trading in the CN

One major specific of the POSIT crossing network lies in that it is open to the sell side. This specific feature allows me to test H4.

Hypothesis H4

H4. ***The CN gives an opportunity to market makers to reallocate their positions with no implicit trading cost and thus lowers inventory costs.***

Under H4, intra-day and closing quoted spreads should be negatively related to the share of volume traded by market makers through the CN.

1.4.4. Global effect on implicit transaction costs and price competitiveness

Finally, the last hypotheses all relate to the general question: ***does the competition effect dominate the fragmentation effect when a CN operates within a DM?*** If so, the competition between price-setting agents would intensify with crossing (cf. H5), resulting in lower temporary market impact of trades (H6) and less expensive cost of trading for all traders (H7).

Hypotheses H5, H6 and H7

H5. ***The competition in price-setting between market makers intensifies with CN-trading.***
If H5 holds, then the number of quote revisions per day would increase with the share of order flow going to the CN.

H6. ***Due to competition effects, temporary market impact decreases with the crossing network activity.***
The higher the temporary market impact of trades, the more sell prices differ from buy prices, the difference increasing in the associated quantities. Trade prices are then more volatile around the daily average transaction price, i.e. the so-called VWAP (volume-weighted average price). Provided H6, that is provided crossing globally helps to reduce the market impact of transactions, intra-day volatility around VWAP would be negatively related to the share of traded volume executed in the CN.

H7. ***CN-trading helps reduce the cost of trading for all traders.***
Under H7, quoted spreads should be negatively related to the share of traded volume executed in the CN (positively otherwise).

To test these hypotheses, the SEAQ market segment and the POSIT crossing network form an ideal field of investigation for the two following reasons:

– SEAQ operates as an almost pure quote-driven market;
– CNs are the only ATSs to operate within this market segment, POSIT being the major one and the only one to accept dealer orders, at the time of the study.

Before presenting the data and the characteristics of the sample, I first describe market mechanisms.

2. The DM organisation and the CN trading mechanisms

At the LSE, middle and small capitalisation domestic equities[11] are listed on SEAQ, an almost pure competitive dealership system.

2.1. SEAQ[12]

SEAQ is the screen-based competitive market making segment of the LSE for non order book domestic equity securities. A SEAQ security is a domestic equity market security for which a minimum of two market makers registers with the Exchange. Each market maker is obliged to display firm two-way prices on SEAQ in quantities at least equal to the *Normal Marketable Size* (NMS),[13] or reduced NMS in the case of reduced size market makers,[14] during the Mandatory Quote Period (MQP), which lasts from 8:00 am to 4:30 am. From 7:30 am to 8:00 am, quotes may be opened but prices are regarded as being indicative only. From 4:30 pm to 5:15 pm, market makers may continue to display firm quotes but are not obliged to do so and the trading system remains open for trading reporting.

During the trading day, the best bid and best offer prices quoted by market makers on SEAQ are commonly referred to as the *yellow strip*. In the event that quotations by two or more market makers are identical in terms of price, the best quote will be the one that was entered first.

The LSE offers crossing facilities three times a day for SEAQ securities that are part of the FTSE 250 Share Index. Three crosses[15] are run during the trading day, taking place at 11:00 am, 3:00 pm and 4:45 pm. Up to the current date, they have failed in attracting sufficient order flow and no substantial volume has been transacted through these crosses.

2.2. The POSIT crossing network

Run in Europe by the agency stockbroker ITG Europe, POSIT is an intra-day electronic trading system, which matches buy and sell orders at predetermined times in the day and uses mid-market pricing for execution. Single or portfolio orders can be submitted to POSIT continuously, at any time of the trading day. Anonymity is protected and order details are never divulged externally or disclosed to the market. Submissions are free of charge.

The matching algorithm within POSIT is run at designated times each day.[16] In order not to allow gaming and manipulating strategies, at the designated time of a match, a random execution time within a seven minute window is generated from the POSIT computer so that no one is aware of the exact match time. Any order received before the designated match time will be included in the match pool, but any order received after the start of the match window will be taken on a best endeavour basis up to the time the match is run. Any order subsequently received would be for the next scheduled match.

The POSIT algorithm compares all submitted orders confidentially and is set to maximise the total value of shares traded, given the constraints[17] associated with submitted orders. Matching orders are crossed at the ruling mid-price taken from the lead market quote for each stock, and reported to the relevant authority after execution. Only executed orders are charged a 10 basis point brokerage commission.

At the current date, the match timetable (in UK time) consists of seven intra-day matching times as follows: 9:00 am, 10:00 am, 11:00 am, 12:00 am, 2:00 pm, 3:00 pm and 4:00 pm. This timetable results from several changes: when ITG Europe launched POSIT for UK equities in November 1998, only two daily matches were run at 11:00 am and at 3:00 pm, then other matches were added. The observation period considered in this article covers the second semester of 2000 and the first semester of 2001. From the 1st of July 2000 to the 15th of January 2001, there were four matches a day, at 9:30 am, 11:00 am, 12:00 am and 3:00 pm. Then, a new 8:45 am match was added on the 16th of January 2001. Finally, in March 2001, with the launch of a 2:00 am match, the match times were moved to the current hourly timetable, excluding the 4 o'clock match which became official later.[18]

SEAQ and POSIT data available over the selected period are presented in the next section.

3. Data, empirical measures and sample description

The theoretical hypotheses presented in section 1 are tested on high frequency market data from the LSE and POSIT order data provided by ITG Europe, for SEAQ UK and Irish stocks, over a first period of six months from the 1st of July 2001 to the 31st of December 2001 (Period 1). Then, to appreciate the stability of the results, a second observation period is considered from the 1st of January to the 30th of June 2001.

3.1. Market and POSIT data

Tick by tick market data from the London stock market include trade and best prices data. Best prices correspond to the best bid and offer market makers' quotes at any time a new quote is posted or a quote is revised. Quantities associated to best prices are not available so that the NMS is used as a proxy.

POSIT data consist of two series of files. One series includes the characteristics of the orders submitted to the CN, such as the sedol code identifying the stock, the size of the order in number of shares, the type of the initiator, that is "institutional investor" or "broker-dealer", the date and time of the match to which the order is being submitted. The second series includes the characteristics of the orders executed in the CN: the stock sedol code, the executed quantity, the type of initiator, the mid-price used for execution and the date and time of the corresponding match.

Before running any empirical tests, this raw data has been rearranged for the purpose of the research in a few ways. The submission files were merged with the execution files, in order to show whether each submission was totally or partially executed, or not executed at all. Then, a procedure was set up to determine whether a submission to POSIT was made for the first time or whether it was an order resubmitted after remaining unexecuted in the previous match. In the end, a single table was built up, containing for each submission to POSIT: the stock sedol code, the date and time of the match, the type of the initiator, the submitted quantity, the executed quantity, the price of execution if any and a flag indicating whether the order was newly submitted or resubmitted after total or partial non execution at the previous match.

Both categories of data are available for 1663 SEAQ UK domestic stocks over Period 1 and for 1612 stocks over Period 2, but only a subset of these stocks are selected for the study: for test feasibility, very low traded stocks are abandoned. In order to select and characterise sample stocks, their risk and liquidity are evaluated through a set of empirical measures such as the volatility of daily close returns, the average NMS in number of shares and in GBP, the average size of a trade, the average spreads, the average number of quote revisions throughout the MQP, the average trade number per day, the average daily traded volume as a multiple of the NMS and the average market imbalance between sales and purchases.

3.2. Risk and liquidity measures

Let us note:

- T_i the number of trading days for stock i within a given observation period,
- NMS_{it} the NMS, in number of shares, of stock i on day t,
- CA_{it} the closing ask price, that is the last ask quote of the MQP, for stock i on day t,
- CB_{it} the closing bid price, that is the last bid quote of the MQP, for stock i on day t,
- CM_{it} the closing quote, that is the last mid-quote of the MQP, for stock i on day t,

- $r_{it} = ln\left(\frac{CM_{it}}{CM_{it-1}}\right)$ the return of stock i on day t, computed in logarithm on closing mid-quotes,
- V_{it} the volume in number of shares, traded for stock i within the trading day t,[19]
- BV_{it} the sum of buying volumes in stock i on day t, and SV_{it}, the sum of selling volumes in stock i on day t,[20]
- A_{in} the best ask price for stock i at time n,
- B_{in} the best bid price for stock i at time n,
- M_{in} the mid price for stock i at time n,
- d_{in} the duration of market quotes posted on stock i at time n,
- N_i the total number of different market spreads quoted for stock i throughout a given observation period,
- P_{ik} the trade price for stock i on trade k,
- Q_{ik} the size of transaction k on stock i, in number of shares,
- μ_{ik} the current mid quote at the time of trade k on stock i,
- K_i the total number of trades for stock i over the considered period.

Volatility and liquidity measures are computed as follows.

3.2.1. Volatility

For each stock i, the volatility σ_i is measured by the unbiased estimator of the close return standard deviation:

$$\sigma_i = \sqrt{\frac{1}{T_i - 1}\sum_{t=1}^{T_i}\left(r_{it} - \frac{1}{T_i}\sum_{t=1}^{T_i} r_{it}\right)^2} \quad (1).$$

3.2.2. Depth

Let us recall that the NMS is the minimum quantity for which market makers are due to quote firm prices. For that reason, the average value of the NMS is used as an indicator of depth. For each stock, the average NMS is calculated in number of shares (NMS_i) as shown in equation (2), and in GBP ($£NMS_i$) like in equation (3).

$$NMS_i = \frac{1}{T_i}\sum_{t=1}^{T_i} NMS_{it} \quad (2).$$

$$\pounds NMS_i = \frac{1}{T_i}\sum_{t=1}^{T_i} CM_{it} \times NMS_{it} \quad (3).$$

Besides, the average GBP size of a trade, denoted TS_i, and equal to

$$TS_i = \frac{1}{K_i}\sum_{k=1}^{K_i} Q_{ik} \times P_{ik} \quad (4),$$

may also be considered as related to the depth of the market.

3.2.3. Spreads

Three measures of spreads are used to appreciate the liquidity of each stock i:

- QS_i, the average quoted touch[21] or market spread (i.e. the difference between the best offer and the best bid quoted on the market reported to the mid-quote), calculated by weighting each quoted spread with its duration of validity,
- ES_i, the average effective spread, that is the mean of spreads actually applied on trades weighted by trade sizes,[22]
- CS_i, the average closing spread computed as the equally-weighted mean of daily closing market spreads.

Equations (5), (6) and (7) display the explicit formulas of calculation:

$$QS_i = \sum_{n=1}^{N_i} \frac{d_{in}}{\sum_{n=1}^{N} d_{in}} \times \frac{A_{in} - B_{in}}{M_{in}} \quad (5),$$

$$ES_i = \sum_{k=1}^{K_i} \frac{Q_{ik} \times P_{ik}}{\sum_{n=1}^{K_i} Q_{ik} \times P_{ik}} \times \frac{\left|P_{ik} - \mu_{ik}\right|}{\mu_{ik}} \quad (6),$$

$$CS_i = \frac{1}{T_i}\sum_{t=1}^{T_i} \frac{CA_{in} - CB_{in}}{CM_{in}} \quad (7).$$

3.2.4. Quote frequency

Quote frequency can be measured by NQR_i, the average number of market quote changes within a MQP, for stock i. NQR_i, that is N_i/T_i, increases with the intensity of the information flow conveyed on a security and the level of competition between the market makers who quote prices for the stock.

3.2.5. Trading frequency

So as to appreciate the level of trading frequency of a given stock i, I do not only look at the average number of trades per day, denoted TN_i and equal to K_i / T_i, but also at the number of times the NMS is traded, on average, inside a trading session. This variable is denoted TF_i and is estimated in the following way:

$$TF_i = \frac{1}{T_i} \sum_{t=1}^{T_i} \frac{V_{it}}{NMS_{it}} \quad (8).$$

For the remainder of the paper, trading frequency shall be referred to as TF_i.

3.2.6. Market imbalance

By market imbalance, I mean the disequilibria between buying and selling trades. The market imbalance for stock i on day t is then defined as $\left|BV_{it} - SV_{it}\right| / \left(BV_{it} + SV_{it}\right)$. The average market imbalance IMB_i, calculated as

$$IMB_i = \frac{1}{T_i} \sum_{t=1}^{T_i} \frac{\left|BV_{it} - SV_{it}\right|}{BV_{it} + SV_{it}} \quad (9).$$

is an indicator of illiquidity. The higher IMB_i, the higher the cost of making the market for stock i.

Looking at the individual values of these measures, a certain number of stocks with missing data or very low trading activity are dropped from the samples.

3.3. Deletions for missing data and thin trading

The empirical tests conducted in section 5 are based on stock-by-stock aggregated measures. In order to obtain individual measures with comparable statistical meaning, they should be estimated on a minimum number of trading days. Therefore, stocks for which market makers' quotes were available for less than 100 trading days of the observation period, were dropped from the samples. However, some very low-priced and illiquid stocks are still included in the remaining set of securities: these equities exhibit surprisingly high spreads and very low trading volumes.

As such extreme values could well bias the results of the tests, I have deleted from the samples, any stock with one, at least, of the following features:

– the average quoted spread QS_i exceeded 20%;

– the average volume traded inside a session, TF_i, was less than 2 NMS;

– or the total number of trades throughout the considered six months' observation period, K_i, was less than 20.

Consequently, the sample for Period 1 (Sample 1) is reduced to 1,400 stocks, for which a total amount of 78,850 million GBP were traded in the market. As for Period 2, the final sample (Sample 2) includes 1,378 stocks for which the total traded volume over the period equalled 79,526 million GBP.

3.4. Characteristics of selected stocks

In terms of risk, depth and transaction costs, the selected subset of SEAQ stocks exhibit the typical features of mid and small cap equities: relatively low prices, high volatility, limited depth and relatively high spreads, with large discrepancies across stocks. Descriptive statistics on volatility, depth, spreads and quote frequency are reported in Table 1.

Table 1 about here

The stocks of the samples are quite risky: the average close-to-close return volatility across Sample 1 (Sample 2) reaches 2.83% (2.66%), this mean being probably pulled up by most risky stocks, as the median volatility only equals 2.11% (2.27%). The market for these stocks is not very deep, the median NMS being 2,000 shares for Sample 1 and 2,512 shares for Sample 2. Let us notice that the market for the most liquid stocks of the samples is much deeper, as the cross-sectional means of the NMS stand far above the median values.

Consistently, average spreads are relatively high compared to what would be observed on a Blue Chip market segment. The cross-sectional mean of average quoted spreads equals 2.38% for Sample 1 and 2.28% for Sample 2, while the average effective spreads are substantially lower. The cross-sectional mean of effective spreads is no more than 1.74% across Sample 1 and 1.58% across Sample 2. Large discrepancies in spreads can be observed from one stock to another. For a great number of stocks, average spreads are superior to the mean value of the sample: as an illustration, median values of spreads always exceed the mean values.

Finally, market makers do not revise their quotes very frequently on this market segment. On average across each sample, quotes are revised 12 times a day for a stock, with, again, huge differences between stocks. For most stocks in the samples, the daily number of changes in price is even less than that, the median standing at 6 on each observation period.

4. Stylised facts on CN trading activity

By nature, the probability of execution in crossing systems remains low, as it cannot be improved by price adjustments. As mentioned in the introduction, crossing only addresses the needs of a very special type of traders, for which the reduction of market impact prevails over immediacy. Therefore, crossing is unlikely to attract more than a few per cent of the total order flow. As an illustration, 11 billion pounds were crossed through POSIT last year while 12,000 billion pounds were traded on the UK market. Concerning SETS FTSE100 stocks, significant volumes are crossed, but they have represented an extremely low share of the total market turnover (under 1%). In fact, the main part of POSIT order flow in UK domestic stocks is related to mid caps, the potential gain from crossing being superior for these stocks, and the major share of the crossing business concentrates on SEAQ stocks that belong to the FTSE250. Let us now examine the level of CN-trading for the stocks selected in samples 1 and 2.

4.1. Market activity and CN-trading over the observation periods

When only considering intra-day trading,[23] about 77 billion GBP were traded for the stocks of the samples within each 6-months' period. This volume represented more than 2 million trades on each semester, the average size of a trade standing between 33 and 36 thousand GBP. Over Period 1, 1.28% of the total trading volumes (in GBP) were transacted through POSIT. This market share represented only 0.34% of the total number of trades, as POSIT trades are larger than others. The average size of order executed in the CN is more than 3 times the average size of trade on the market. Crossing activity in POSIT rose substantially in Period 2, reaching 2.34% of total traded volumes and 0.67% of the total number of trades.

This increase in crossing cannot only be assigned to a rise in the relative amount of submissions in the CN. POSIT-submitted orders in percentage of the total market volume remain around 50% (49% in Period 1 and 51% in Period 2). If accounting for resubmissions, this ratio goes up to 94% in Period 1 and to 104% in Period 2, as many orders are submitted to several consecutive matches in case of non execution. The increase in POSIT market share is then more probably due to the lower imbalance between selling and buying orders (cf. lines 3 and 4 of Table 2) in the CN, resulting in a better rate of execution in the CN: 4.13% of volumes submitted to the CN in Period 2 were executed instead of 2.63% in Period 1.

Table 2 about here

Looking at the breakdown of CN orders between trader types displayed in Table 2, it is notable that the reduction in the order imbalance is mainly related to market makers strategies. As already mentioned, POSIT is open to both the buy and the sell sides, so that two categories of traders submit orders to POSIT: institutional investors and broker-dealers, in other words market makers. The latter tend to submit more selling orders than buying orders but this imbalance in market makers' orders seem to vary over time and lessens significantly over the 2nd period: market makers placed nearly twice (1.8 times) more sell orders than buy orders in the CN in Period 1, while this ratio is no more than 1.3 over Period 2.

With respect to the rates of execution, market makers get higher fill rates. Institutional investors account for about 52% or 53% of the total CN-submitted order flow and submit larger orders, whereas market makers represent the major part of crossed volumes (70% in Period 1 and 59% in Period 2). They submit smaller orders and have a lower rate of resubmission on unexecuted orders. They are undoubtedly more opportunistic in their way to use the CN.

Beyond these global figures, the share of CN-trading can highly differ from one stock to another. Over Period 1, orders had been submitted into the CN for 1,251 stocks out of 1,400. 568 stocks had been traded at least once in the CN, the CN market share exceeding 1% for 281 of these stocks and 5% for 20 of them. As for Sample 2, 1,265 out of 1,378 stocks were CN-submitted and 703 were actually crossed in POSIT, 475 with a POSIT market share superior to 1% and 54 with a POSIT market share over 5%.

4.2. Characteristics of CN-traded stocks

This subsection focuses on the specificities, if any, of stocks for which some orders are actually submitted into or executed on the CN. To this aim, the following sub-samples are considered on each observation period:

– sub-sample A includes stocks for which at least one order was submitted to the CN, while sub-sample B contains non submitted stocks;
– sub-sample A1 includes stocks actually crossed in POSIT, whereas sub-sample A2 corresponds to CN-submitted but never executed stocks;
– sub-sample α includes CN-traded stocks with a POSIT market share in volumes of less than 1%;
– sub-sample β includes CN-traded stocks with a POSIT market share between 1 and 5%;
– and finally, sub-sample γ includes CN-traded stocks with a CN market share over 5%.

Measures of depth, volatility, trading frequency, market imbalance and quote frequency, as defined in sub-section 3.2, are computed for each stock and then, equally-weighted means of these measures are computed and compared by pair of sub-samples. According to the mean values, stocks for which no order was submitted to POSIT are the most illiquid in the samples: they have the smallest NMS and the largest market imbalance. They are very infrequently traded (less than 3 trades a day on average) and have very sticky quotes (less than 5 quote revisions per day on average). This is consistent with the positive externality hypothesis. According to Hendershott and Mendelson (2000), CNs are characterised by two opposite externalities: a positive externality because an increase in the CN trading volume will rise the CN execution rate, and a negative externality, that is a *crowding effect*, when orders accumulate on the same side in the CN. The liquidity effect related to the positive externality can hardly be achieved for very illiquid and scarcely quoted stocks because the potential number of traders remain limited. Moreover, there is probably little fundamental research on these equities, so that traders with long-lived information on these stocks are few and CN-trading is less profitable.

Inside the group of CN-submitted stocks, about half of them have effectively been crossed in POSIT. The differences in depth, risk, trading frequency and quote frequency between crossed stocks and other submitted stocks are all highly significant on both observation periods. They show that CN-traded stocks are less risky and more actively traded: A1 stocks have larger NMS, higher trading volumes and more frequent trades, and more competitive quotes, than A2 stocks. In a way, this finding is rather intuitive and consistent with theory. As demonstrated in Hendershott and Mendelson (2000), a CN needs to achieve critical mass so as to execute order flow. As a CN does not provide a pricing mechanism, it needs a reliable price discovery process on the primary market and a minimum threshold of trading volume by participants to build a pool of liquidity. The ability of reaching such a critical mass will obviously be more probable when the market is active, deep and well-balanced in terms of selling and buying interest, as high market imbalance may generate crowding effects on one side of the market.

However, the critical mass argument is not sufficient to explain the cross-sectional differences in POSIT market share. When examining the sub-sample of POSIT-crossed stocks, it is interesting to notice that the stocks which have the highest CN market share by volume, are not necessarily the most liquid in Sample A1, in terms of turnover. In fact, γ stocks, for which the CN market share exceeds 5% of the total traded volume, are less frequently traded and quote-revised than others, although their volatility is inferior to the one of less CN-traded stocks.

Apparently, the CN over-performs when the market lacks depth and remains surprisingly inactive in comparison with the level of risk. This observation suggests that the CN attracts patient traders who would be reluctant to trade directly in the market and thus gives liquidity to the market on latent orders. Potential benefits from the CN opening, such as this, are based on the cost savings provided by the crossing system.

4.3. Cost savings on CN-executed orders

The potential benefits from CN-trading rest on the lower execution costs CNs offer. First, crossing commissions are usually less than full service brokerage commissions. Secondly, CN participants obtain lower implicit costs: they bear no bid-ask spread and no price impact since the trade price is independent of order size. For orders with a size less or equal to the NMS, the implicit cost saving from trading in the CN strictly equals the half of the bid-ask spread. For CN-executed orders with a size superior to the NMS, which is the case for most POSIT orders, the implicit cost saving exceeds the half spread as the order may move the price out of the touch.

The estimation of the implicit costs related to market impact would require specific modelling. As it is not the focus of this work, for simplicity, I do not compute the total implicit costs saved by POSIT traders but only the part corresponding to the market bid-ask spread. Doing so, I obtain that POSIT users saved 9,195 thousand GBP over Period 1 and 15,750 thousand GBP over Period 2. On average, the cost saving per share corresponding to spread saving was 0.0232 GBP over Period 1 and 0.0217 GBP over Period 2. This cost saving per share was higher for institutional investors than for market makers (see Table 3).

Table 3 about here

However, the potential cost savings for CN traders are limited because the CN does not guarantee execution. Fill rates are no more than a few per cent and this non-execution risk is associated with potential opportunity costs, as shown in Næs and Ødegaard (2001). Hence, the total benefit from CN-trading is the result of a trade-off between cost savings and opportunity costs.[24]

After this glimpse on POSIT trading activity, the next section is dedicated to the main purpose of this study, that is the analysis of the way market liquidity is related to CN-trading, and it is based on the testable hypotheses established at Section 1.

5. Testing the relationship between the CN trading activity and the dealer market liquidity: methodology and results

The methodology used to test hypotheses H1 to H7 consists of cross-sectional regressions of stock-by-stock market quality measures on variables that measure the trading activity in the CN. The analysis is voluntarily conducted at a macro-level, on aggregated measures for the market, and differs from a trade-by-trade analysis. For this reason, the cross-sectional regressions conducted hereafter do not suffer from the selectivity bias[25] that characterises trade-by-trade regressions, where the choice of the trading mechanism for each trade is endogenous.

The results are homogenous from Period 1 to Period 2. They globally show that the gains from competition dominate the potential costs of fragmentation. The CN might well skim off liquidity trading from the DM. However, the unexecuted CN order flow does not bring additional risk and liquidity costs on to the market. The risk sharing benefits offset the cream-skimming costs, and dealer trading in the CN induces a competition effect.

5.1. Opportunistic CN-trading and unexecuted CN order flow

Hypotheses H1 and H2 address the impact of CN unexecuted order flow on the riskiness and the liquidity of the DM. The level of unexecuted order flow for a stock i, on a given period, is measured by the rate of non execution in the CN, denoted U_i, and equal to the total volume of unexecuted POSIT orders reported to the total volume of orders newly submitted to POSIT during this period. When no orders are submitted to the CN, U_i is set to zero.

According to H1, U_i would increase the risk of the market after the matches. To test this relation, the riskiness of the DM at the end of the trading day will be represented by the close-to-close return volatility per unit of traded volume, that is the ratio σ_i / V_i, where σ_i is the return volatility as estimated in equation (1) and V_i is the average daily traded volume for stock i.

Prior to further investigation, several variables have been identified as potential control variables for σ_i / V_i:

- all measures of spreads defined at paragraph 3.2.3 (QS_i, ES_i and CS_i), given the well-known relationship between risk and spreads,
- the average trading frequency measured in logarithm, $ln(TF_i)$, and the average number of trades per day TN_i, as a less risky stock is probably more frequently traded,
- the logarithm of the average NMS in number of shares, $ln(NMS_i)$, and in GBP, $ln(£NMS_i)$, as I expect stocks with a deeper market to be less volatile,
- finally, the average imbalance IMB_i, as the volatility per unit of traded volume could be increasing with the disequilibria between selling and buying orders.

When regressing σ_i / V_i on each of the variables, no significant relation is found either with $ln(NMS_i)$ or with TN_i. As expected, σ_i / V_i is positively related to any spread measure, negatively related to trading frequency, negatively related to $ln(£NMS_i)$ and positively related to market imbalance. Interestingly, the most explanatory variable is the average closing spread, CS_i. No additional variable improves the quality of the regression, whatever the considered period.

Consequently, H1 is tested OLS-regressing σ_i / V_i on U_i across each sample and controlling for CS_i. Regression coefficients and associated t-values are reported in Table 4.

Table 4 about here

U_i coefficients are not significantly different from zero for any period and H1 is rejected.

H2 also focuses on the impact of CN unexecuted order flow. According to H2, opportunistic CN orders, if not executed, would produce additional liquidity costs when coming back to the DM, so that spreads would be positively related to U_i. Any test of H2 then requires to identify the relevant control variables for spreads.

The following range of potential control variables are examined. First of all, several measures of volatility are considered, as spreads are obviously depending on volatility:

– the standard deviation of close-to-close returns σ_i,

– the variance of close-to-close returns σ_i^2,

– the standard deviation of open-to-close returns σ_{oc_i},

– and the variance of open-to-close returns $\sigma_{oc_i}^2$.

Second, spreads are expected to be decreasing in trading volumes, represented by the logarithm of the average GBP daily traded volume $ln(£V_i)$, and in trading frequency again measured by $ln(TF_i)$. Also, they should be positively related to IMB_i and negatively related to NQR_i, as the number of quote revisions is an indicator of competition intensity between market makers. Finally, three other variables are considered: $ln(NMS_i)$, $ln(£NMS_i)$ and BD_i, the average share of daily volume declared as broker-dealer to broker-dealer trades in the data.[26]

In order to choose the most relevant control variables, OLS-regressions are run following a stepwise procedure. The variable having the highest explanatory power is first selected. Then, the variable that most increase the explanatory power of the model is added, and so on until the model cannot be improved. In the end, for each spread measure and for each observation period, three control variables are selected: $ln(£V_i)$, σ_i and $ln(NMS_i)$, all coefficients being negative, except the one for $ln(NMS_i)$. The positive relation between the spreads and the NMS may be interpreted in the following way. If two stocks are identical in terms of risk and liquidity, spreads will be obviously wider for the one that has the largest NMS, as market makers are due to quote firm prices and risk capital on bigger quantities.

Consequently, tests of H2 consist of regressing quoted spreads on the rate of non execution in POSIT, while controlling for trading volumes, closing price volatility and NMS. The results displayed in Table 5 lead to the rejection of H2, as quoted spreads are never positively related to U_i.

Table 5 about here

To conclude on H1 and H2, both hypotheses are rejected. Any opportunistic trading that is skimmed off from the dealer market to POSIT and comes back to the dealer market in case of non execution, does not significantly impact closing quote risk and liquidity costs.

5.2. The risk-sharing benefits from new liquidity trading in the CN offsets the cream-skimming costs.

Although the POSIT unexecuted order flow does not affect spreads and volatility, I cannot conclude yet to the absence of any fragmentation or cream-skimming effect. The answer to this question depends on the way the existence of the CN modifies the liquidity-based demand. Either opportunistic or patient liquidity traders leave the DM to try the CN first, and the DM becomes more costly (H3a); or, the CN attracts new liquidity traders who would not trade otherwise, so that market makers get lower adverse selection and inventory risks (H3b). Under H3a (H3b) spreads widen (narrow) with the share of order flow submitted to the CN.

The validation of either H3a or H3b is thus based upon the relation observed between quoted spreads and the relative amount of order flow submitted into POSIT.

The relative amount of POSIT-submitted order flow over a given period for stock i is denoted NS_i and computed as the total volume submitted to POSIT for stock i divided by the total volume traded on the market for stock i. NS_i includes new submissions only and does not account for resubmissions of unexecuted orders.

The regressions of individual average quoted spreads on NS_i values (cf. Table 6.1) do not allow to assess that one effect is dominant over the other.

Table 6.1 about here

H3a is rejected as none of the NS_i coefficients is significantly positive. Yet, H3b cannot be validated either: although most of them negative, coefficients are not significantly different from zero.

As the concern here is liquidity trading, it might be relevant to focus on the POSIT orders submitted by institutional investors. For that reason, similar regressions are run on NSI_i, the component of NS_i that corresponds to institutional investors' orders only. The results, reported in Table 6.2, do not strongly differ from the previous ones.

Table 6.2 about here

Eventually, submissions into POSIT do not create additional liquidity costs. The CN does not skim off liquidity trading from the DM in a sufficient way so as to significantly increase adverse selection on the central market. If some liquidity traders actually switch from the DM to the CN, the increase in spreads that this might cause is probably offset by some risk sharing benefit. To enlighten this point, the next subsection will provide some other evidence on risk sharing benefits.

5.3. The benefits of CN dealer trading

Using unique data from the LSE, Reiss and Werner (1998) have shown that inter-dealer trading facilitated inventory risk sharing among dealers. The same idea motivates hypothesis H4: CN dealer trading can also be expected to lessen the cost of managing inventories for market makers. Provided H4, market makers would be able to tighten quotes when they trade or expect to trade in the CN, and quoted spreads would narrow with the amount of dealer orders executed in the CN.

So as to validate or invalidate H4, the average quoted and closing spreads are regressed on the relative volume traded by market makers in POSIT over the period. This relative volume, denoted XM_i, is calculated, for each stock i, as the total POSIT volume traded by market makers reported to the total market volume. The results are set out in Table 7. XM_i coefficients are significantly negative at the 5% level for all measures of spreads, and are stable from Period 1 to Period 2, except for effective spreads over Period 2. The significance of the results is higher for average intra-day quoted spreads, with P-values superior to 99%. Consequently, hypothesis H4, according to which dealer trading in the CN reduces the cost of market making, can be accepted.

Table 7 about here

5.4. Competition and the net effect of the CN activity on implicit transaction costs

This last sub-section presents tests of the net effect of the CN activity on the cost of trading. This net effect depends on the trade-off between competition benefits and fragmentation costs. If the existence of the CN strengthens the competition between price-setting agents, as proposed in hypothesis H5, then CN-trading would accelerate quote revisions. The CN might also have the opposite effect by fragmenting the order flow. As long as an order remains submitted to the CN, awaiting for execution, without coming back to the DM, it is not visible from the market. If such a fragmentation harms price formation, quote revisions will become scarce when the share of order flow submitted and resubmitted to the CN increases, and H5 will not hold.

Therefore, the validation of H5 is based on the relation between NQR_i, the average number of quote changes per day for stock i and the two following CN-related measures:

– S_i, the total volume of POSIT-submitted orders, including new submissions as well as resubmissions, divided by the total market transaction volume;

– X_i, the total POSIT-executed volume reported to the total market trading volume.

Before regressing NQR_i on S_i and X_i, four control variables for NQR_i have been selected among a wide range of potential explaining variables. The number of quote changes appears to be:

– positively related to TN_i, the average number of trades per day,

– positively related to $ln(\pounds NMS_i)$, the average GBP value of the NMS in logarithm,

– positively related to the share of dealer-to-dealer trading BD_i,

– and negatively related to the market imbalance IMB_i.

Tables 8.1 and 8.2 exhibit estimates and statistic values.

Table 8.1 about here

Table 8.2 about here

S_i coefficients are not significantly positive on any observation period, while X_i coefficients are positive and significant at the 5% level (1% level) over Period 1 (Period 2). The fragmentation of the order flow between POSIT and the DM does not seem to harm the competition in prices, whereas quote revisions are significantly more frequent for stocks with a relatively higher share of POSIT-executions. Let us note that the second effect is more significant on Period 2, when the rate of execution in POSIT was higher. This allow me to accept H5.

If the competition effect dominates the fragmentation effect, then, on average, crossing should reduce the temporary market impact of trades (hypothesis H6). As a proxy for temporary market impact, I took the average daily volatility around VWAP, denoted σ_{vwap_i} for stock i. VWAP is the volume-weighted average price of the stock on a given trading day and is used by operators as a benchmark either to price after-hours transactions or to measure trading performance. The higher the bid-ask bounce and the market impact of trades, the more individual trade prices will deviate from VWAP. For this reason, σ_{vwap_i}, computed as the average of daily standard deviations of transaction prices from VWAP for stock i, measures short-term volatility around the mean level of prices due to implicit transaction costs and market impact of trades. Again, I have selected control variables for σ_{vwap_i} following a stepwise procedure. The variables that most explain the variance of σ_{vwap_i} across the samples are consistent with the economic intuition. Unsurprisingly, σ_{vwap_i} increases with the volatility of daily returns σ_i, with quoted spreads QS_i, with the size of the NMS measured by $ln(NMS_i)$ and, of course, with the daily number of trades TN_i.

While controlling for these four variables, σ_{vwap_i} is regressed on X_i. Then, X_i is split between its sell side component XM_i and its buy side component, XI_i, which equals the total institutional CN-volume for stock i in percentage of the total market volume. Results in Tables 9.1 and 9.2 validate H6. They indicate that crossing reduces temporary market impact, this effect being essentially related to market makers crosses.

Table 9.1 about here

Table 9.2 about here

Finally, the net impact of CN-trading on the cost of trading is examined by regressing average quoted spreads on X_i. The estimated coefficients (see Table 10) indicate that spreads decrease with an increase in the CN volume. However, the t-statistic exceeds the 5% critical value only over Period 1.

Table 10 about here

With respect to my previous findings on hypothesis H4, the decreasing relationship between spreads and CN volumes can be assigned to POSIT trades coming from market makers. However, as the relationship tested in H7 has a weaker significance than the one tested in H4, it means that the rest of the CN-executed order flow, that is the CN volume initiated by institutional investors, has an opposite effect. On the one hand, trading in the CN lessens the cost of market making for dealers, but on the other hand, when institutional investors' orders are executed in POSIT, dealers are probably losing a part of their potential revenues.

All things combined, the positive effect of dealer CN-trading overbalances the negative impact of institutional CN-trading, so that crossing results in a statistically weak decrease of the cost of trading.

6. Conclusion

The development of ATSs, since the 70s, has considerably changed the structure of financial markets and the industry of investment services. In the US, ECNs and CNs have gained significant market volume share over the past decades, while, in Europe, only two CNs have emerged at the end of the 90s, the most prominent being POSIT. Since the launch of POSIT in Europe, in 1998, institutional investors and broker-dealers have several venues to trade European stocks. They can: either submit orders to the central market, incur the bid-ask spread but get higher execution guarantee; or submit orders to a CN, lose execution certainty but trade at mid-quote if executed. The implications for liquidity are not well known yet, and the objective of this paper was to address this issue in the case of a CN operating within a DM.

When multiple markets with different trading mechanisms are available to traders, the order flow fragments between trading locations when the population of traders is heterogenous: each trading system address the needs of a particular class of traders and they cluster together according to their trading preferences. Multi-market trading may then either create a *competition* effect and improve liquidity, or conversely harm liquidity due to the *fragmentation* of the order flow. In the case of a CN operating within a DM, both markets will co-exist when investors assign different values to order execution (Dönges and Heinemann, 2001). The consequences for liquidity are ambiguous (Hendershott and Mendelson, 2000). On the one hand, additional liquidity trading in the CN produces positive *risk-sharing* effects. On the other hand, opportunistic CN-trading induces negative *cream-skimming* effects.

To test whether the competition and the risk-sharing effects dominate the fragmentation and cream-skimming effects, I use high frequency data from the SEAQ quote-driven segment of the LSE and private order data from the POSIT crossing network, over two six-months' periods. These data are interesting for two reasons. Firstly, to my knowledge, no empirical work has been conducted yet on order data from a crossing network. Secondly, the example of the UK mid and small caps is a very instructive field of research to examine the effects of CN-trading on the liquidity of a DM because the SEAQ trading platform can be considered as a pure dealership market and POSIT is the only ATS attracting a significant part of the order flow at the LSE.

During my observation periods, that is the second semester of 2000 and the first semester of 2001, the CN market share reaches around 2% of the total volume traded for the stocks in the sample. Institutional investors account for about 52% of the POSIT submitted order flow, the other part being submitted by dealers, which account for two thirds of the POSIT executed volumes. Cross-sectional differences between stocks reveal that the CN does not attract any order on most illiquid stocks. CN-traded stocks are less risky and more liquid than others, which is consistent with the positive externality hypothesis of Hendershott and Mendelson (2000). However, the critical mass argument does not completely explain the cross-sectional differences in POSIT market shares: the stocks with the highest CN market shares are not necessarily the ones with the highest market trading volumes. In fact, the CN over-performs on stocks that are infrequently traded compared to their level of risk and liquidity. This suggests that the CN probably allows trades that would not take place otherwise. On average, the spread-cost saving per share on CN-executed orders slightly exceeds 0.02 GBP, the average spread saving being higher on institutional orders than on market makers' ones.

As for the relationship between CN-trading and the DM liquidity, the empirical tests conducted here fail in detecting a dominant negative fragmentation effect. According to my findings, CN-submitted order flow does not worsen adverse selection on the central market and unexecuted CN order flow does not make the after-crosses market riskier. The CN skims off liquidity-motivated orders from the DM, but the risk sharing benefits and the competition effects from crossing overbalance the cream-skimming costs.

The oligopolistic power of market makers on the central market is negatively correlated to the CN activity. The competition between quote-setting operators seems to strengthen with CN-trading, as quote revisions are more numerous for stocks that are more traded through the CN, and temporary market impact is reduced. The main explanation for that appears to be the risk-sharing benefit entailed by dealer trading in the CN. Market makers use the CN as a liquidity-providing system, reducing inventory costs and allowing them to improve quote competitiveness.

By way of conclusion, these results are, in many ways, complementary to those of Madhavan and Cheng (1997) and Keim and Madhavan (1996), who examine upstairs vs downstairs trading. The CN considered here can somehow be viewed as a special form of upstairs market, with the difference that it is anonymous, electronic and fully confidential. Both traditional upstairs markets and POSIT work by matching naturals and allow trades that might never occur. In so, they help reduce imbalances and thus short-term volatility. As upstairs markets, crossing validate the quotes on the central market, and thus benefit the downstairs price discovery process. Concerning this last point, it would be worth doing some empirical work on the issue of price discovery and the informational effects of the CN order flow. The results also call for further research on the liquidity effects: an inter-temporal or trade-by-trade analysis would greatly complement this exploratory study and would provide stronger evidence on causality effects.

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Table 1

Characteristics of the samples: average depth, volatility, spreads and quote frequency

	Sample 1 – 1400 stocks Period 1 – 2nd sem. 2000			Sample 2 – 1378 stocks Period 2 – 1st sem. 2001		
	Weighted mean	**Standard deviation**	**Median**	**Weighted mean**	**Standard deviation**	**Median**
NMS in number of shares	13,079	17,061	2,000	17,589	20,645	2,512
NMS in GBP	38,681	34,297	3,325	46,488	44,549	3,430
Close-to-close return volatility	2.83%	1.81%	2.11%	2.66%	1.77%	2.27%
Average quoted spread	2.38%	1.47%	3.24%	2.28%	1.54%	3.57%
Average effective spread	1.74%	1.65%	2.24%	1.58%	1.55%	2.31%
Average closing spreads	4.01%	2.53%	4.96%	3.91%	2.95%	5.61%
Average number of quotes	12.9	8.5	6	12.7	5.7	6

This table displays, for each observation period, the distribution, across the samples, of the NMS in number of shares, the NMS in GBP, the daily volatility computed on logarithmic close-to-close returns, the time-weighted average quoted spread, the trade-size-weighted average effective spread, the average closing spread and the number of quote changes per day. The cross-sectional means and standard deviations are based on individual stock average measures weighted by total GBP traded volumes over the period. The medians of each sample are also reported.

Table 2

Trading activity in POSIT

	Period 1		Period 2	
	From institutional investors	**From broker-dealers**	**From institutional investors**	**From broker-dealers**
Submissions including all orders (new submissions and resubmissions of unexecuted orders)				
- in % of total submitted volume	60.58%	39.42%	58.56%	41.44%
Submitted volumes including new submissions only (excluding resubmissions)				
- in % of total submitted volume	52.44%	47.56%	53.19%	46.81%
Average size of an submitted order	627,358	233,740	420,138	169,212
Submitted buy volumes including new submissions only (excluding resubmissions)				
- in % total submitted volume	23.84%	17.10%	28.12%	20.56%
Submitted sell volumes including new submissions only (excluding resubmissions)				
- in % of total submitted volume	28.60%	30.46%	25.07%	26.25%
Executed volumes				
- in % total executed volume	30.21%	69.79%	41.08%	58.92%
Total executed volume over total submitted volume	1.52%	3.87%	3.19%	5.20%
Average size of an executed order	177,177	112,489	148,467	95,445

This table shows the breakdown of POSIT order flow between institutional investors and broker-dealers and provides the average sizes of POSIT submitted and executed orders, over Period 1 and Period 2. The four first panels of the table report statistics on submissions. Figures in the first panel include all submissions, that is orders submitted to POSIT for the first time as well as orders resubmitted after non execution in the previous match. In the second panel, statistics are based on new submissions only, without including resubmissions. The third and the fourth panels respectively correspond to buy and sell orders submitted into the CN (excluding resubmissions). The last panel reports statistics on executions.

Table 3

Spread-cost savings on CN-executed orders

	Total spread savings in GBP		Average spread saving per share in GBP	
	Period 1	**Period 2**	**Period 1**	**Period 2**
All orders	9,194,734	15,750,354	0,0232	0,0217
Institutional orders	3,299,948	7,012,798	0,0310	0,0240
Market makers' orders	5,894,786	8,737,556	0,0203	0,0202

This table presents estimations of the implicit costs saved by POSIT traders. These estimations are based on the market bid-ask spread at the time orders are crossed and do not include market impact. For a CN-executed order the total spread saving equals the half market spread in GBP multiplied by the executed volume in number of shares and the spread saving per share is the difference between the mid (ask) and the bid (mid) in GBP for a sale (purchase). Columns 2 and 3 give the total amount of spread savings for all executed orders, for institutional orders and for market makers orders respectively over Period 1 and Period 2. Columns 4 and 5 display, for each period, the average spread saving per share in GBP, all orders combined and for each category of orders.

Table 4

Test of hypothesis H1
Closing price volatility and CN unexecuted order flow

Dependent variable	Observation period	Control variables		Explaining variable	R^2
		Intercept	CS_i	U_i	
σ_i / V_i	Period 1 (1,400 obs.)	$-8.43.10^{-3}$** (-4.822)	$1.611.10^{-3}$** (19.026)	$-1.12.10^{-5}$ (-0.683)	21.6%
	Period 2 (1,378 obs.)	-1.31.10-2** (-6.412)	1.815.10-3** (20.736)	2.090.10-5 (1.052)	23.8%

This table presents the estimates, for observation periods 1 and 2, of the following cross-sectional regression: $\sigma_i / V_i = a + bCS_i + cU_i + \varepsilon_i$. The dependent variable σ_i / V_i is the close-to-close return volatility divided by the average daily traded share volume for stock i. CS_i , the average closing market spread, serves as a control variable. The independent variable U_i is the rate of non execution in the CN computed as the total unexecuted share volume over the total CN-submitted share volume. ε_i is an error term. Student statistics stand in parentheses. Coefficients are marked with two stars when significant at the 1% level.

Table 5

Test of hypothesis H2 – Spreads and CN unexecuted order flow

Dependent variable	Observation period	Control variables				Explaining variable	R^2
		Intercept	$ln(£V_i)$	σ_i	$ln(NMS_i)$	U_i	
QS_i	Period 1	13.991**	-1.278**	0.672**	0.541**	$-5.60.10^{-3}$**	62.7%
	(1,400 obs.)	(32.362)	(-31.714)	(21.793)	(8.804)	(-2.695)	
	Period 2	14.877**	-1.343**	0.503**	0.607**	$-1.19.10^{-2}$**	64%
	(1,378 obs.)	(35.864)	(-33.349)	(19.203)	(10.089)	(-5.451)	
CS_i	Period 1	16.130**	-1.776**	1.524**	1.024**	$-1.08.10^{-2}$**	67.9%
	(1,400 obs.)	(25.327)	(-29.057)	(32.322)	(10.990)	(-3.423)	
	Period 2	17.207**	-1.862**	1.399**	1.158**	$-1.94.10^{-2}$**	72%
	(1,378 obs.)	(27.276)	(-30.396)	(35.131)	(12.650)	(-5.832)	

This table displays the estimates of cross-sectional regressions of quoted spread measures onto the rate of non execution in POSIT, U_i. The dependent variables are successively QS_i, the duration-weighted average quoted touch and CS_i, the average closing market spread, index i standing for stock i. In each regression, the control variables are the following: the logarithm of the average intra-day GBP traded volume denoted $ln(£V_i)$, the close-to-close return volatility σ_i and the logarithm of the average NMS in number of share denoted $ln(NMS_i)$. Student values are given in parentheses. Coefficients marked with two stars are significant at the 1% threshold.

Table 6.1

Test of hypothesis H3 – Cream skimming vs Risk sharing: Spreads and CN-submitted order flow

Dependent variable	Observation period	Control variables				Explaining variable	R^2
		Intercept	$ln(£V_i)$	σ_i	$ln(NMS_i)$	NS_i	
QS_i	Period 1	13.504**	-1.311**	0.669**	0.538**	$-3.43.10^{-5}$	62.5%
	(1,400 obs.)	(31.675)	(-33.479)	(21.650)	(8.735)	(-0.303)	
	Period 2	14.408**	-1.382**	0.493**	0.595**	$-2.19.10^{-4}$	63.3%
	(1,378 obs.)	(35.074)	(-33.764)	(18.690)	(9.791)	(-1.662)	

This table displays, for Period 1 and Period 2, the estimates of the cross-sectional regressions of the average quoted spread onto NS_i, the total amount in number of shares of orders submitted for the first time into POSIT over the total intra-day traded volume for stock i. The dependent variable is QS_i, the duration-weighted average quoted touch. The control variables are the following: the logarithm of the average intra-day GBP traded volume denoted $ln(£V_i)$, the close-to-close return volatility σ_i and the logarithm of the average NMS in number of share denoted $ln(NMS_i)$. Student values are given in parentheses. Coefficients marked with two stars are significant at the 1% threshold.

Table 6.2

Test of hypothesis H3 – Cream skimming vs risk sharing: Spreads and institutional CN-submitted order flow

Dependent variable	Observation period	Control variables				Explaining variable	R^2
		Intercept	$ln(£V_i)$	σ_i	$ln(NMS_i)$	NSI_i	
QS_i	Period 1 (1,400 obs.)	13.448** (31.631)	-1.307** (-33.431)	0.670** (21.683)	0.538** (8.736)	$5.216.10^{-5}$ (0.450)	62.5%
	Period 2 (1,378 obs.)	14.347** (35194)	-1.376** (-33.879)	0.493** (18.690)	0.592** (9.745)	$-1.96.10^{-4}$ (-1.171)	63.4%

This table displays, for Period 1 and Period 2, the estimates of the cross-sectional regressions of the average quoted spread onto NSI_i, the total amount in number of shares of orders submitted for the first time into POSIT over the total intra-day traded volume for stock i. The dependent variable is QS_i, the duration-weighted average quoted touch. The control variables are the following: the logarithm of the average intra-day GBP traded volume denoted $ln(£V_i)$, the close-to-close return volatility σ_i and the logarithm of the average NMS in number of share denoted $ln(NMS_i)$. Student values are given in parentheses. Coefficients marked with two stars are significant at the 1% threshold.

Table 7

Test of hypothesis H4 –Spreads and dealer CN-trading

Dependent variable	Observation period	Control variables				Explaining variable	R^2
		Intercept	$ln(£V_i)$	σ_i	$ln(NMS_i)$	XM_i	
QS_i	Period 1 (1,400 obs.)	13.056** (30.467)	-1.280** (-32.713)	0.645** (20.656)	0.574** (9.290)	-0.286** (-4.200)	63.0%
	Period 2 (1,378 obs.)	13.856** (33.380)	-1.332** (-32.390)	0.485** (18.424)	0.612** (10.092)	-0.239** (-4.223)	63.7%
CS_i	Period 1 (1,400 obs.)	15.568** (23.813)	-1.812** (-30.344)	1.501** (31.489)	1.048** (11.111)	-0.234* (-2.255)	67.7%
	Period 2 (1,378 obs.)	15.792** (24.894)	-1.866** (-29.682)	1.375** (34.179)	1.153** (12.450)	-0.254** (-2.93)	71.5%

This table shows, across both observation periods, the estimated coefficients for cross-sectional regressions of spread measures onto XM_i, the total share volume traded in POSIT by market makers reported to the total intra-day market volume for stock i. The dependent variables are successively: QS_i, the duration-weighted average quoted touch, and CS_i, the average closing market spread, index i standing for stock i. In each regression, the control variables are the following: the logarithm of the average intra-day GBP traded volume denoted $ln(£V_i)$, the close-to-close return volatility σ_i and the logarithm of the average NMS in number of share denoted $ln(NMS_i)$. Student statistics stand in parentheses. Coefficients are marked with two stars when significant at the 1% level.

Table 8.1

Test of hypothesis H5 – Quote revisions and CN-submitted order flow

Dependent variable	Observation period	Control variables					Explaining variable	R^2
		Intercept	TN_i	$ln(\pounds NMS_i)$	BD_i	IMB_i	S_i	
NQR_i	Period 1 (1,400 obs.)	4.011** (4.948)	$9.356.10^{-2}$** (33.280)	0.404** (6.131)	0.355** (12.562)	$-3.74.10^{-2}$** (-6.456)	$1.576.10^{-5}$ (0.461)	74.4%
	Period 2 (1,378 obs.)	4.582** (6.402)	$7.346.10^{-2}$** (20.868)	0.427** (6.921)	0.366** (12.579)	$-4.68.10^{-2}$** (-9.212)	$8.098.10^{-5}$ (0.677)	73.2%

This table gives the estimated coefficients over Period 1 and Period 2 for the following regression: $NQR_i = a + bTN_i + c\,ln(\pounds NMS_i) + dBD_i + eIMB_i + fS_i + \varepsilon_i$, where NQR_i is the average number of quote changes per day for stock i. The explaining variable S_i is computed as the total share volume submitted to the CN including new submissions and resubmissions of unexecuted orders. The control variables are the average number of trades per day TN_i, the logarithm of the average NMS in GBP denoted $ln(\pounds NMS_i)$, the average daily percentage of volume declared as broker-dealer to broker-dealer trades denoted BD_i and IMB_i, the average market imbalance between purchases and sales in percentage of the intra-day trading volume. ε_i is an error term. Student statistics stand in parentheses. Coefficients are marked with two stars when significant at the 1% level.

Table 8.2

Test of hypothesis H5 – Quote revisions and CN- executed order flow

Dependent variable	Observation period	Control variables					Explaining variable	R^2
		Intercept	TN_i	$ln(£NMS_i)$	BD_i	IMB_i	X_i	
NQR_i	Period 1 (1,400 obs.)	4.057** (5.008)	$9.410.10^{-2}$** (33.320)	0.387** (5.822)	0.349** (12.300)	$-3.65.10^{-2}$** (-6.299)	$7.640.10^{-2}$* (1.967)	74.4%
	Period 2 (1,378 obs.)	4.645** (6.511)	$7.495.10^{-2}$** (21.116)	0.389** (6.206)	0.363** (12.538)	$-4.45.10^{-2}$** (-8.690)	0.105** (2.806)	73.4%

This table gives the estimated coefficients over Period 1 and Period 2 for the following regression: $NQR_i = a + bTN_i + c\,ln(£NMS_i) + dBD_i + eIMB_i + fX_i + \varepsilon_i$, where NQR_i is the average number of quote changes per day for stock i. The explaining variable X_i is the POSIT market share in total intra-day market volume for stock i. The control variables are the average number of trades per day TN_i, the logarithm of the average NMS in GBP denoted $ln(£NMS_i)$, the average daily percentage of volume declared as broker-dealer to broker-dealer trades denoted BD_i and IMB_i, the average market imbalance between purchases and sales in percentage of the intra-day trading volume. ε_i is an error term. Student statistics stand in parentheses. Coefficients are marked with two stars when significant at the 1% level.

Table 9.1

Test of hypothesis H6 – Market impact and CN-executed order flow

Dependent variable	Observation period	Control variables					Explaining variable	R^2
		Intercept	σ_i	QS_i	$ln(NMS_i)$	TN_i	X_i	
$\sigma_{vwap\,i}$	Period 1 (1,400 obs.)	-1.372** (-12.677)	9.545.10-2** (10.163)	9.710.10-2** (18.185	0.199** (14.038)	3.401.10-3** (4.912)	-3.87.10-2** (-3.27)	50.3%
	Period 2 (1,378 obs.)	-0.969** (-11.150)	8.337.10-2** (13.678)	7.809.10-2** (18.276)	0.153** (13.280)	5.333.10-3** (7.187)	-2.98.10-2** (-3.769)	57.5%

This table presents the estimates of the following cross-sectional regression: $\sigma_{vwap_i} = a + b\sigma_i + bQS_i + c\,ln(NMS_i) + dTN_i + eX_i + \varepsilon_i$, for observation periods 1 and 2. The dependent variable σ_{vwap_i} is the average of daily standard deviations of transaction prices from VWAP for stock i, and are chosen as control variables the close-to-close return volatility σ_i, the duration-weighted average quoted spread QS_i, the logarithm of the NMS in number of shares denoted $ln(NMS_i)$ and TN_i, the average number of trades per day. The independent variable X_i is the POSIT market share in total intra-day market volume for stock i. ε_i is the error term. Student statistics stand in parentheses. Coefficients are marked with two stars when significant at the 1% level.

Table 9.2

Test of hypothesis H6 – Market impact, dealer CN-trading and institutional CN-trading

Dependent variable	Observation period	Control variables					Explaining variables		R^2
		Intercept	σ_i	QS_i	$ln(NMS_i)$	TN_i	XM_i	XI_i	
$\sigma_{vwap\,i}$	Period 1 (1,400 obs.)	-1.395** (-12.881)	$9.399.10^{-2}$** (10.015)	$9.573.10^{-2}$** (17.893)	0.204** (14317)	$3.358.10^{-3}$** (4.860)	-7.76.10-2** (4.242)	$5.652.10^{-3}$ (0.285)	50.5%
	Period 2 (1,378 obs.)	-0.970** (-11.154)	$8.342.10^{-2}$** (13.683)	$7.797.10^{-2}$** (18.234)	0.153** (13.291)	$5.340.10^{-3}$** (7.195)	$-3.70.10^{-2}$** (-3.059)	$-1.98.10^{-2}$ (-1.315)	57.5%

This table shows, across both observation periods, the coefficients estimated when regressing $\sigma_{vwap\,i}$ on XM_i and XI_i, i.e. respectively the total share volume traded in POSIT by market makers and the total share volume traded in POSIT by institutional investors, in percentage of the total intra-day market volume for stock i. The dependent variable σ_{vwap_i} is the average of daily standard deviations of transaction prices from VWAP for stock i, and are chosen as control variables the close-to-close return volatility σ_i, the duration-weighted average quoted spread QS_i, the logarithm of the NMS in number of shares denoted $ln(NMS_i)$ and TN_i, the average number of trades per day. ε_i is the error term. Student statistics stand in parentheses. Coefficients are marked with two stars when significant at the 1% level.

Table 10

Test of hypothesis H7 – Spreads and CN-executed order flow

Dependent variable	Observation period	Control variables				Explaining variable	R^2
		Intercept	$ln(£V_i)$	σ_i	$ln(NMS_i)$	X_i	
QS_i	Period 1 (1,400 obs.)	13.267** (30.961)	-1.290** (-32.639)	0.659** (21.172	0.550** (8.913)	-0.106* (-2.294)	62.6%
	Period 2 (1,378 obs.)	14.082** (33.192)	-1.349** (-31.700)	0.491** (18.566)	0.594** (9.775)	$-6.48.10^{-2}$ (-1.618)	63.3%

This table shows, across both observation periods, the estimated coefficients for the cross-sectional regressions of average quoted spreads onto X_i, the POSIT market share in total intra-day market volume for stock i. The dependent variables is QS_i, the duration-weighted average quoted touch for stock i. The control variables are the following: the logarithm of the average intra-day GBP traded volume denoted $ln(£V_i)$, the close-to-close return volatility σ_i and the logarithm of the average NMS in number of share denoted $ln(NMS_i)$. Student statistics stand in parentheses. Coefficients are marked with two stars (one star) when significant at the 1% level (5% level).

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[1] The SEC defines ATSs as automated systems that centralise, display, match, cross or otherwise execute trading interest but that are not registered with the Commission as national securities exchanges or separated by a registered securities association. In Europe, the FESCO, now renamed CESR, published in June 2001 a set of standards proposed for application on ATSs, where ATSs are defined as entities "which, without being regulated as an exchange, operates an automated system that brings together buying and selling interests – in the system and according to rules set by the system's operator – in a way that forms, or results in, an irrevocable contract."

[2] The term *broker-dealer* designates exchange members with dual capacity: they can either be market makers or agency brokers.

[3] The Instinet system was the first ECN to open in the US and operates as an anonymous order book.

[4] According to Barclay, Hendershott and McCormick (2001), ECNs were involved in 30% of the total dollar volume traded in a sample of 150 NASDAQ stocks during June 2000, and today, ECNs approximately account for 40% of the dollar volume traded in NASDAQ securities and 3% of the dollar volume traded in NYSE-listed stocks while these market volume shares were respectively 13% and 1.4% in 1993.

[5] POSIT stands for *Portfolio System for Institutional Traders*. This system was created in 1987, as a joint venture between ITG Inc. and BARRA Inc., the California based quantitative house.

[6] SEAQ is the *Stock Exchange Automated Quotations* system. This screen-based trading system was introduced on October 27, 1986, as part of the City's Big Bang, to carry market makers' bid and offer quotes and trade reports for UK securities.

[7] ITG Europe is a 100% subsidiary of ITG Inc. based in Dublin, with a branch in London and acts as a pure agency classical broker. It is a member of the London Stock Exchange, Deutsche Börse and Euronext.

[8] UK, Germany, Switzerland, France, Belgium, Netherlands, Italy, Spain, Sweden, Finland and Ireland.

[9] For an exhaustive review of the literature on this topic, see Lee (2002).

[10] The terms *market makers* and *dealers* will be used interchangeably in the paper.

[11] Domestic equities consist of ordinary shares issued by UK, Channel Islands and Isle of Man companies and other companies with primary UK listing (principally Irish companies).

[12] This sub-section draws on the regulatory guide of the LSE for non SETS domestic equities.

[13] The NMS classification of SEAQ securities is reviewed quarterly using the following formula: (value of customer turnover in previous 12 months in £)/(closing mid-price on last day of quarter×10000). NMS's are then rounded up or down to one of the following bands: 100, 200, 500, 1000, 2000, 3000, 5000, 10000, 15000, 25000, 50000, 75000, 100000, 150000, 200000.

[14] Some market makers are granted special permission to display prices in smaller quantities than NMS. The reduced NMS is half the NMS rounded down to the nearest NMS band.

[15] Prior to April 2001, these crosses use to be batch auctions where only limit orders could be entered.

[16] POSIT technology also offers clients the ability to generate trades that require market prints (e.g. internal crosses across different underlying clients) by means of "directed crosses". These bespoke matches may take place at any time during the trading day, outside of the normal scheduled match times and may use the standard POSIT mid-point pricing or some other benchmark pricing, e.g. VWAP. These directed crosses are excluded from our dataset.

[17] Clients can associate different types of constraints on the orders they submit to POSIT, so as to avoid unfavourable match executions: price limits, minimum value or number of shares to be executed, or maximum cash imbalance for portfolio orders.

[18] On the 28th of March 2000, an unofficial 4:00 pm match was introduced: it was only run some days according to trading activity. This match became official and regular at the end of 2002.

[19] The trading intra-day period I consider lays from 8:00 am to 5:00 pm, as I noticed that trading volumes remained high until 5:00 pm, even if the MQP closes at 4:30 pm.

[20] To determine the side of a trade, I require two conditions: the side officially reported by the market maker who declared the trade and the difference between the transaction price and the current mid-quote at the time of the trade. Following Lee and Ready (1991), a positive difference is supposed to indicate a purchase while a negative difference would indicate a sale. In case of contradiction between both conditions, I consider that the side of the trade is unknown and the transaction is excluded.

[21] The term *touch* is used at the LSE to designate the spread between the lowest ask quote and the highest bid quote, and is referred to as the *yellow strip* on SEAQ: it is equivalent to the *market spread* or the *inside spread*.

[22] To calculate the effective spread applied to a trade, the side of the trade is first determined following the criteria mentioned in footnote 26. When the side of a transaction cannot be identified, the trade is excluded from the calculation of ES_i .

[23] As the CN does not open out of the trading period, overnight trading is irrelevant for the present study and all market figures, in the paper, only include intra-day activity. Any trade is considered as an intra-day transaction when its reported time stands between 8:00 am and 5:00 pm (cf. note 25).

[24] For a detailed analysis of differential costs between ATS-executed orders and broker-executed orders, see Conrad, Johnson and Wahal (2001) and Næs and Ødegaard (2001) .

[25] In my samples, evidence on the endogeneity of the CN activity measures used as independent variables, are weak enough not to alter the regression estimates.

[26] $BD_i = \frac{1}{T_i}\sum_{t=1}^{T_i}\frac{BD_{it}}{V_{it}}$ where BD_{it} is the amount of trading volume declared as broker-dealer to broker-dealer trades, on day t for stock i and V_{it} is the volume traded on day t for stock i.