The Role of Transaction Costs for Financial Volatility: Evidence from the Paris Bourse

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Abstract

Minimum price variation rules (tick size rules) in the French stock market prior to 1999 provide a natural experiment on the role of transaction costs for financial price volatility. For stock prices above French francs (FF) 500, the minimal tick size for quotes increases from FF 0.1 to FF 1. This tick size increase generates a 20 percent higher median effective spread and therefore artificially inflates transaction costs. Based on 5 minute intraday return intervals, we calculate 6,774 daily realized volatility measures for all CAC 40 stocks in the price range from FF 400 to FF 600 and measure the volatility impact of the transaction cost increase at FF 500. We find that the median daily realized standard deviation of returns is approximately 27 percent higher in the high cost regime. Panel regressions confirm this result at a high level of statistical significance. In the light of this evidence a security transaction tax should increase asset return volatility.

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Abstract

Minimum price variation rules (tick size rules) in the French stock market prior to 1999 provide a natural experiment on the role of transaction costs for financial price volatility. For stock prices above French francs (FF) 500, the minimal tick size for quotes increases from FF 0.1 to FF 1. This tick size increase generates a 20 percent higher median effective spread and therefore artificially inflates transaction costs. Based on 5 minute intraday return intervals, we calculate 6,774 daily realized volatility measures for all CAC 40 stocks in the price range from FF 400 to FF 600 and measure the volatility impact of the transaction cost increase at FF 500. We find that the median daily realized standard deviation of returns is approximately 27 percent higher in the high cost regime. Panel regressions confirm this result at a high level of statistical significance. In the light of this evidence a security transaction tax should increase asset return volatility.

That the sins of the London Stock Exchange are less than those of Wall Street may be due, not so much to differences in national character, as to the fact that to the average Englishman Throgmorton Street is, compared with Wall Street to the average American, inaccessible and very expensive. The Jobber's 'turn', the high brokerage charges and the heavy transfer tax payable to the Exchequer, which attend dealings on the London Stock Exchange, sufficiently diminish the liquidity of the market (...) to rule out a large proportion of the transaction characteristic of Wall Street. The introduction of a substantial government transfer tax on all transactions might prove the most serviceable reform available, with a view to mitigating the predominance of speculation over enterprises in the United States.

John Maynard Keynes, *The General Theory of Employment, Interest and Money*, 1936.

Despite the prevailing opinion to the contrary, I am very dubious that in fact speculation in foreign exchange would be destabilizing. Evidence from some earlier experiences and from current free markets in currency in Switzerland, Tangiers, and elsewhere seem to me to suggest that, in general, speculation is stabilizing rather than the reverse, though the evidence has not yet been analyzed in sufficient detail to establish this conclusion with any confidence.

Milton Friedman, *Essays in Positive Economics*, 1953.

This paper provides a new empirical perspective on a long and continuing debate about the relationship between trading costs and financial market volatility. At least since Keynes stock market critique in 1936, stock price volatility has been related to low transaction costs which allegedly facilitate destabilizing financial speculation. In spite of the prominence of this idea in the general public, hardly any evidence exists on whether higher transaction costs foster or mitigate financial price volatility.

The question is interesting in at least three respects. First, regulatory, organizational and technological progress has considerably decreased transaction costs. Widespread financial market liberalization in the 1980s lowered trading commission and electronic trading in the 1990s further diminished stock trading cost.[1] But at the same time individual stock volatility appears to have increased in the U.S. (Campbell, et al. (2001)). It is unclear if there is a causal link here or just coincidence. Second, transaction costs are influenced by the microstructure organization of the market. The introduction of smaller pricing grids (ticks) in the U.S. with price steps of 1/16th of a dollar instead of 1/8th appears to have reduced transaction costs for

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[1] See for example Domowitz *et al.* (2001) and Jones (2002).

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the majority of investors. Does this regulatory transaction cost benefit come at the expense of higher stock price volatility or do we obtain more price stability at the same time? Third, transaction costs sometimes include a tax component. While security transaction taxes have generally decreased in the 1990s, they remain nevertheless important in a few countries like the U.K.[2] Moreover, parts of the anti-globalization movement have elevated global security transaction taxes to one of their policy objectives. The policy debate about financial market stability seems to evolve around convictions rather than sound evidence.

To our knowledge this is the first paper which provides clean and strong statistical evidence on the nexus between transaction costs and stock price volatility.[3] We use a large data set on the French stock transactions between 1995 and 1999 to show that higher transaction costs increase stock return volatility. Prior to 1999 and the introduction of the euro, French stocks were subject to an important transaction cost increase if their price moved above the French francs (FF) 500 price threshold. Above FF 500, the minimal tick size for quotes in the centralized electronic order book increased by a factor of 10 from FF 0.1 to FF 1. The smallest feasible percentage spread for stock quotation therefore increased from 2 to 20 basis points. We document that the 20 basis point spread is indeed frequently binding for stock prices above FF 500 and therefore constitutes an exogenous cost component induced by the pricing grid of the electronic order book. The French stock market thus provides an ideal natural experiment on the role of transaction costs for stock return volatility.

Our sample selection consists of all CAC 40 index stocks which trade in the price interval from FF 400 to FF 600 over the 4 year period from January 1995 to December 1998. Effective spread measurements on approximately 4.7 million trades show that the median effective spread is 20 percent higher for stocks with prices just above FF 500. For the same sample we calculate daily realized volatility based on 5 minute intraday return intervals. The median realized standard deviation of returns is 27 percent higher for the stocks trading at prices above FF 500. Our volatility inference is based on 6,774 daily realized volatility measurements and the result is obtained at a high level of statistical significance.

We also explore the natural experiment in its conditional dimension with respect to market wide volatility. Low market wide volatility measured by daily realized stock index volatility

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[2] Stamp duties in the U.K. amount to an astonishingly high 0.5 percent of the transaction volume.

[3] The only other study based on similar research methodology is Bessembinder (2000) with a focus on transaction costs rather than volatility.

generally reduces spreads on individual stocks. The minimum feasible spread of 20 basis points just above FF 500 therefore tends to become more frequently binding for the quoted spreads. Low index volatility should therefore accentuate the transaction cost and volatility differential between the two regimes. It is straightforward to show that on trading days with below average index volatility, stocks in the large tick regime have a 51 percent higher median effective spread compared to 3 percent on days of high index volatility. In accordance with the positive relationship between transaction costs and volatility, we find that the realized volatility differential between the tick regimes considerably increases on days of low index volatility. The conditional analysis therefore re-enforces the unconditinal result.

Our evidence directly bears on the historic debate about the (de-)stabilizing role of short-term speculation. Higher transaction costs fall disproportionally on short-term speculators. But if this trading activity tends to increase or reduce price volatility has always been controversial. The evidence on the price stabilizing effect of lower transaction costs can therefore be interpreted as a rehabilitation of the short-term speculator. Reduced transaction cost increase his incentives for intertemporal arbitrage. Short-term speculation appears to be generally price stabilizing as conjecutured by Friedman (1953), Miller (1991) and others.

The following section discusses the existing literature on the nexus between transaction costs and price volatility and the role of tick size regulation. We also explain how our results relate to the volatility effect of a security transaction tax. Section 3 introduces the institutional framework of the French stock market. We discuss in particular its tick size regime, the electronic trading system and the publicly available microdata. Methodological issues of spread and volatility measurement are discussed in section 5. Sections 6.1 and 6.2 present the empirical results for effective spreads and realized volatility, respectively. Section 7 concludes.

I. Literature

A. Nexus between Transaction Costs and Volatility

The theoretical literature provides little guidance as to the relationship between transaction costs and financial price volatility. Some economists like Tobin (1978, 1984), Stiglitz (1989), Summers and Summers (1989), Eichengreen, Tobin and Wyploz (1995) conjectured

that higher transaction costs discourage destabilizing investors with short-run horizons while being less costly for stabilizing investors with long-run horizons. Higher trading costs may privilege trading based on economic fundamentals. The opposing view is articulated by Friedman (1953), who argues that speculative behavior is generally price stabilizing irrespective of the time horizon. Miller (1991), Schwert and Seguin (1993), Dooley (1996), among others, argues that short-term speculation may be as beneficial as investment behavior based on a longer time horizon.[4] The relative merit these opposing views need to be judged in the light of the empirical evidence.

But the existing empirical evidence on the issue is also inconclusive.[5] Previous studies on the linkage between transaction costs and volatility are based on an effort to identify intertemporal transaction cost variations. Mulherin (1990) examines a long-run series of estimated trading costs in the NYSE and relates it to the daily volatility of the Dow Jones returns over the period 1897 to 1987. The data suggest a negative but statistically insignificant correlation. However, such long-run evidence is problematic because of parallel changes in the underlying market structure and possible measurement errors for the estimated transaction costs. Umlauf (1993) contributes an observation from the Swedish transaction tax experience in the 1980s. He finds that neither the introduction of a 1 percent round-trip transaction tax in 1984 nor its increase to 2 percent in 1986 decreased volatility in the Swedish stock market. However, the Swedish tax was collected from domestic security brokers and was increasingly avoided as a large percentage of trading volume in Swedish securities moved to international markets (Campbell and Froot, 1994). Jones and Seguin (1997) report on the liberalization of mandated minimal commission rates in the U.S. This regulatory change decreased transaction costs in the NYSE and the AMEX markets in 1975. The authors find a reduction in the market volatility in the year following the deregulation, but the same volatility decrease, although less pronounced, was also registered for the previously unregulated Nasdaq market. In general, regulatory changes in transaction costs may coincide with unrelated changes in market volatility. This renders the identification of the volatility effect difficult in a pure time series study. Bessembinder and Rath (2002) use a statistically more powerful event study

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[4] For a general discussion on the Tobin tax see ul Haq et al. (1996). We are fully aware that a comprehensive discussion of the Tobin tax includes many aspects outside the scope of this paper. However, the linkage between transaction costs and volatility is at the core of the theoretical debate.

[5] See Grundfest and Shoven (1991) for the same argument about the empirical evidence.

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methodology on stocks which reduce their trading costs by moving from the Nasdaq market to the NYSE. They find strong evidence that the newly NYSE listed stocks reduces both trading costs and the standard deviation of daily returns. Unfortunately, NYSE listings may simultaneously alter other volatility parameters, for example the investor composition. The stock exchange listing effect cannot be distinguished from a pure transaction costs effect.

This paper is based on a cross sectional identification of transaction cost differences within the same market. The large discontinuity in the pricing grid of the French electronic trading system provides a unique natural experiment for such a cross sectional study. To the extent that the nominal price of a stock is randomly determined by past stock splits, any two small adjunct price intervals will contain a random selection of stocks.[6] Moreover, stocks pass from the low cost regime with the small ticks to the high cost regime with large ticks at different times. We therefore obtain a data panel which allows us to control for market wide volatility effects.

B. Ticks in the Literature

The literature on market microstructure has produced a large number of studies on the role of tick size for transaction costs. Two effects can be distinguished. First, bid-ask spreads may often come relatively close to the average tick size (Angel (1997)). The minimal tick size regulation is therefore a frequently binding constraint and imposes exogenous differences in transaction costs. Second, higher tick sizes may decrease broker incentives for competitive quote improvement. Electronic trading systems generally reward quote improvements with privileged execution (price priority). The costs of such quote improvements in terms of price sacrifice is increased for a higher tick size. Harris (1994) predicts that larger tick size therefore reduces the incentive for competitive quote improvement and increases quoted spreads. Simultaneously, lower quoted spreads may reduce the incentive for liquidity provision. A smaller tick size may therefore result in lower market depth as measured by the liquidity offered at the best limit prices.

A large number of studies confirmed the positive relationship between quoted spreads and percentage tick size for many different markets. Lau and McInish (1995) examine a tick size

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[6]We assume that companies cannot choose their stock splits as to target one price interval relative to another. This is certainly a correct assumption if the two sample intervals are joint and sufficiently narrow. We also note that stock splits are typically undertaken with respect to full integers.

reduction in the Stock Exchange of Singapore (SES) from \$0.50 to \$0.10 for stocks above \$25 on July 18, 1994. The AMEX reduced its tick size in two stages. In 1992, ticks switched from 1/8th to 1/16th of a dollar for stocks below \$5 (Ahn, Cao, and Choe (1996)) and this rule was extended to all stocks on May 7, 1997 (Ronen and Weaver (2001)). The Toronto Stock Exchange (TSE) lowered tick size in a move from a fractional to a decimal trading system on April 15, 1996. Bacidore (1997); Porter and Weaver (1997); and Ahn, Cao, and Choe (1998) all find consecutive quoted spread decreases. In 1997, the tick size reduction from 1/8th to 1/16th in both the NYSE and Nasdaq gave rise to further transaction cost studies by Bollen and Whaley (1998); Goldstein and Kavjecz (2000); and Jones and Lipson (2001). Again, lower tick size comes with lower quoted spreads.

But transaction costs for large orders are influenced by both quoted spreads and market depth. A more meaningful measure of effective transaction cost is the volume weighted average of the execution prices (along the price elastic liquidity supply function) relative to the midprice. This so-called 'effective spread' accounts for the price impact of larger market orders. Generally, results for effective spreads are qualitatively similar to those for quoted spreads. Bacidore (1997); Porter and Weaver (1997); Ahn, Cao and Choe (1998) confirm that the smaller tick size in the TSE reduced effective spreads by approximately 20 percent. For the NYSE, Bollen and Whaley (1998) estimate an effective spread reduction of nearly 8 percent. Bessembinder (1997) studies Nasdaq stocks undergoing a tick size modification at the \$10 price threshold and finds a 11 percent effective spread decrease due to smaller ticks.[7] While overall transaction costs decrease with the tick size, this benefit may mostly accrue to investors and speculators with small and medium size orders. For institutional investors with very large orders, the reduction in market depth may outweigh the benefit of narrower spreads (Jones and Lipson (1999, 2001)). However, short-term speculators are certainly free to choose their optimal trade size. They can therefore unambiguously reduce their trading costs in a trading environment with smaller ticks.

C. Tick Size Effects and Security Transaction Taxes

Can tick size effects serve as an experiment to evaluate the volatility effect of a security transaction tax? For the liquidity demand side, it certainly makes no difference if the trans-

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[7]Unlike in the Paris Bourse, the Nasdaq tick size change from 1/32th to 1/8th at prices of \$10 is based on a market convention rather than imposed by the trading system.

action cost increase originates in tick size regulation or in a security transaction tax with the same spread increase. Hence, demand side effects are equivalent. However, the same does not hold for the liquidity suppliers or brokers, for whom a security transaction tax is different from a binding tick size constraint. While a tax is a rent for the tax authority, binding tick size regulation constitutes a rent for the liquidity suppliers.

The latter makes liquidity provision more profitable and may generate a more liquid market. This results in higher market depth documented by Goldstein and Kavajecz (2000) for the NYSE and Ahn, Cao and Choe (1998) for the TSE.[8] Greater market depth should generally reduce volatility because of a lower price impact of large market orders. The positive liquidity supply effect of a tick size increase is absent if the larger spread is induced by a security transaction tax. In this case the liquidity provision (through limit order submission) itself is subjected to taxation and no increase in liquidity provision can be expected. These considerations lead us to conclude that security transaction taxes generate more price volatility than binding tick size regulation for a similar increase in spreads. The volatility effects of higher transaction costs estimated in our study should therefore be interpreted as a *lower limit* for the volatility increase due to a security transaction tax.

II. Institutional Framework

Since the beginning of the 1990s, the Paris Bourse operates as a computerized and centralized limit order market. It allows for continuous trading from 10.00 a.m. to 5.00 p.m. The opening price at 10.00 a.m. is determined by a call auction. All brokers with trading terminals enjoy equal trading opportunities in the computerized system known as CAC (Cotation Assistée en Continu). There are no market makers or floor traders with special obligations.

A. The Tick Size Regimes

Investors can submit limit orders at any price on a prespecified pricing grid, defined by the tick size. This tick size, that is, the minimum price step between two prices accepted by the trading system, depends upon the price level of the security. For prices below French francs (FF) 5 the tick size is FF 0.01; for prices between FF 5 and FF 100 the tick size is

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[8] By contrast, Ronen and Weaver (2000) find no change in market depth related to the adoption of 1/16th in the AMEX in May 1997.

FF 0.05; for prices between FF 100 and FF 500 the tick size is FF 0.1; for prices between FF 500 and FF 5000 the tick size is FF 1; and above FF 5000 the tick size is FF 10. During the sample period 1995-1998, the French franc was worth approximately $ 0.18. Most stocks trade in the price range from FF 200 to FF 1000 and are therefore subject to either FF 0.1 ticks (referred to as small ticks) or FF 1 ticks (referred to as large ticks). The value of FF 500 marks an empirically important discontinuity in the electronic order book at which the price grid increases by a factor of 10.[9] The pricing grid imposes a technical lower bound on the smallest possible percentage spread between the best bid and ask price. Spreads cannot decrease below 20 basis points for stocks just above FF 500, while it can drop to 2 basis points below a security price level of FF 500. We show in section 6.1 that the minimum spread imposed by the large tick regime is indeed frequently binding and therefore artificially inflates investor trading costs.

Statistical inference based on the step function of the pricing grid provides a better natural experiment compared to market wide tick size reform, which subjects all stock (or entire stock groups) to a one time tick size modification. By contrast, grid size step functions imply that the spread constraint operates on a random subsample of stocks with the unconstrained stocks available as a control group. We can therefore distinguish the transaction costs effect on volatility from other market wide volatility shocks.

The tick size regime of the French stock market was modified with the introduction of euro quotations on January 2, 1999. The new euro price gird was designed to limit the maximal percentage ticks size at 10 basis points. Tick size for prices below € 50 is € 0.01; for prices between € 50 and € 100 the tick size becomes € 0.05; for prices between € 100 and € 500 the tick size is € 0.1; and for prices above € 500 the tick size is € 0.5. The empirically most relevant tick size discontinuity at around € 50 is now reduced to a grid factor of 5. The minimum percentage spread can no longer exceed 10 basis points compared to 20 basis points before 1999. This suggests that we focus our empirical analysis on the period prior to the euro introduction when tick size regulation is more likely to impose a constraint on the quoted spread.[10]

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[9]By comparison the tick size jump from 1/32th to 1/8th at $10 in the Nasdaq market prior to 1997 is based on an informal market convention rather a rule imposed by the trading system. Moreover, it concerns mostly small and illiquid stocks. Also, the NYSE tick size breakpoint at 1 dollar is irrelevant for most stocks.

[10]Compare Bourghelle and Declerck (2002) for a study on market liquidity changes at the Paris Bourse related to the transition to the euro tick regime.

B. The Trading System

Like most electronic markets, the Paris Bourse enforces price and time priority. Orders are executed at the best available price. If two limit orders offer the same price, execution preference is given to the limit order which arrives first. The electronic order book itself is very transparent. Information on the five best bid and ask prices and the number of shares demanded or offered at each of these prices is continuously available to the public. Brokers can observe the entire limit order book and the identification codes of the brokers placing orders.

An exception to full order book transparency are so-called "hidden orders". These are orders for which only a fraction of the available liquidity appears on the trading screen. For example, a hidden order may consist of a sell of 10,000 shares, but the seller allows only 1,000 shares to become visible on the screen. The remaining 9,000 shares are in this sense "hidden" in the electronic book. The invisible fraction of the order preserves price priority, but not time priority. Once the visible fraction of 1000 shares has been fully executed, another 1,000 shares of the hidden order fraction becomes automatically visible. The visible part of a hidden order is required to amount to at least 10 times the minimum tradable quantity in a stock. Hidden orders allow traders to choose the transparency of their trading strategy. They are particularly useful to traders with the need to conceal trading intentions on large quantities.[11]

One specificity of the trading system is the treatment of "market orders" without limit price. The CAC trading system treats them automatically as limit orders at the best momentarily available price. Execution is therefore partial if the demand exceeds the available liquidity at the best price. The non-executed fraction of such an order is transformed into a limit order. However, traders can always obtain full execution by selecting a sufficiently unfavorable limit price.

Essentially all trades are executed at prices in the electronic book, except pre-matched block trades, which are subject to special rules. If the pre-matched block trades occur at or inside the current spread, they can bypass the limit order book. If they occur outside the current spread, then the priority of the previously posted limit order is respected. For

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[11] For an analysis of the role of hidden orders at the Paris Bourse, see Harris (1996).

example, if the block price exceeds the best ask, then the limit orders between the best ask and the block price are purchased by the block buyer at the block price. Approximately 1.1 percent of the trades and 17.2 percent of the volume occurs through pre-matched trades.

By law, the French stock market is a centralized market. Transactions governed by French contracts must be executed on the Bourse. Trading outside France is of course possible. Dealers in London may for example bypass the Paris market by using the London International Stock Exchange Automated Quotation System (SEAQ) to search for counterparties with a trading interest. De Jong, Nijman and Roell (1995) document with a short data sample in 1991 that this happens particularly for large trades. The London transaction prices are negotiated between dealers and not subject to formal tick size constraints. We assume that such interdealer trades outside France do not substantially modify the transaction cost pattern induced by the tick size regulation in the main Paris market. Robustness of this assumption can be checked by excluding those stocks for which more liquid parallel markets exist. We identify all sample stocks with cross listings in the London Stock Exchange or the New York Stock Exchange (ADRs) during the period 1995 to 1999. This is the case of 6 out of 28 stocks in the sample.[12] Parallel trading is presumably strongest in these stocks. However, their exclusion from the analysis did not quantitatively alter the results.

III. Data and Sample Selection

The Paris Bourse publicly provides comprehensive historical microdata on best limit quotes and security transactions.[13] Our data selection is motivated by two concerns. First, tick size regime induced transaction cost differences are likely to be most relevant for large and highly liquid stocks. These tend to have relatively small transaction costs and the tick size constraint for spread quotation is more frequently binding. We therefore limit our analysis to the stocks in the CAC 40 index comprising the 40 largest and most liquid French stocks. CAC 40 stocks account for approximately 64 percent of all transactions in our data period. Second, the transition to the euro quotation of stock prices in 1999 also brought a

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[12]The London cross listings occured for Lafarge on 10/30/1972, for Total on 9/26/1973, for Saint-Gobain on 7/2/1987, and for Alcatel Alstom on 6/25/1998. NYSE trading in ADRs prior to 1999 was feasible for Alcatel Alstom, AXA, France Telecom and Total.

[13]Previous studies on the same data source include Biais, Hillion, and Spatt (1995, 1999), and Venkataraman (2001).

modification of the tick size regime towards smaller tick size. Statistical identification of an exogenous transaction costs effect is therefore a priori better assured by using data prior to January 1999. We focus our analysis on 4 years of microdata from January 1995 to December 1998.

But 4 years of quote and transaction data for all CAC 40 stocks still exceeds our data processing possibilities. We therefore choose to observe only those CAC 40 stocks which are quoted in a price window around the tick size discontinuity at FF 500, namely between FF 400 and FF 600. The tick size constraint for the minimal percentage spread is obviously most severe directly above FF 500 and least so directly below. As stock prices move away from the FF 500 threshold, the two tick regimes become more similar in terms of their minimal feasible percentage spread. For example, a tick size of FF 1 at a stock price of FF 1000 allows for a 10 basis point percentage spread just as a tick size of FF 0.1 for a stock price of FF 100. The choice of a relatively small price window from FF 400 to FF 600 limits the number of observations and focuses on those observations for which the tick size regulation is most discriminatory.

All data are obtained directly from the Paris Bourse on monthly CD-ROMs which combines a variety of data files on transactions and quotes in different market segments. We match two of these files to calculate effective spreads for individual trades. A first data file (coded BDM2D2) provides a continuous record of the best bid and ask price of every stock. These data allow us to construct a continuous midprice as the benchmark for the transaction prices. A second data file (coded BDM1D2) contains a complete record of all trades and subtrades stripped of the identity of the counterparties. A single order executed against various limit orders is documented with the corresponding number of subtrades. By matching the transaction price with the midprice at the transaction time, we calculate the effective percentage spread for each trade and the trade weighted effective spreads for each executed order. We also use a third data file (coded BDM5D2) with records of the index level for the CAC 40 index every 30 seconds. This allows us to calculate realized index volatility.

Unfortunately, the data on the best quotes does not contain any information about the best bid and ask price during the opening auction. Registration of the best quotes only starts with the first transaction in the regular continuous trading period. We can therefore only calculate a midprice shortly after the 10.00 a.m. opening auction. Spread calculations on

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transactions in the opening auction are therefore difficult. These transactions are ignored in the consecutive analysis.[14]

IV. Methodology

This section discusses the transaction cost and volatility measurement. Our statistical methodology consists in a straightforward comparison of transaction costs and return volatility for stock observations in the two tick size regimes. We refine the volatility analysis with panel regressions controlling for stock specific effects and volatility autocorrelation.

A. Transaction Cost Measurement

The transaction cost measurement follows standard conventions. For individual trades and subtrades, we calculate the effective spreads as twice the distance from the midprice. For a transaction price P^T and a midprice P^M as the arithmetic average of the best bid and ask price, we obtain the effective spread as

$$s^{Trade} = \frac{2\left|P^T - P^M\right|}{P^M}.$$

But for convenience, we mostly refer to the log effective spread, $ls^{Trade} = \log s^{Trade}$, because its distribution is less skewed.

Alternatively, we can measure transaction costs for executed orders. A single order might be executed in n subtrades against limit prices $P_1^T, P_2^T, ..., P_n^T$ with corresponding quantities $V_1, V_2, ..., V_n$. We denote the executed order volume as $V = \sum_{i=1}^n V_i$. The effective transaction price follows as the value weighted average of the traded prices, $\overline{P}^T = \sum_{i=1}^n P_i^T V_i / V$, and the effective spread of an executed order is defined as

$$s^{Order} = \frac{2\left|\overline{P}^T - P^M\right|}{P^M}.$$

The log effective spread again follows as $ls^{Order} = \log s^{Order}$.

We highlight that the effective spread for orders measures the transaction costs only with respect to a single transaction. Brokers might break large client orders into many smaller

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[14]We also filter the data for outliers. Transactions for which the quoted spread exceeds 10 percent or is negative are discarded.

orders for consecutive execution. These multiple transactions are likely to result in higher transaction costs than those measured by the effective spread because of a consecutive price impact. But the transaction data of the Paris Bourse do not allow us to identify transaction sequences pertaining to the same broker. The effective spreads are therefore the best available transaction cost measure.[15]

B. Realized Volatility Measurement

The accurate measurement of stock price volatility is crucial for our analysis. The French stock market provides us not only with a record of all transactions prices, but also with data on the best bid and ask price. Best bid and ask quotes can be used to calculate the midprice as their arithmetic average throughout the trading day. We can use the continuously recorded midprice to measure ex-post realized daily volatilities as the squared sum of returns over very short time intervals. These realized volatility measures do not depend on any stochastic volatility model and become, in theory, free of measurement error as the sampling frequency of the returns approaches infinity. Concerns about microstructure noise due to non-synchronous trading and bid-ask bounce effects may in practise recommend longer sampling intervals as suggested by Andersen, et al. (2001). Following the previous literature, we choose to measure realized volatility based on midprice returns over 5 minute intervals.[16]

Trading days at the Paris Bourse start with an opening auction around 10.00 a.m. and concludes with a final (batch) auction at around 5.00 p.m. Unfortunately, the data on the best bid and ask quotes is available only immediately after termination of the opening auction with the start of the regular continuous trading session. A midprice can therefore only be calculated after the opening auction. We therefore discard the first 5 minute interval and start our record of midprices only at 10.05 a.m. The five-minute return series are constructed from the logarithmic differences between midprices for transaction recorded at or immediately before the full five-minute mark from 10.05 a.m. in the morning to 5.00 p.m. in the evening. We obtain a total of $83 = 12 \times 7 - 1$ daily return observations r_{tj}^i, where t denotes the trading day, j the intraday time interval, and i the stock. The realized volatility of stock i, on day t

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[15] For a transaction cost analysis of large institutional traders, see Jones and Seguin (1999, 2001).

[16] Since the French stock market data is generated by a centralized electronic order book, non-synchronous trading should not be a concern unlike in the U.S. data. Price data from Nasdaq for example is entered manually with time lags as long as 90 seconds.

is defined as

$$v_{it}^2 = \sum_{j=1,2,\ldots,83} (r_{jt}^i)^2,$$

and the realized standard deviation as v_{it}. Since both volatility measures are leptokurtic and skewed to the right, it is often useful to work with the corresponding logarithmic standard deviation given by

$$lv_{it} = \log v_{it},$$

and henceforth referred to as log realized volatility. This volatility measure is approximately Gaussian as argued by Andersen et al. (2001).

We examine intraday returns for autocorrelation. The median first order autocorrelation is slightly negative at -0.0248. Comparable measures for U.S. stock returns based on transaction records from the TAQ (Trade And Quotation) database shows much stronger negative autocorrelation. Andersen et al. (2001) report a median autocorrelation of -0.214 for 5 minute return intervals on 30 DJIA stocks. They therefore subject their time series to a MA(1) filter to correct for bid-ask bounce effect. The small degree of return autocorrelation in the French data allows us to work directly with the unfiltered data.

V. Evidence

Since our data selection criterion is based on both a stock belonging to the CAC 40 index and a particular price range, it is useful to first provide an overview of the resulting stock sample. Table I presents summary statistics separately for stocks in the price range from FF 400 to FF 500 (small ticks) and from FF 500 to FF 600 (large ticks). A total of 28 stocks in the index are trading (in terms of their average daily midprice) between FF 400 to FF 600 for at least one day between January 1995 and December 1998. Of those, 21 stocks trade in both tick size regimes, while 2 stocks trade exclusively in the large ticks regime and 5 trade only in the small ticks regime. On average stocks are recorded in the small tick regime for 147 days and in the large tick regime for 131 days. Overall, we obtain 3,377 stock trading days in the small and 3397 stock trading days in the large tick regime. The average number of daily trades are 779 and 653 for the small and large ticks, respectively. Average daily volumes are FF 107 million and FF 110 million, respectively.

A. Transaction Cost Evidence

Transactions costs can be measured with respect to trades or executed orders. In the latter case we group all subtrades resulting from the same order into one single transaction. We count a total of 4,696,422 trades and 2,918,829 executed orders. Excluded in this count are pre-matched trades (1.15 percent of all trades) and all trades in the opening auction for which we cannot calculate the midprice (8.95 percent of all trades).

Table II, panel A, summarizes the distribution of the log effective spread by tick size regime for all trades. We provide a 1 percent confidence interval for the various centiles of both spread distributions using the binomial-based method.[17] All reported centiles significantly differ for the two spread distributions. The median (mean) log effective spread in the small tick regime is -1.849 (-1.923) compared to -1.667 (-1.371) for large ticks. The median effective spread increase therefore amounts to 20 percent ($\approx e^{-1.667+1.849} - 1$) for trading with large ticks. Table II, panel B, reports the corresponding effective spread statistics for executed orders. Like for trades, we find that the percentiles of the distribution are very different across the two tick regimes with a strong censoring effect on the left tail in the large tick regime. The latter shows a skewdness of 1.485 and 1.528 for trades and executed orders, respectively.

It is instructive to visualize the distribution of log effective spreads. Figure 1 plots the log effective spread for a random sample of 20,000 trades as a function of the price level. If effective spreads were plotted directly, their y-axis value would often coincide because of the discretness of the ticks. To avoid this clustering effect, we add a small amount of random noise to each spread observation. This makes individual spread observations visually distinct and the feasible spreads apprear as a narrow band of points instead of a line. More points and a darker band show a higher density of spread observations. The lowest band in Figure 1 corresponds to effective spreads of 2 basis points ($\log(0.02) \approx -3.91$) for tick steps of FF 0.1 below FF 500. The following band corresponds to a 4 basis point spread, etc. Continuity of the band over the entire price range from FF 400 to FF 600 is only reached with the 20 basis point spread band ($\log(0.20) \approx -1.61$). Hence, we can clearly visualize that the tick size regulation is frequently binding for stock prices below FF 500. Figure 2 provides a non-parametric kernel density estimation of the effective spread of 2,540,764 trades below

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[17] We used the "centile" command in STATA combined with the cci (conservative confidence interval) option which forces confidence limits to fall exactly on sample values.

and 2,155,658 trades above FF 500. The two density distributions of the effective spread are indeed very distinct. Low spread density peaks occur below 20 basis points only for the small tick regime. For the large tick regime the density peaks with the first feasible spread, indicating the censoring effect of the tick constraint. Figure 3 provides the analogous density plot for the effective spread on executed orders, which closely resembles the corresponding plot for trades.

Next we examine the spread distribution for executed orders conditional on index volatility. The volatility of the CAC 40 index is measured similar to individual stock volatility as daily log realized volatility over 5 minute return intervals. The 4 year period is split into trading days of below and above average index volatility. Table III shows in panel A and B the transaction costs distribution for the low and high volatility days, respectively. Since low market wide volatility tends to decrease spreads, we expect the tick size constraint to become more binding and accentuate the regime difference. Indeed, for low index volatility the median effective spread in the large ticks regime is 51 percent ($\approx e^{-1.6762+2.0885} - 1$) larger than for the small ticks regime. Conditional on the sample of high index volatility days we find a median spread increase of only 3 percent ($\approx e^{-1.6724+1.7038} - 1$). The tick size constraint is therefore more severely binding on days of low market wide volatility.

We can also illustrate the conditional regime difference graphically. Figure 4 shows the average log effective spread for excuted orders by regime as a function of the log realized index volatility. We use a non-parametric kernel estimator to average over 1,587,683 and 1,331,146 spread observations in the small and large tick regime, respectively. Only 20,000 randomly drawn spread observations are plotted to illustrate the spread distribution. The regime difference for the mean log effective spread decreases as the index volatility increases. This shows again that the tick size constraint is most binding under low index volatility.

These results clearly show that the tick size constraint in the French stock market is frequently binding for CAC40 index stocks with prices above FF 500 and comes with a statistical and economically significant transaction cost increase. Moreover, the constraint is most binding and therefore inflates transaction costs more whenever the overall market volatility is low. Based on this exogenous transaction cost identification we can now proceed to explore the volatility implications.

B. Volatility Evidence

The continuous price record of the Paris Bourse allow us a very precise daily volatility measurement. Table IV provides the summary statistics for each individual stock in the sample set by tick regime. Of the 21 stocks subject to both ticks regimes, 20 show a higher mean for the log realized volatility in the large tick regime. Overall, the average log realized volatility is 2.46 for small ticks compared to 2.69 for large ticks. Higher distributional moments also differ. Log realized volatility in the small tick regime is approximately normal, while it is more skewed and leptokurtic for large ticks. We also note that the standard deviation of log realized volatility is higher for small ticks than for large ticks. Table V states the volatility centiles by regime together with a 1 percent confidence interval. The large tick regime has significantly higher volatility for every quantile, although the regime difference is most pronounced for the small percentiles as illustrated by the density estimation in Figure 5.

We conclude that larger ticks shift to the right both the distribution of effective spreads and the distribution of daily log realized volatility. The median standard deviation of realized volatility increases on average by 27 percent ($e^{2.4348-2.6744} - 1 \approx 0.27$). This represents an economically significant increase which is of the same magnitude as the transaction cost increase.

It is again interesting to explore the conditional distribution of realized volatility. In particular, we ask if the volatility effect is more pronounced conditional on low market wide volatility. Since the regime differential with respect to transaction costs is larger for low volatility days, the same should apply to indiividual stock volatility if transaction costs and volatility feature a positive structural link. Again we use a non-parametric kernel estimator to compute the mean log realized volatility of the sample stocks (by tick regime) as a function of the daily log realized index volatility. Figure 6 shows the small ticks mean as a solid and the large ticks mean as a dashed line through the 6,774 daily volatility observations. The graph reveals that the volatility increase of large ticks is indeed strongest under low index volatility just when transaction costs due to the tick constraint are most inflated.

Finally, we confirm these findings with a formal panel regression analysis in Table VI. The most parsimonious specification regresses the daily volatility measures on a regime dummy for

large ticks and fixed or random effects for each stock. The regime dummy is highly significant and quantitatively similar for both fixed and random effects. The Hausman test finds only a marginally significant difference between the coefficient estimates. Regression specification II includes current and lagged index volatility (INDEXVOL) as independent variables. We now obtain a much better fit with an overall pseudo R-square of 0.399. The regime dummy is approximately 0.31 under both fixed and random effects. However, the Hausman test rejects the equivalence of the random and fixed effects estimates at a 1 percent level.

A likely specification problem resides in the autocorrelation of stock volatility. We therefore augment the regression in specification III with lagged values of stock volatility (STOCK-VOL). Lagged stock volatility is highly significant (up to four lags) and further improves the regression fit. The positive regime effect remains highly significant with a t-value of 19. Its coefficient value drops to 0.194 and 0.191 for the fixed and random effect model, respectively. This is not surprising. Inclusion of lagged dependent variables in the specification implies that the TICK DUMMY coefficient captures only the short-run effect of the regime change. We can recover the permanent tick size effect by rescaling the coefficient by the factor $1/(1 - \beta_1 - \beta_2 - \beta_3 - \beta_4)$, where β_i represents the coeffient on the lagged dependent variable STOCKVOL with lag i. The long-run volatility effect of large ticks follows as 0.326 and 0.320 for the fixes and random effect model, respectively. The Hausman test does not reject the null hypothesis of equivalence of the regression coefficients. Under this preferred specification, we attribute a 32 percent increase in log realized volatility to the tick size increase.

Table VII reports volatility regressions for a subsample of trading days with above or below average index volatility. For the panel specification III with fixed effects, we find that the TICK DUMMY coefficient is 0.239 on days of low index volatility and 0.159 on days of high index volatility. The corresponding permanent tick size effects are obtained by rescaling as 0.388 and 0.267, respectively. The conditional panel regression therefore confirms that a higher transaction cost differences across regimes translate into a higher volatility difference. Again, we find the positive structural linkage between transaction costs and financial price volatility reaffirmed.

VI. Conclusions

Unlike the previous literature we analyze the linkage between transaction costs and return

volatility through a cross sectional identification of the transaction costs differences based on exogenous tick size regulation. We show that an increase in the tick size at FF 500 in the French stock market increases the median effective spread and therefore transaction costs by approximately 20 percent for stocks in the CAC 40 index. This finding corresponds to qualitatively similar results in the existing literature. In a second step, we use the cross sectional difference in transaction costs induced by tick size regulation to explore the volatility implication. This aspect has not received much attention in previous research in spite of the obvious relationship to the policy debate on the linkage between financial volatility and transaction costs.

Measuring daily realized volatility over 5 minute return intervals for 6,774 stock trading days around the tick size discontinuity at FF 500, we find that higher transaction costs increase the stock return volatility. The increase in the median daily realized standard deviation of returns is approximately 27 percent and therefore of the same magnitude as the tick size induced transaction cost increase. Panel regressions with fixed and random effects give quantitatively similar results.

We also confirm these findings in their conditional dimension with respect to market wide volatility. Lower volatility of the leading French stock index (CAC 40) tends to reduce the effective spreads and makes the tick size constraint for quotes above FF 500 more binding. The median effective spread is therefore 51 percent higher in the high ticks regime on low volatility days and only 3 percent higher on high volatility days. Low market wide volatility therefore accentuates the transaction cost difference between the two regimes. In accordance with a positive causal relationship between transaction costs and stock volatility, we find that realized volatility differential between the two regime also widens. The regime specific permanent markup in log realized volatility amounts to 0.267 and 0.388 under high and low index volatility, respectively.

We therefore conclude that the effect of transaction costs on volatility is positive and significant both statistically and economically. The general volatility increase registered for U.S. stock markets documented by Campbell et. al. (2000) is therefore unlikely to be explained by the important transaction costs decrease in the same markets over the last two decades. A more competitive tick size structure with lower feasible minimum price variations is on the contrary likely to reduce return volatility. On the policy side, security transaction

costs should increase rather than decrease return volatility. Our volatility measures are likely to underestimate the destabilizing role of security transaction taxes since they - unlike large ticks - also reduce the stabilizing liquidity supply. In the light of our evidence and the liquidity supply argument, a Tobin tax should be deemed counterproductive. On the larger issue of short-term speculation and financial price stability, our evidence supports Friedman's (1953) general defense of financial speculation. High transaction costs discourage short-term arbitrage, and this can explain why volatility increases for higher transaction costs.

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Table I: Stocks Characteristics by Tick Regime

Reported are average number of daily trades (and subtrades), average daily volume (in millions of French francs); and average market capitalization (in billions of FF) for all stocks in the French CAC 40 index with a price range from FF 400 to FF 600 over the 4 year period from January 1995 to December 1998. We distinguished daily observations according to the tick size regime to which each stock is subjected. Stocks quoted in the price range from FF 400 FF to FF 500 are subject to a minimum tick size of FF 0.1 ("Small Ticks"), while stocks in the price range from FF 500 to FF 600 are subject to a minimum tick size of FF 1 ("Large Ticks").

| | Small Ticks | | | | Large Ticks | | | |
| | | Daily Averages of | | | | Daily Averages of | | |
Stock Name	Daily Obs.	Trades	Volume	Market Cap.	Daily Obs.	Trades	Volume	Market Cap.
Sanofi	86	514	81	46.6	209	651	108	58.1
Total	147	767	168	106.8	85	1,444	406	138.8
Elf Aquitaine	94	2,444	234	116.7	91	2,044	330	151.4
Bouygues	107	345	32	11.5	541	293	33	12.6
Lyonnaise des Eaux	417	366	46	26.8	202	576	97	32.3
Lafarge	134	914	104	41.6	91	909	123	54.7
AXA	88	1,699	360	142.7	40	1,971	467	189.8
CFF	8	304	13	5.9	48	221	11	6.7
BIC	176	539	45	25.5	13	480	37	24.1
Bancaire (CIE)	91	256	24	12.5	381	260	27	14.7
General des Eaux	157	562	85	55.0	288	609	120	63.2
Spie Batignolles	59	1,088	161	70.5	7	831	120	78.0
Paribas	166	1,247	188	59.5	66	1,628	342	84.4
CCF	125	624	85	32.7	43	573	94	38.0
Alcatel Alstom	461	957	144	68.3	69	2,905	486	87.9
Havas	330	445	59	28.0	40	631	225	44.3
Valeo	110	613	73	33.7	65	506	70	39.0
Societe General	16	695	88	40.9	465	606	97	49.0
Credit LCL France	396	345	32	15.8	179	493	57	20.6
BNP	57	2,021	292	96.9	52	1,819	313	112.1
SGS Thomson	92	725	117	59.8	17	654	106	72.4
Schneider	3	526	78	25.3	–	–	–	–
France Telecom	57	4,165	503	425.3	–	–	–	–
Accor	–	–	–	–	114	262	38	14.5
Peugeot	–	–	–	–	169	443	71	28.9
Saint-Gobain	–	–	–	–	101	590	90	47.7
Cap Gemini	–	–	–	–	3	1,712	251	40.4
Canal Plus	–	–	–	–	18	244	15	12.7
All Stocks	3,377	779	107	53.4	3,397	653	110	44.6

Table II: Effective Spreads for Trades and Executed Orders by Tick Regime

The distribution of the log effective spread is provided separately for trades (in Panel A) and executed orders (in Panel B) for all stocks in the French CAC 40 index with a price range (in French Francs) from FF 400 to FF 600 over the 4 year period from January 1995 to December 1998. A single order can be partially excuted against various limit orders resulting in multiple subtrades. All effective spreads are calculated separately for stocks quoted in the price range from FF 400 FF to FF 500 subject to a minimum tick size of FF 0.1 ("Small Ticks") and stocks in the price range from FF 500 to FF 600 subject to a minimum tick size of FF 1 ("Large Ticks").

	Panel A: Effective Spreads for Trades and Subtrades					
	Small Ticks			Large Ticks		
Percentiles	Centiles	1% Conf. Interval		Centiles	1% Conf. Interval	
1%	−3.8669	−3.8669	−3.8669	−1.7893	−1.7893	−1.7893
5%	−3.7567	−3.7567	−3.7564	−1.7758	−1.7758	−1.7758
10%	−3.1551	−3.1555	−3.1547	−1.7639	−1.7639	−1.7639
25%	−2.4753	−2.4761	−2.4744	−1.7272	−1.7272	−1.7272
50%	−1.8488	−1.8499	−1.8483	−1.6668	−1.6668	−1.6668
75%	−1.3005	−1.3009	−1.2997	−1.0219	−1.0225	−1.0207
90%	−0.7602	−0.7608	−0.7595	−0.5869	−0.5869	−0.5869
95%	−0.4340	−0.4350	−0.4340	−0.2983	−0.3001	−0.2983
99%	0.1522	0.1520	0.1534	0.2886	0.2886	0.2894
Observations			2,540,764			2,155,658
Mean			−1.923			−1.371
Std. Dev.			0.944			0.528
Skewdness			−0.157			1.465
Kurtosis			2.791			4.702

	Panel B: Effective Spreads for Executed Orders					
	Small Ticks			Large Ticks		
Percentiles	Centiles	1% Conf. Interval		Centiles	1% Conf. Interval	
1%	−3.8713	−3.8713	−3.8713	−1.7893	−1.7893	−1.7893
5%	−3.7680	−3.7683	−3.7680	−1.7775	−1.7775	−1.7775
10%	−3.2040	−3.2050	−3.2032	−1.7639	−1.7639	−1.7639
25%	−2.6119	−2.6122	−2.6117	−1.7308	−1.7308	−1.7308
50%	−1.9815	−1.9826	−1.9803	−1.6743	−1.6743	−1.6743
75%	−1.4598	−1.4600	−1.4596	−1.0664	−1.0664	−1.0664
90%	−0.9331	−0.9337	−0.9325	−0.9243	−0.9254	−0.9243
95%	−0.6625	−0.6630	−0.6615	−0.5794	−0.5800	−0.5794
99%	−0.1338	−0.1338	−0.1332	−0.1017	−0.1017	−0.0998
Observations			1,587,683			1,331,146
Mean			−2.046			−1.455
Std. Dev.			0.892			0.428
Skewdness			−0.213			1.528
Kurtosis			2.692			4.761

Table III: Effective Spread for Executed Orders by Tick Regime and Index Volatility

The distribution of the log effective spread on executed orders is provided conditional on the volatility of the CAC 40 index for all stocks composing this index with a price range (in French Francs) from FF 400 to FF 600 over the 4 year period from January 1995 to December 1998. We condition on all trading days with an index volatility below (Panel A) and above (Panel B) average index volatility. All effective spreads are calculated separately for stocks quoted in the price range from FF 400 FF to FF 500 subject to a minimum tick size of FF 0.1 ("Small Ticks") and stocks in the price range from FF 500 to FF 600 subject to a minimum tick size of FF 1 ("Large Ticks").

Panel A: Effective Spreads for Low Index Volatility

| Percentiles | Small Ticks | | | Large Ticks | | |
	Centiles	1% Conf. Interval		Centiles	1% Conf. Interval	
1%	−3.8703	−3.8703	−3.8703	−1.7893	−1.7893	−1.7893
5%	−3.7747	−3.7749	−3.7743	−1.7758	−1.7758	−1.7758
10%	−3.6900	−3.6903	−3.6900	−1.7639	−1.7639	−1.7639
25%	−2.6548	−2.6552	−2.6538	−1.7308	−1.7308	−1.7308
50%	−2.0885	−2.0888	−2.0883	−1.6762	−1.6762	−1.6743
75%	−1.5252	−1.5262	−1.5250	−1.0801	−1.0801	−1.0784
90%	−1.0229	−1.0233	−1.0219	−0.9420	−0.9420	−0.9420
95%	−0.7617	−0.7619	−0.7609	−0.6058	−0.6070	−0.6052
99%	−0.2202	−0.2202	−0.2196	−0.1545	−0.1545	−0.1544
Observations			1,204,897			993,052
Mean			−2.115			−1.473
Std. Dev.			0.874			0.409
Skewdness			−0.185			1.585
Kurtosis			2.673			4.912

Panel B: Effective Spreads for High Index Volatility

| Percentiles | Small Ticks | | | Large Ticks | | |
	Centiles	1% Conf. Interval		Centiles	1% Conf. Interval	
1%	−3.8755	−3.8755	−3.8755	−1.7909	−1.7909	−1.7909
5%	−3.7423	−3.7425	−3.7423	−1.7809	−1.7809	−1.7809
10%	−3.1053	−3.1062	−3.1053	−1.7690	−1.7690	−1.7690
25%	−2.3425	−2.3435	−2.3418	−1.7308	−1.7308	−1.7308
50%	−1.7038	−1.7048	−1.7038	−1.6724	−1.6724	−1.6724
75%	−1.1936	−1.1944	−1.1924	−1.0350	−1.0350	−1.0350
90%	−0.7431	−0.7435	−0.7419	−0.6515	−0.6515	−0.6515
95%	−0.4543	−0.4543	−0.4533	−0.4198	−0.4200	−0.4178
99%	0.0413	0.0413	0.0413	0.0322	0.0322	0.0322
Observations			382,786			338,094
Mean			−1.827			−1.401
Std. Dev.			0.914			0.475
Skewdness			−0.387			1.338
Kurtosis			2.880			4.169

Table IV: Daily Log Realized Volatility by Stock

Distribution statistics of daily log realized volatilies are calculated based on 5 minute intervals for all stocks in the French CAC 40 index with a price range (in French Francs) from FF 400 to FF 600 over the 4 year period from January 1995 to December 1998. Daily realized volatilities are distinguished according to the tick size regime to which each stock is subjected. Stocks quoted in the price range from FF 400 FF to FF 500 are subject to a minimum tick size of FF 0.1 ("Small Ticks"), while stocks in the price range from FF 500 to FF 600 are subject to a minimum tick size of FF 1 ("Large Ticks").

Stock Name	Small Ticks					Large Ticks				
	Obs.	Mean	St. Dev.	Skew.	Kurt.	Obs.	Mean	St. Dev.	Skew.	Kurt.
Sanofi	86	2.289	0.388	0.348	3.401	209	2.876	0.300	0.119	3.255
Total	147	2.310	0.295	0.309	3.566	85	3.041	0.263	0.239	2.754
Elf Aquitaine	94	2.086	0.339	0.119	3.435	91	2.823	0.252	0.601	3.076
Bouygues	107	2.347	0.396	0.034	2.429	541	2.584	0.339	0.025	2.898
Lyonnaise des Eaux	417	2.255	0.368	0.050	3.110	202	2.565	0.308	0.142	2.445
Lafarge	134	2.699	0.427	0.078	3.335	91	3.048	0.291	0.013	2.653
AXA	88	2.300	0.461	1.793	7.223	40	3.048	0.353	0.030	2.268
CFF	8	2.406	0.658	−0.179	1.394	48	2.786	0.432	−0.117	2.553
BIC	176	2.853	0.353	−0.195	2.505	13	3.135	0.349	0.526	1.870
Bancaire (CIE)	91	2.551	0.373	−0.421	2.385	381	2.682	0.326	0.113	3.357
General des Eaux	157	2.481	0.370	0.061	3.180	288	2.513	0.254	−0.147	3.390
Spie Batignolles	59	2.710	0.397	−0.074	2.142	7	3.126	0.199	0.081	1.692
Paribas	166	2.666	0.380	0.352	3.309	66	2.909	0.274	0.192	3.115
CCF	125	2.798	0.405	0.020	3.107	43	3.013	0.274	−0.079	2.798
Alcatel Alstom	461	2.311	0.419	0.805	4.390	69	2.870	0.511	1.460	5.285
Havas	330	2.401	0.405	−0.090	2.583	40	2.807	0.335	−0.021	2.670
Valeo	110	3.023	0.399	−0.208	2.727	65	3.180	0.313	0.407	2.784
Societe General	16	2.630	0.255	−0.145	2.359	465	2.489	0.309	1.306	8.725
Credit LCL France	396	2.242	0.418	0.288	4.315	179	2.767	0.312	−0.020	2.448
BNP	57	2.922	0.290	0.530	4.066	52	3.007	0.399	1.974	9.826
SGS Thomson	92	2.917	0.383	−1.071	5.061	17	3.014	0.154	0.215	2.165
Schneider	3	2.237	0.259	0.006	1.000	−	−	−	−	−
France Telecom	57	3.112	0.385	0.406	2.902	−	−	−	−	−
Accor	−	−	−	−	−	114	2.525	0.303	0.018	3.392
Peugeot	−	−	−	−	−	169	2.702	0.371	0.207	2.940
Saint-Gobain	−	−	−	−	−	101	2.616	0.256	−0.189	4.478
Cap Gemini	−	−	−	−	−	3	3.826	0.178	0.316	1.000
Canal Plus	−	−	−	−	−	18	2.755	0.288	−0.045	1.632
All Stocks	3,377	2.464	0.466	0.261	3.003	3,397	2.691	0.368	0.419	3.914

Table V: Distribution of Daily Log Realized Volatility by Tick Regime

Daily log realized volatilies are calculated based on 5 minute intervals for all stocks in the French CAC 40 index with a price range (in French Francs) from FF 400 to FF 600 over the 4 year period from January 1995 to December 1998. We provide the distribution of the daily realized volatilities separately according to the tick size regimes to which each stock is subjected. Stocks quoted in the price range from FF 400 FF to FF 500 are subject to a minimum tick size of FF 0.1 ("Small Ticks"), while stocks in the price range from FF 500 to FF 600 are subject to a minimum tick size of FF 1 ("Large Ticks").

| Percentiles | Small Ticks | | | Large Ticks | | |
	Centiles	1% Conf. Interval		Centiles	1% Conf. Interval	
1%	1.4459	1.4463	1.4495	1.8974	1.8975	1.9053
5%	1.7432	1.7432	1.7438	2.1265	2.1269	2.1269
10%	1.8859	1.8858	1.8866	2.2345	2.2330	2.2357
25%	2.1293	2.1292	2.1293	2.4342	2.4340	2.4344
50%	2.4348	2.4348	2.4365	2.6744	2.6742	2.6745
75%	2.7828	2.7827	2.7829	2.9205	2.9204	2.9207
90%	3.0913	3.0887	3.0920	3.1560	3.1555	3.1560
95%	3.2560	3.2539	3.2560	3.3122	3.3120	3.3121
99%	3.6231	3.6167	3.6213	3.6401	3.6381	3.6401
Observations			3,377			3,397
Mean			2.464			2.691
Std. Dev.			0.466			0.368
Skewdness			0.261			0.419
Kurtosis			3.004			3.915

Table VI: Volatility Regressions

Daily realized volatility (in logs) based on 5 minute return intervals is calculated for all stocks in the French CAC 40 index with a price range (in French Francs) from FF 400 to FF 600 over the 4 year period from January 1995 to December 1998 and regressed on a dummy variable of the tick size regime (TICK DUMMY) as a exogenous transaction cost proxy. Stocks with "low transaction costs" in the price range from FF 400 FF to FF 500 are subject to a minimum tick size of FF 0.1 ("Small Ticks"), while stocks with "high transaction costs" in the price range from FF 500 to FF 600 are subject to a minimum tick size of FF 1 ("Large Ticks"). Fixed and random effect models are estimated for 3 specifications. INDEXVOL measures the (demeaned) daily log realized volatility of the CAC40 index based on 5 minute return intervals and INDEXVOL(-1) the corresponding lagged value. STOCKVOL(-1) denotes the lagged (previous day) demeaned log realized volatility of the individual stock. Standard errors are provided in parenthesis and significance levels at 5 percent (*), 3 percent (**) and 1 percent (***) level are marked.

Dependent Variable:	Dialy Log Realized Volatility					
	Specification I		Specification II		Specification III	
Model	Fixed Eff.	Random Eff.	Fixed Eff.	Random Eff.	Fixed Eff.	Random Eff.
Constant	2.403***	2.517***	2.437***	2.487***	2.443***	2.510***
	(0.0072)	(0.0595)	(0.0089)	(0.0322)	(0.0090)	(0.0299)
TICK DUMMY	0.350***	0.349***	0.309***	0.306***	0.194***	0.191***
(Large Ticks = 1)	(0.0112)	(0.0112)	(0.0092)	(0.0092)	(0.0101)	(0.0101)
INDEXVOL	–	–	0.587***	0.588***	0.556***	0.558***
			(0.0140)	(0.0140)	(0.0137)	(0.0137)
INDEXVOL(-1)	–	–	0.090***	0.091***	-0.059^{***}	-0.058^{***}
			(0.0144)	(0.0144)	(0.0156)	(0.0156)
INDEXVOL(-2)	–	–	0.028**	0.028**	-0.065^{***}	-0.064^{***}
			(0.0140)	(0.0140)	(0.0153)	(0.0153)
STOCKVOL(-1)	–	–	–	–	0.224***	0.224***
					(0.0124)	(0.0124)
STOCKVOL(-2)	–	–	–	–	0.092***	0.092***
					(0.0126)	(0.0126)
STOCKVOL(-3)	–	–	–	–	0.050***	0.050***
					(0.0114)	(0.0115)
STOCKVOL(-4)	–	–	–	–	0.038***	0.038***
					(0.0109)	(0.0109)
Observations	6,774	6,774	6,645	6,645	6,456	6,456
Stocks	28	28	27	27	27	27
R-sq (within)	0.126	0.126	0.407	0.407	0.454	0.454
R-sq (between)	0.018	0.018	0.217	0.221	0.271	0.276
R-sq (overall)	0.068	0.068	0.398	0.399	0.431	0.432
$\text{Corr}(u_i, X\beta)$	-0.286	0	0.020	0	0.081	0
σ (stock)	0.319	0.308	0.201	0.158	0.195	0.145
σ (obs)	0.367	0.367	0.298	0.298	0.284	0.284
Hausman test	$\chi^2(1) = 2.87$	$P(H_0) = 0.09$	$\chi^2(4) = 15.21$	$P(H_0) = 0.004$	$\chi^2(8) = 6.57$	$P(H_0) = 0.584$
Permanent effect TICK DUMMY					0.326	0.320

Table VII: Conditional Volatility Regressions

Tradings days for the period from January 1995 to December 1998 are split into high and a low volatility days relative to the mean realized index return volatility for the CAC 40 index. For both subsamples we regress stock specific daily realized volatility (in logs) on a dummy variable of the tick size regime (TICK DUMMY) as a exogenous transaction cost proxy. Stocks with "low transaction costs" in the price range from FF 400 FF to FF 500 are subject to a minimum tick size of FF 0.1 ("Small Ticks"), while stocks with "high transaction costs" in the price range from FF 500 to FF 600 are subject to a minimum tick size of FF 1 ("Large Ticks"). Fixed and random effect models are estimated conditional on low or high index volatility. INDEXVOL measures the (demeaned) daily log realized volatility of the CAC40 index based on 5 minute return intervals and INDEXVOL(-1) the corresponding lagged value. STOCKVOL(-1) denotes the lagged (previous day) demeaned log realized volatility of the individual stock. Standard errors are provided in parenthesis and significance levels at 5 percent (*), 3 percent (**) and 1 percent (***) level are marked.

Dependent Variable:	Daily Log Realized Volatility			
	Conditional on Low Index Volatility		Conditional on High Index Volatility	
Model	Fixed Eff.	Random Eff.	Fixed Eff.	Random Eff.
Constant	2.366***	2.471***	2.475***	2.511***
	(0.0152)	(0.0331)	(0.0131)	(0.0287)
TICK DUMMY	0.239***	0.235***	0.159***	0.153***
(Large Ticks =1)	(0.0156)	(0.0154)	(0.0139)	(0.0137)
INDEXVOL	0.436***	0.441***	0.651***	0.650***
	(0.0298)	(0.0298)	(0.0238)	(0.0238)
INDEXVOL(-1)	−0.045**	−0.044**	−0.080***	−0.0780***
	(0.0215)	(0.0216)	(0.0226)	(0.0226)
INDEXVOL(-2)	−0.059***	−0.058***	−0.052**	−0.049**
	(0.0225)	(0.0225)	(0.0211)	(0.0211)
STOCKVOL(-1)	0.225***	0.224***	0.213***	0.213***
	(0.0173)	(0.0174)	(0.0177)	(0.0177)
STOCKVOL(-2)	0.080***	0.080***	0.093***	0.093***
	(0.0175)	(0.0175)	(0.0183)	(0.0183)
STOCKVOL(-3)	0.044***	0.044***	0.055***	0.055***
	(0.0160)	(0.0160)	(0.0164)	(0.0164)
STOCKVOL(-4)	0.035**	0.035**	0.043***	0.044***
	(0.0152)	(0.0153)	(0.0157)	(0.0157)
Observations	3,464	3,464	2,992	2,992
Stocks	27	27	27	27
R-sq (within)	0.298	0.298	0.397	0.396
R-sq (between)	0.065	0.067	0.064	0.068
R-sq (overall)	0.293	0.293	0.318	0.320
$Corr(u_i, X\beta)$	−0.019	0	0.081	0
σ (stock)	0.223	0.148	0.195	0.128
σ (obs)	0.293	0.293	0.284	0.271
Hausman test	$\chi^2(8) = 3.42$	$P(H_0) = 0.906$	$\chi^2(8) = 6.57$	$P(H_0) = 0.584$
Permanent effect TICK DUMMY	0.388	0.381	0.267	0.257

Supplementary Table: Robustness to Foreign Stock Trading

The benchmark volatility regression is undertaken for a subsample of stocks excluding those with cross listings in the London Stock Exchange (LSE) or in the New York Stock Exchange (NYSE). A total of 4 sample stocks have cross listings in the LSE (Alcatel Alstom, Lafarge, Saint-Gobain, Total) and 4 are cross listed with American Depository Receipts in the NYSE (Alcatel Alstom, AXA, France Telecom and Total) for the period 1995 to 1999. We use daily realized volatility (in logs) based on 5 minute return intervals.as the dependend variable. It is regressed on a dummy variable of the tick size regime (TICK DUMMY) as a exogenous transaction cost proxy. INDEXVOL measures the (demeaned) daily log realized volatility of the CAC40 index based on 5 minute return intervals and INDEXVOL(-1) the corresponding lagged value. STOCKVOL(-1) denotes the lagged (previous day) demeaned log realized volatility of the individual stock. Standard errors are provided in parenthesis and significance levels at 5 percent (*), 3 percent (**) and 1 percent (***) level are marked.

| Dependent Variable:	Daily Log Realized Volatility			
	Full Sample		Excluding Cross Listed Stocks	
Model	Fixed Eff.	Random Eff.	Fixed Eff.	Random Eff.
Constant	2.443***	2.510***	2.442***	2.511***
	(0.0090)	(0.0299)	(0.0106)	(0.0356)
TICK DUMMY	0.194***	0.191***	0.188***	0.185***
(Large Ticks =1)	(0.0101)	(0.0101)	(0.0112)	(0.0111)
INDEXVOL	0.556***	0.558***	0.536***	0.537***
	(0.0137)	(0.0137)	(0.0156)	(0.0156)
INDEXVOL(-1)	−0.059***	−0.058***	−0.048***	−0.047***
	(0.0156)	(0.0156)	(0.0174)	(0.0174)
INDEXVOL(-2)	−0.065***	−0.064***	−0.064***	−0.063***
	(0.0153)	(0.0153)	0.0172	0.0172
STOCKVOL(-1)	0.224***	0.224***	0.213***	0.213***
	(0.0124)	(0.0124)	(0.0138)	(0.0138)
STOCKVOL(-2)	0.092***	0.092***	0.076***	0.076***
	(0.0126)	(0.0126)	(0.0139)	(0.0139)
STOCKVOL(-3)	0.050***	0.050***	0.051***	0.051***
	(0.0114)	(0.0115)	(0.0128)	(0.0128)
STOCKVOL(-4)	0.038***	0.038***	0.036**	0.036**
	(0.0109)	(0.0109)	(0.0123)	(0.0123)
Observations	6,456	6,456	5269	5269
Stocks	27	27	21	21
R-sq (within)	0.454	0.454	0.401	0.401
R-sq (between)	0.271	0.276	0.263	0.269
R-sq (overall)	0.431	0.432	0.374	0.374
$Corr(u_i, X\beta)$	0.081	0	0.068	0
σ (stock)	0.195	0.145	0.192	0.152
σ (obs)	0.284	0.284	0.290	0.290
Hausman test	$\chi^2(8) = 6.57$	$P(H_0) = 0.584$	$\chi^2(8) = 4.55$	$P(H_0) = 0.805$
Permanent effect TICK DUMMY	0.326	0.320	0.300	0.297
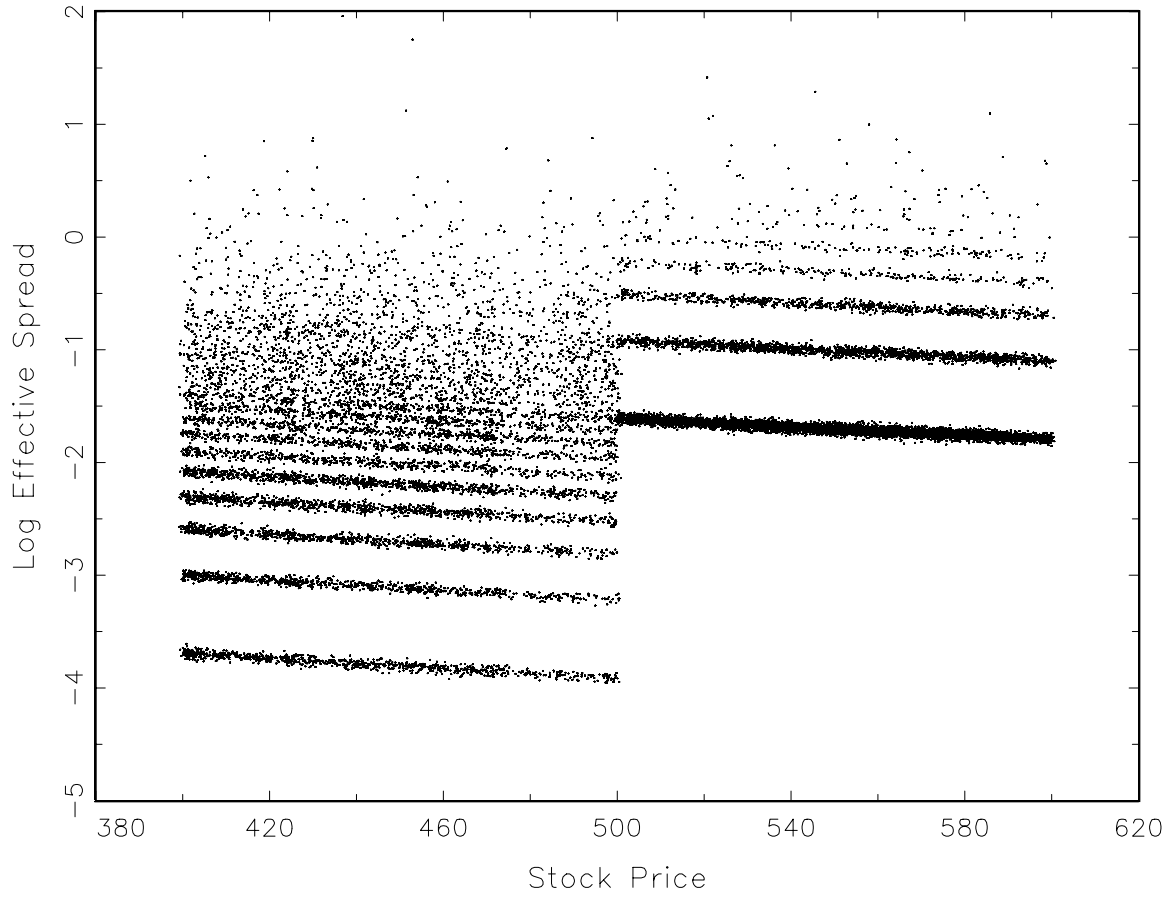
Figure 1: The log effective spread is plotted for a random sample of 20,000 trades on stocks in the price range from FF 400 to FF 600. At FF 500 the minimal tick size increases from FF 0.1 to FF 1. A small amount of noise is added to each observation to render them visually distinguishable.
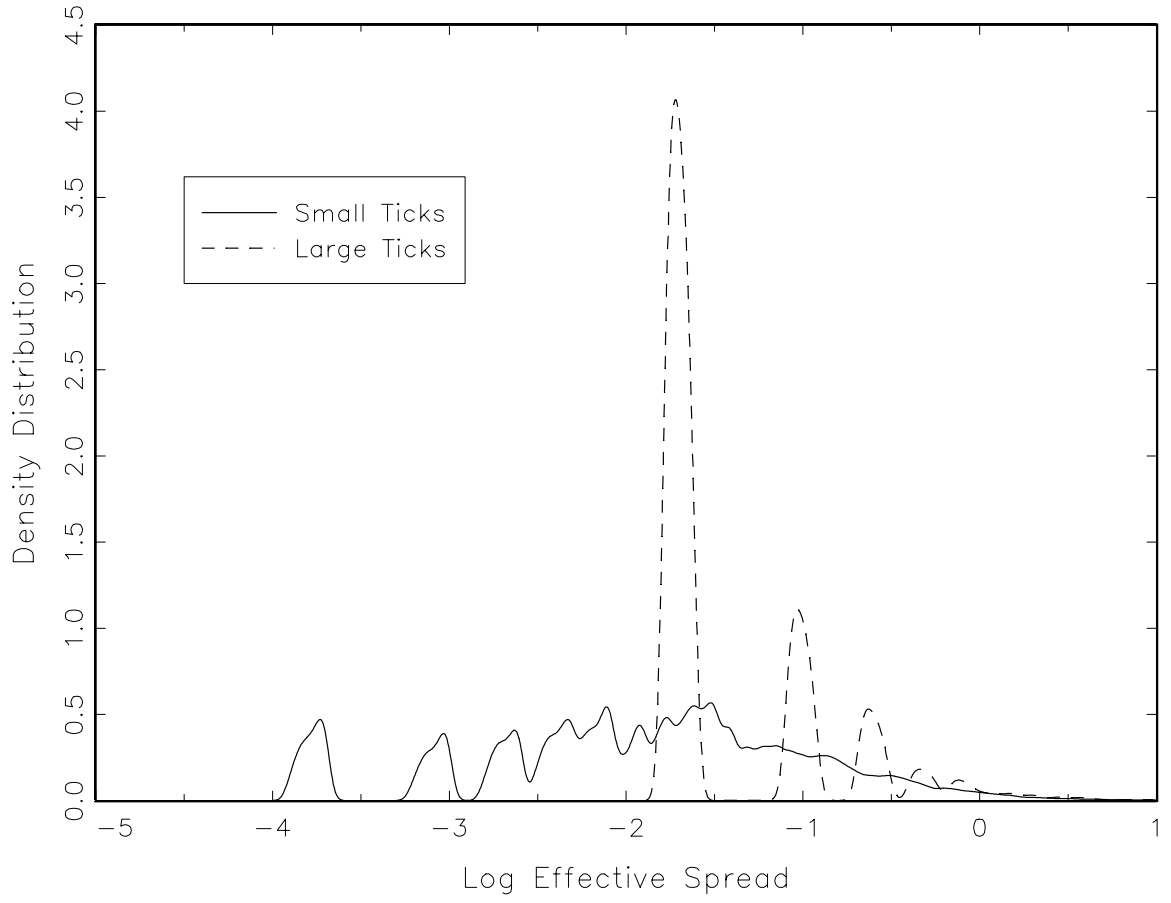
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Figure 2: The kernel density estimate of the log effective spread is presented for 2,540,764 trades in the small tick regime and 2,155,658 trades in the large tick regime.
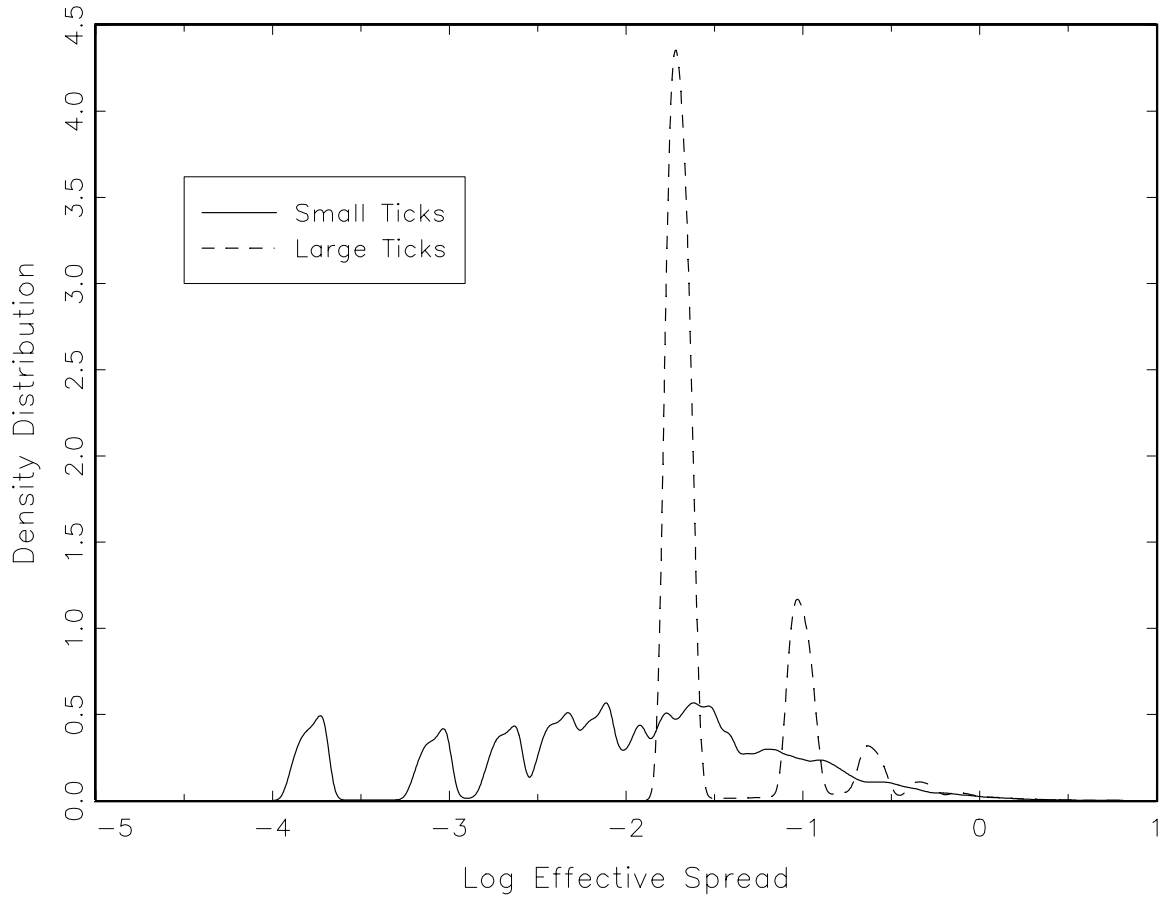
Figure 3: The kernel density estimate of the log effective spread is presented for 1,587,683 executed orders in the small tick regime and 1,331,146 executed orders in the large tick regime.
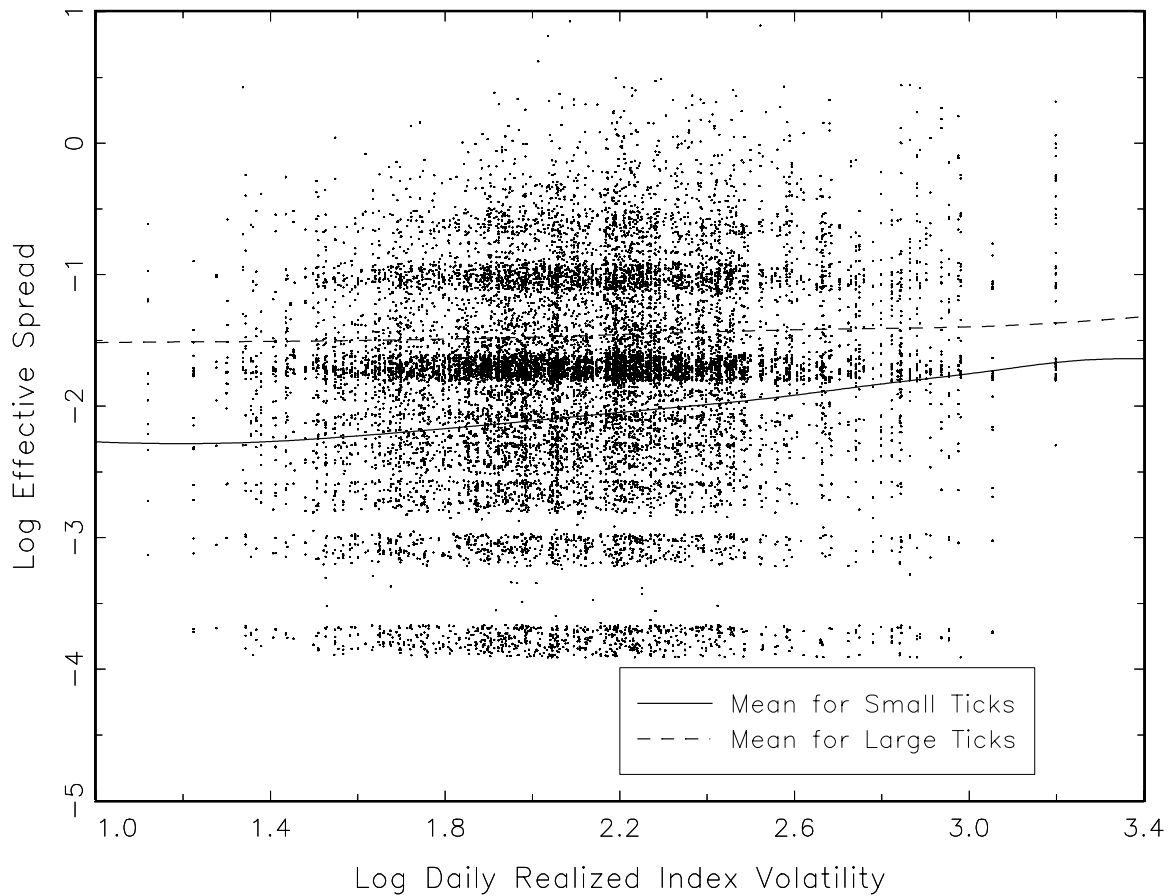
Figure 4: The non-parametric kernel estimate of the mean log effective spread of executed orders is plotted separately for stocks subject to small and large ticks as a function of the log realized volatility of the CAC 40 index on the same day. A random sample of 20,000 spread observations is added to illustrate the distribution.
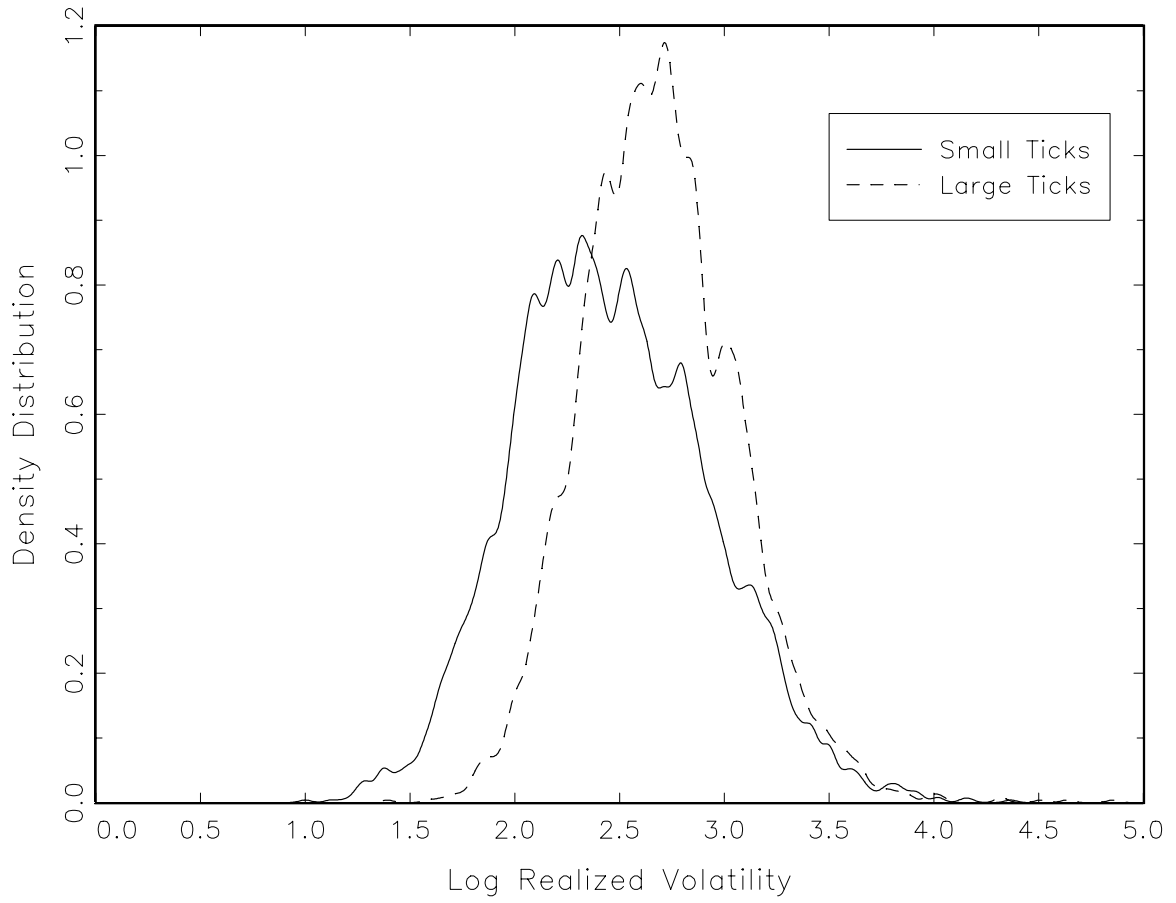
Figure 5: The kernel density estimate of the log daily realized volatility for 3,377 volatility measures in the small tick regime and 3,397 volatility measures in the large tick regime.
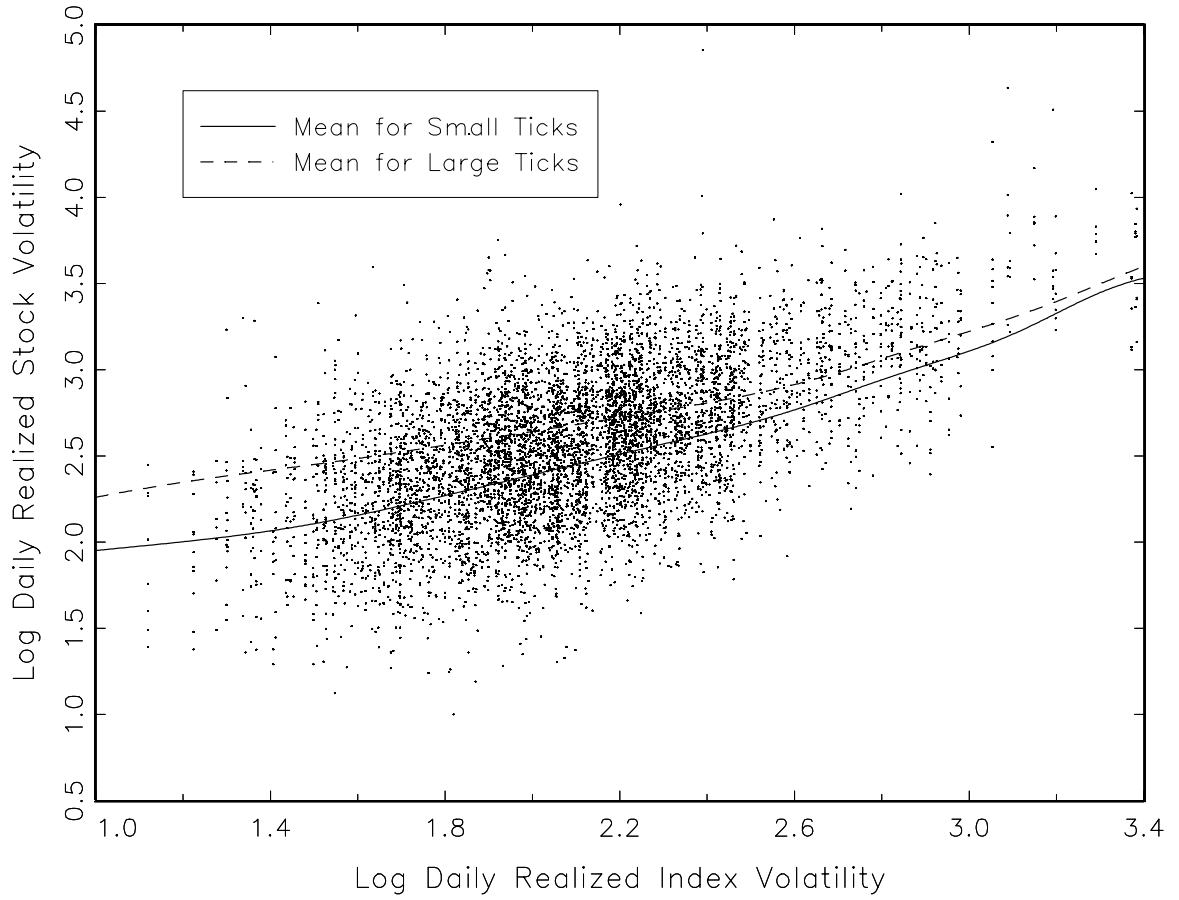
Figure 6: The non-parametric kernel estimate of the mean log daily realized volatility is plotted separately for stocks subject to small and large ticks as a function of the log realized volatility of the CAC 40 index on the same day. The 6774 realized volatility measures are based on 5 minute intraday return intervals.