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Market Liquidity and Competition Among Designated Market Makers

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Abstract. Do competition and incentives offered to designated market makers (DMMs) improve market liquidity? We employ data from NYSE Euronext Paris to show that exogenous changes in contract design lead to significant decreases in quoted and effective spreads. In particular, market liquidity increases the most for stocks with the largest increase in competition among DMMs. Our analysis shows that competition among DMMs is an important aspect of contract design, along with elements such as rebates and requirements.

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Keywords: designated market makers • DMMs • liquidity provision

1. Introduction

Electronic market making is now widespread throughout the world, and many major stock exchanges (the New York Stock Exchange, Euronext, the London Stock Exchange, and Deutsche Börse, among others) have market-making agreements in place with electronic traders. The role of designated market makers (DMMs) in exchanges, which is now largely played by high-frequency traders (HFTs), and their influence on market quality are not well understood and require careful empirical examination to assess whether competition among DMMs and the incentives offered to them could affect overall market liquidity.¹ The previous literature has tended to concentrate on the liquidity provision incentives provided by (i) making-taking fees applied either to DMMs or to all market participants (e.g., Colliard and Foucault 2012, Malinova and Park 2015) or (ii) a combination of making-taking fees and market-making requirements (e.g., Bessembinder et al. 2020). However, to the best of our knowledge, there is no published research on the role of exogenous changes in competition among DMMs that are also HFTs, particularly in the context of electronic centralized limit order book markets.

In this paper, we aim to fill this void and empirically investigate the role of competition in facilitating liquidity provision among HFTs who are willing to act as DMMs. We probe the role of competition by examining the change in the subset of HFTs that are privileged and obligated to assume the DMM role. This subset of HFTs is determined and altered from time to time by the exchange. DMM competition is an aspect that is under-researched in the literature on DMM fees, rebates, and requirements, likely because in many markets, such as the United States, there is only one DMM per stock. For instance, two papers that show a causal effect of the importance of DMMs for market liquidity are Clark-Joseph et al. (2017) and Bessembinder et al. (2020). Both papers are based on U.S. data and thus on the “one DMM per stock” rule.

Stock exchanges have several instruments at their disposal to stimulate DMMs to provide market liquidity. These instruments can be classified into two broad categories: (i) the competitive environment imposed on DMMs and (ii) incentives or benefits offered to and penalties imposed on DMMs through fees, rebates, and market-making requirements.² In this paper, we isolate the effect of competition among DMMs from the effect

of the incentives (both rebates and requirements) on market liquidity and show that competition is an important aspect of contract design, in addition to rebates and requirements that have been well studied in the previous literature.³

To analyze the effect of competition among DMMs on market liquidity, we use a detailed data set from NYSE Euronext Paris on the Cotation Assistée en Continu (CAC 40) index constituents (the main French stock market index), which includes one flag that identifies HFTs and another that identifies the activities of DMMs.⁴

The identification strategy used in the paper relies on a quasinatural experiment that took place on June 3, 2013, when NYSE Euronext Paris implemented several changes to the rules of its “Supplementary Liquidity Provider” (SLP) program, which had been introduced in 2011.⁵ Specifically, the new SLP rules increased the rebate that DMMs receive for passive execution, tightened the requirements they must fulfill (such as the amount of time present at the best bid-offer [BBO] level), and increased competition by changing the set of stocks for which they are required to provide liquidity (resulting in an increase in the number of DMMs from five, six, or seven to eight DMMs per stock). We note that HFTs that play the role of DMMs in modern equity markets are known to be quantity (but not price) competitors (Broggaard and Garriott 2019); thus, an increase in the number of DMMs might lead to increased competition among them.

We use cross-sectional heterogeneity in changes in competition among DMMs across stocks to distinguish between the effects of the market-making requirements together with the maker-taker fee schedule and the competitive structure itself. In particular, we are able to capture the effect of competition because the new SLP rules caused a heterogeneous increase in the number of DMMs present in each stock. To establish the causal effects of DMMs’ incentives and competition among DMMs on market liquidity, we employ a difference-in-difference (DiD) methodology and assign CAC 40 index constituents as the treatment group and Deutscher Aktienindex (DAX 30) constituents (the main German stock market index) as the control group.⁶

Our main findings can be summarized as follows. First, the new SLP rules are beneficial for market liquidity in both statistical and economic terms. In particular, we document a 6.60% (5.02%) decrease in the quoted (effective) spreads after the implementation of the new SLP rules.⁷ Second, we show that in our setup, a substantial portion of this decrease is attributable to an exogenous increase in competition among DMMs (a roughly 90% improvement in the effective spread). Hence, although the exact magnitude of the liquidity improvement would of course be case specific, other limit order book markets might also benefit from competition among DMMs.

The effects arising from the change in the DMMs’ competitive environment are nontrivial: If the new structure were too loose and ineffective, DMMs could simply pocket the rebates and quote the same spread as any voluntary liquidity provider. However, in the presence of competition, DMMs are willing to undercut one another’s quotes (potentially up to the size of the rebate received). A market maker who is not a DMM and simply competes for the provision of liquidity for a stock would of course be able to improve market liquidity (Biais et al. 2000, Aït-Sahalia and Sağlam 2017). However, such a trader might not be able to force a sole DMM to give up its rebate to the market; only competition among DMMs would have that effect. To sum up, without dismissing the important role of incentives for DMMs in general, we argue that competition among DMMs is also an important aspect of contract design, in addition to market-making requirements and fees and rebates.⁸

We also emphasize that increasing the number of DMMs is not equivalent to increasing the market-making requirements of a single DMM. The issue of regulating a monopolist (i.e., the case of a single DMM per stock) is well established in the microeconomics literature (e.g., Baron and Myerson 1982). The fundamental problem is that a regulator (in our case, a stock exchange) faces an asymmetry of information regarding the cost structure of the monopolist. In order to mitigate that asymmetry, regulatory policy should provide incentives for the monopolist to be truthful about its cost function. As a result of such an incentive-compatible policy, one might even end up in a situation in which the price (in our case, the spread) is even higher than in a completely unregulated monopolistic case. However, the case of oligopolistic competition with multiple DMMs per stock is entirely different. It is much more natural to assume symmetric information about the costs that these competitors incur. Hence, the regulator need not know the exact cost function of a firm but can rely on competitive forces to reduce the equilibrium spread.

Our contribution to the literature is threefold. First, we contribute to the literature on competition among dealers in quote-driven markets by establishing the importance of this question in relation to order-driven markets. Second, we add to the literature on liquidity provision in the era of HFTs and show that competition among DMMs still plays an important role despite abundant voluntary liquidity provision by HFTs. Finally, we show that there is a conceptual difference between overall competition among HFTs and competition among DMMs, whose role is often also played by HFTs.

The remainder of this paper proceeds as follows. Section 2 contextualizes our paper within the literature on DMMs and HFTs, but in more detail. Section 3 provides relevant institutional details about NYSE Euronext Paris, especially changes in its competitive structure

and incentives in terms of both fees and rebates and requirements, and develops testable hypotheses. Section 4 presents the empirical evidence, whereas Section 5 reports robustness checks. Section 6 concludes.

2. Literature Review

We contribute to three streams in the literature as mentioned above, and we discuss each of these in detail below. Our first contribution is made to the somewhat-dated market microstructure literature, which studies competition between dealers and focuses on the competition among dealers in over-the-counter (OTC) markets or other quote-driven markets. Tinic and West (1972), Benston and Hagerman (1974), Stoll (1978), and Menyah and Paudyal (1996) study the relation between the number of dealers and market liquidity in quote-driven markets. Their main finding is that spreads decrease as the number of dealers increases. However, none of these papers demonstrates a *causal* relationship between the increase in the number of dealers and the spread. The decision about how many and which stocks to participate in is endogenous and made by individual dealers. Controlling for potential endogeneity is thus important, as is clearly shown by several follow-up papers that explicitly discuss endogeneity concerns and attempt to resolve this issue. For instance, Goldstein and Nelling (1999) estimate a system of simultaneous equations, whereas Klock and McCormick (1999) use an instrumental variable approach to address the issue. A more recent paper by Zhang et al. (2017) echoes the above-mentioned findings for quote-driven markets in a DiD setup using data from the China National Equities Exchange and Quotations (NEEQ) system.⁹

We add to this research stream by studying the effect of a forced, exogenous increase in competition among DMMs on market liquidity in a limit order book market setting, which is a different market structure than OTC markets or other quote-driven markets. More specifically, dealers in quote-driven markets, in contrast to DMMs in limit order books, are not obligated to transact at the specified quoted price. Rather, their quotes represent a general willingness to trade, which they could implement in conjunction with price discrimination, and their activity is not anonymous. More importantly, unlike DMMs in limit order book markets, dealers in OTC markets compete only with one another and do not face competition from voluntary liquidity providers. This means that there are no HFTs or other traders that could voluntarily provide liquidity and thus compete with dealers in quote-driven markets. The result that more dealers lead to an increase in market liquidity is far more obvious and is indeed anticipated *ex ante* in quote-driven markets.

Our second contribution is to the literature on the role of DMMs and competition among them in limit order

book markets in the era of HFTs. In the presence of voluntary high-frequency liquidity providers, it is not *ex ante* obvious whether there is any need for DMMs in the first place. The role of a monopolistic DMM in limit order book setups has been documented by Clark-Joseph et al. (2017) and Bessembinder et al. (2020). Both studies provide causal evidence that the activities of DMMs have a positive effect on market liquidity.¹⁰ In addition, Anand and Venkataraman (2016) show that voluntary liquidity providers tend to synchronously withdraw from the market when market conditions are unfavorable, leaving the burden of liquidity provision solely to DMMs. However, the empirical literature has thus far largely neglected the issue of competition *among* DMMs,¹¹ even though competition in a broad sense is mentioned in a few theoretical models. For example, whereas Biais et al. (2000) and Ait-Sahalia and Sağlam (2017) explicitly allow for different degrees of competition among market makers, others often assume that the market-making business is fully competitive. In other words, they follow the conventional wisdom in modern markets that one can safely assume that DMMs face enough competition from voluntary liquidity providers and that it is thus sufficient to assign one DMM per stock.

In this paper, we provide evidence that competition among DMMs for the same stock, and not the *overall* competition among liquidity providers (voluntary and otherwise), constitutes an important aspect of the contract design that exchanges ought to consider when introducing solutions to improve market liquidity, even for stocks that are already subject to a high level of HFT activity.¹²

Our third contribution regards the role of HFTs and their interaction with DMMs in limit order book markets. Over the past decade, technological innovation, faster computers with sophisticated execution algorithms, and new trading platforms have completely transformed the global landscape of equity trading. A new class of electronic liquidity providers has emerged; the “old” class of specialists has almost disappeared, leaving room for a “modern” version of DMMs that make extensive use of colocation facilities, high-speed connections, and fast computers.¹³ In other words, modern market making is firmly in the hands of HFTs.¹⁴ There is abundant evidence that HFTs (and algorithmic trading more generally) improve market liquidity by posting limit orders when spreads are wide (e.g., Carrion 2013), trading against transitory price pressures (e.g., Brogaard et al. 2014), and trading against extreme price movements (e.g., Brogaard et al. 2018). In addition, Brogaard and Garriott (2019) show that competition among proprietary HFTs, as opposed to DMMs, improves market liquidity. Our study contributes to this literature by examining the effect of HFTs that switch roles from proprietary traders to DMMs while keeping constant both the

level of competition among HFTs and their relative speed differentials.¹⁵ Competition among proprietary HFTs, which act without restrictions, is conceptually different from that of HFTs that act as DMMs, subject to exchange supervision. In general, HFTs might voluntarily choose to be market makers, but they usually do not receive any special treatment (or shoulder any obligations) for market-making activities that might influence their behavior, whereas DMMs do. Hence, our approach allows us to focus on how competition among HFTs that perform the role of DMMs (which have a competitive advantage over other HFTs because of the special rebates for passive execution) influences market quality. Furthermore, we investigate the effect of an exchange enforcing competition, rather than the effect of competition arising endogenously (e.g., through eliminating barriers to entry, which might affect market liquidity). If there is sufficient competition for liquidity provision arising from HFTs that are voluntary liquidity providers, increasing the number of DMMs might have no effect on market liquidity. This approach speaks to the novelty of our investigation, because the outcome of the forced increase in competition is neither trivial nor predictable; hence, the evidence revealed by our analysis should be of interest to policymakers.

3. Institutional Details and Hypothesis Development

Our analysis is based on a quasinnatural experiment at NYSE Euronext Paris, the leading stock market in France, following certain changes to the market-making regime under which DMMs provide liquidity to blue-chip stocks. NYSE Euronext Paris is an order-driven market with an open limit order book, so any market participant can in principle act as a de facto liquidity provider by submitting limit orders to the market. However, in 2011, NYSE Euronext Paris introduced the SLP program to license DMMs and thus enhance liquidity provisions for blue-chip stocks. The *Info-Flash* of January 13, 2011 (NYSE Euronext 2011), covers the details of the program's implementation.¹⁶ According to Grant (2011), seven firms initially joined the program and became DMMs. In the remainder of this paper, we refer to SLP members as DMMs. In the subsections that follow, we discuss the sticks (competition and requirements) and carrots (rebates) that NYSE Euronext Paris employs to incentivize DMMs. We center our analysis (and the related SLP program discussion) on constituents of the CAC 40 index (the main French stock market index).

3.1. SLP Program: Competition and Requirements

The 2012 SLP program requires that each firm appointed as a DMM must (NYSE Euronext 2011)

A. Commit to be present in at least one basket of stocks (CAC 40 stocks are partitioned into *four* baskets) (competition).

B. Satisfy the following three rules (requirements):

1. "Be present at least 95% of the time on both sides of the market during the continuous trading session."

2. "Display a minimum volume of at least EUR 5,000 at the best limit price on average across all stocks included in the basket."

3. "Deliver the presence time committed to by the applicant during the tender process at the Euronext best limit for each assigned basket of securities, with a minimum of 10% per each security included in the basket."

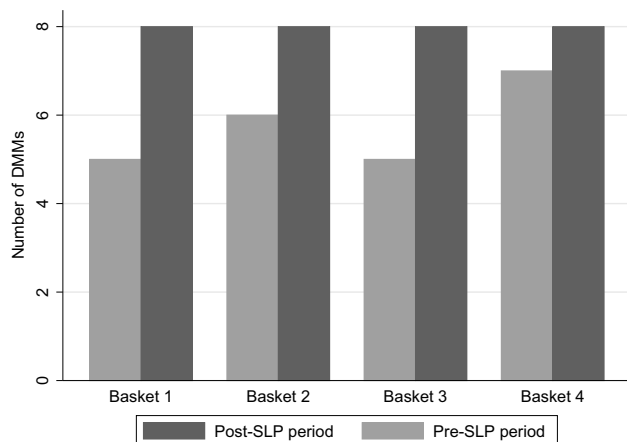
In the *Info-Flash* of May 9, 2013 (NYSE Euronext 2013b), the exchange announced several changes to the SLP program that would take effect on June 3, 2013. The main differences pertained to basket composition (Rule A) and the proportion of trading time present at the best limit (Rule B3). CAC 40 stocks were initially split into four baskets, but starting on June 3, 2013, all CAC 40 components would be placed in the same basket.¹⁷ This change increased the number of DMMs present in each stock in the CAC 40 index, because they were all obliged to remain active in *all* CAC 40 index constituents. This change in basket composition would increase competition among DMMs (beyond the entry of one new DMM into the SLP program).

According to the Autorité des Marchés Financiers (AMF), France's stock market regulator, seven DMMs were present as CAC 40 index constituents in April and May 2013. Moreover, these seven DMMs were *not* uniformly present across baskets during that period. After the new SLP rules were implemented, these seven DMMs were present in *all* CAC 40 index constituents, and one new DMM joined the SLP program.¹⁸

Figure 1 shows the increased number of DMMs present in each basket of stocks after the new SLP rules were implemented: from five to eight, from six to eight, from five to eight, and from seven to eight in Baskets 1 to 4, respectively.¹⁹ We stress that it is not simply the increase in the number of DMMs per basket that would increase competition, but rather the competitive behavior of the DMMs that the exchange might induce. We necessarily test whether competition among DMMs has indeed increased by looking at the number of cases when DMMs' quoting activity improves bid-ask spreads before and after the implementation of the new SLP rules. We note that the change in competition was the only exchange-driven change to affect the stocks in a heterogeneous way because of the different number of DMMs present in each basket of stocks before the implementation of the new SLP rules.²⁰

The key characteristics of the new 2013 SLP contract are (NYSE Euronext 2013b) as follows:

Figure 1. Number of DMMs by Basket Around the Implementation of the New SLP Rules



Notes. This figure charts the number of DMMs present in each of the four baskets of stocks in the pre-SLP period (April 1–June 3, 2013) and post-SLP period (June 3–July 31, 2013). We refer readers to the Internet Appendix for basket composition details. We note that in the pre-SLP period, seven DMMs were active as CAC 40 index constituents; in the post-SLP period, a new DMM joined the SLP program. Data on the number of DMMs per basket come from AMF.

A. Commit to be present in all stocks that belong to CAC 40 (competition).

B. Amendments to rule no. (3) (requirements):

(3.3) Minimum passive execution level of 0.70% in percentages of the aggregate monthly volume traded on Chi-X, BATs, Turquoise, and NYSE Euronext,”

(3.4) “Minimum presence time of 25% at the NYSE Euronext best limit for each assigned basket, weight-averaged over the entire CAC 40 basket and the calendar month,” and

(3.5) “Minimum passive execution level of 0.10% and a minimum presence time of 10% at the NYSE Euronext best limit of the continuous trading session for each security, weight-averaged over the calendar month.”

Thus, in June 2013, the overall market environment for DMMs changed in two ways: (i) increased competition between DMMs through changes in the requirement for all DMMs to be present in all baskets and the entry of new market makers into the SLP program and (ii) tightened requirements for the time presence at the BBO level for DMMs.

3.2. SLP Program: Benefits

NYSE Euronext Paris initially provided the following maker-taker scheme for SLP members: for each executed market order (consuming liquidity), the fee for SLP members would be 0.30 basis points (bps), and for each executed limit order (providing liquidity), the rebate for SLP members would be -0.20 bps until May 2013; it increased to -0.22 bps as of June 3, 2013. However, the *Info-Flash* of October 1, 2013 (NYSE Euronext

2013a), announced that the rebate would revert to -0.20 bps as of November 1, 2013.²¹ This attractive maker-taker fee structure applied only to those SLP members that fulfilled the exchange requirements. SLP members that did not fulfill those requirements were charged 0.55 bps per order execution, independently of whether they consumed or provided liquidity. We note that although the rebate may seem small in absolute magnitude, it amounts to 9.9% and 11.5% of average quoted spreads in the pre- and post-SLP periods, respectively.

3.3. Hypotheses

Our institutional setting allows us to develop two hypotheses. The first focuses primarily on DMMs’ incentives and requirements in general, whereas the second deals with the cross-sectional effect of competition among DMMs.

Hypothesis 1. *Market liquidity increases with an exogenous change in DMMs’ incentives and requirements.*

With this hypothesis, we aim to test whether the incentives and requirements introduced by the new SLP rules for DMMs indeed affected market liquidity, because it is not clear ex ante whether those changes in the rules were sufficient to have that effect. Therefore, it is worth conducting an empirical investigation to answer this question. Once we confirm that changes in the SLP rules do matter, we move on to test the role of competition resulting from the increased requirement that DMMs be present in all CAC 40 stocks rather than in only one basket in improving market liquidity at the cross-sectional level. We formulate the following resultant hypothesis:

Hypothesis 2. *Market liquidity increases most for stocks with the largest increase in competition among DMMs.*

A priori, the results in terms of market liquidity and competition among DMMs are not obvious. There could be at least two outcomes. On the one hand, if there is sufficient competition stemming from voluntary liquidity providers, then the increase in competition between DMMs should have no effect on market liquidity. On the other hand, DMMs are different from voluntary liquidity providers because they enter into contractual agreements with the stock exchange to fulfill certain obligations in return for better fee and rebate structures. Given this, we argue that competition among DMMs would be fundamentally different than competition among voluntary liquidity providers (or among a single DMM and voluntary liquidity providers). Therefore, an increase in competition between DMMs should have a positive effect on market liquidity. By testing Hypothesis 2, we are able to disentangle these two polar cases.

4. Empirical Analysis

In this section, we examine the effect of an exogenous change in DMMs’ incentives and requirements on

market liquidity in a DiD setting using the introduction of the new SLP rules as an exogenous shock to the contract design between exchanges and DMMs. First, we describe our data and provide summary statistics for our sample (see Section 4.1). Second, we empirically analyze the effect of the implementation of the new SLP rules on market liquidity (see Section 4.2) and the effect on market liquidity of the resultant cross-sectional heterogeneity in altering competition among DMMs (see Section 4.3).

4.1. Data and Summary Statistics

In the following sections, we describe the treatment and control groups used for our analysis and present summary statistics for market liquidity measures.

4.1.1. Treatment Group: Data Description. We direct our attention to CAC 40 index constituents. Our database is obtained from the Base Européenne de Données Financières à Haute Fréquence (BEDOFIH) and is based on data from NYSE Euronext Paris. We concentrate our analysis on 36 stocks that belong to the CAC 40 Index.²² The BEDOFIH database provides time-stamped quotes and trades (in microseconds) covering the complete history of each order.²³

The 2012 SLP program (NYSE Euronext 2012) covers 90 stocks split into six baskets (15 stocks in each basket). Baskets 1 to 4 comprise largely French stocks, whereas Baskets 5 and 6 comprise non-French ones. The BEDOFIH database includes only French stocks that have NYSE Euronext Paris as their main trading venue: therefore, our database contains only data for Baskets 1 to 4. These baskets are primarily composed of CAC 40 index constituents and CAC Next 20 index constituents (this tier consists of main candidates considered for inclusion in CAC 40). The BEDOFIH database includes 52 SLP stocks, of which 36 are from the CAC 40 and 15 from the CAC Next 20. Given that stock market liquidity, which constitutes the main dependent variable of our analysis, is strongly related to trading volume and size, we focus

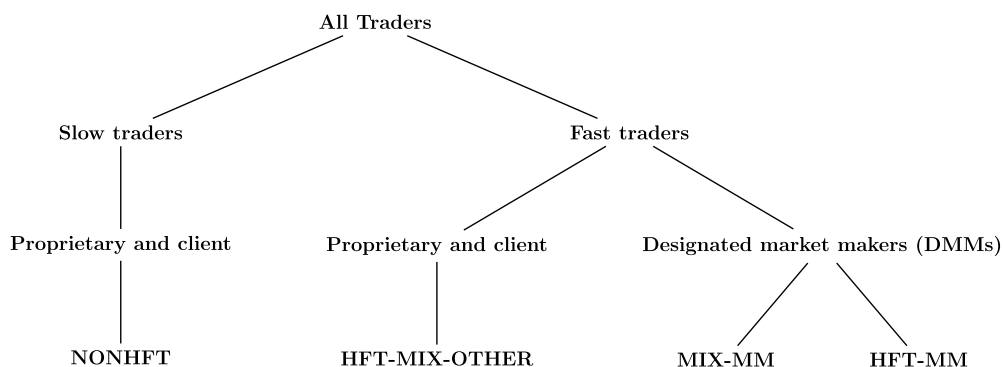
on CAC 40 index constituents to avoid the possibility that our results may be driven by the smallest and thus most illiquid stocks in the SLP program.²⁴

Data from NYSE Euronext Paris are complemented by a flag provided by the AMF that classifies each trader into one of three groups: HFT, MIX, and NONHFT. HFTs are pure-play HFT companies like Getco and Virtu, whereas the MIX group covers investment banks and large brokers that can have substantial HFT activities, such as BNP Paribas and Goldman Sachs. The remaining companies are placed in the NONHFT category. This classification is revised annually, and the three trader groups are mutually exclusive (see AMF 2017 for a detailed description of the methodology undergirding this classification).

NYSE Euronext Paris provides information about the account type used to submit each order. For the purpose of our analysis, we distinguish between two such types: the market-making account (MM) and all other accounts (OTHER). The exchange confirms that the orders flagged for liquidity provision purposes are strictly monitored and verified by the exchange's compliance department. Figure 2 depicts a schematic diagram of the trader account types we analyze.

4.1.2. Control Group: Data Description. In our main analysis, stocks that belong to the DAX 30 (the main German stock market index) make up our control group. The average market capitalization, trading volume, and inverse of the stock price, which captures the impact of a potentially binding tick size²⁵ of DAX 30 index constituents, are comparable, in both economic and statistical terms, to those of CAC 40 index constituents as of February 2013 (see Panel A of Table 1). More specifically, the average market capitalization of CAC 40 (DAX 30) stocks is EUR 26.058 (26.447) billion, the average daily trading volume of CAC 40 (DAX 30) stocks is EUR 2.771 (2.004) billion, and the inverse of the stock price of CAC 40 (DAX 30) stocks is 0.041 (0.035).

Figure 2. Trader Account Types



Note. This figure illustrates the trader account types used in this paper and obtained from the BEDOFIH database.

Table 1. Data Description

Treatment vs. Control groups	No. of stocks	MCAP, EUR bln	Inverse of price	Trading volume, EUR mln
Panel A: CAC 40 vs. DAX 30				
CAC 40	36	26.058	0.041	2.771
DAX 30	30	26.447	0.035	2.004
Difference		-0.389 (-0.07)	0.006 (0.70)	0.766 (1.13)
Panel B: CAC 40 vs. non-SLP				
CAC 40	36	26.058	0.041	2.771
Non-SLP	36	9.742	0.049	0.194
Difference		16.316*** (2.99)	-0.008 (-0.62)	2.577*** (4.99)

Notes. This table reports the number of stocks and the average market capitalization in EUR bln, the trading volume in EUR mln, and the inverse of the stock price in February 2013 for CAC 40 index constituents (36 stocks that have NYSE Euronext Paris as their main trading venue), DAX 30 index constituents, and the 36 largest non-SLP stocks. We also report the difference-in-means test between CAC 40 and DAX 30 index constituents and between CAC 40 index constituents and the 36 largest non-SLP stocks. Data on stock market capitalization and price come from Datastream, whereas data on trading volume come from the BEDOFIH and TRTH databases for French and German stocks, respectively. MCAP, market capitalization; bln, billion; mln, million. Value in parenthesis is the value of the *t*-test for the difference.

p* < 0.1; *p* < 0.05; ****p* < 0.01.

None of the differences is significant at the conventional significance levels of 10%, 5%, or 1%.

We obtain data on trades and BBO quotes for DAX 30 index constituents time-stamped at the millisecond level from Xetra from the Thomson Reuters Tick History (TRTH) database. We note that the data provided by TRTH are much less granular than those provided by BEDOFIH in that TRTH does not distinguish between trader types.

We also examine whether non-SLP stocks available in the BEDOFIH database might serve as a reasonable control group for CAC 40 stocks. In particular, we look at the 36 largest non-SLP stocks as of February 2013, that is, the non-SLP stocks most similar to the CAC 40 stocks. However, non-SLP stocks have an average market capitalization of EUR 9.742 billion, as opposed to EUR 26.058 billion for CAC 40 stocks, and an average trading volume of EUR 0.194 million, as opposed to EUR 2.771 billion for CAC 40 stocks (see Panel B of Table 1). We note that these differences in market capitalization and trading volume are statistically significant at the 1% level. Given that market liquidity is strongly related to company size and trading volume, we conclude that non-SLP stocks are not necessarily the most suitable control group for the purpose of our analysis. Moreover, CAC 40 stocks and non-SLP stocks have a very different composition of trader types: in particular, HFT-MM and MIX-MM are not present in non-SLP stocks (see Internet Appendix IA.4). We also identify the nonnegligible chances of spillover effects as a result of the implementation of the new SLP rules to non-SLP stocks. Therefore, we stick to DAX 30 stocks as the control group for the main analysis.²⁶

4.1.3. Summary Statistics: Market Liquidity. In the spirit of several existing papers, we measure market liquidity by quoted and effective half-spreads, in which the

quoted spread measures the round-trip quoted cost of one share transaction, whereas the effective spread measures the round-trip cost of an actual transaction. Both spreads are computed at the time of the *t*th trade:

$$\text{Quoted Half-Spread}_t = \frac{(\text{Ask}_t - \text{Bid}_t)}{2 * \text{Midpoint}_t} \quad (1)$$

$$\text{Effective Half-Spread}_t = \frac{|P_t - \text{Midpoint}_t|}{\text{Midpoint}_t} \quad (2)$$

We compute the liquidity variables for each trade in our sample and winsorize them at the 95% level, that is, at 2.5% and 97.5% for each stock *j*. We then compute the share-weighted average of these variables for each stock *j*, day *d*, and trader account type *k*.

Table 2 presents the summary statistics for our sample period for CAC 40 and DAX 30 index constituents. We focus our attention on the two months before (the pre-SLP period, Panel A) and the two months after (the post-SLP period, Panel B) June 3, 2013, the implementation date of the new SLP rules.

In particular, we provide evidence on the market-wide quoted and effective half-spreads for both CAC 40 and DAX 30 index constituents, averaged across stock-days. For example, during the pre-SLP period, the market-wide quoted (effective) half-spread of CAC 40 index constituents is equal to 2.03 (2.09) bps, with the corresponding number equaling 2.05 (2.46) bps for DAX 30 index constituents. However, in the post-SLP period, the quoted and effective half-spreads for the CAC 40 and DAX 30 clearly deviate from each other. More specifically, in the post-SLP period, the quoted (effective) half-spread for the CAC 40 is 1.92 (1.99) bps; for the DAX 30, it is 2.12 (2.52) bps.

Panel C of Table 2 reports the results of the univariate *t*-tests for pre- and post-SLP mean comparison. The tests confirm that for CAC 40 index constituents, market liquidity significantly improves in the post-SLP period

Table 2. Summary Statistics: Spreads Around New SLP Rules

Market liquidity measures	French stocks				German stocks	
	CAC 40	HFT-MM	MIX-MM	HFT-MIX-OTHER	NONHFT	DAX 30
Panel A: Pre-SLP period						
Quoted half-spread	2.03	1.83	1.91	2.02	2.52	2.05
Effective half-spread	2.09	1.84	1.95	2.08	2.73	2.46
Panel B: Post-SLP period						
Quoted half-spread	1.92	1.75	1.86	1.95	2.36	2.12
Effective half-spread	1.99	1.76	1.90	2.02	2.62	2.52
Panel C: Difference						
Quoted half-spread	−0.116***	−0.083*	−0.048	−0.077*	−0.161***	0.069
Effective half-spread	−0.108***	−0.077*	−0.052	−0.059	−0.108**	0.054

Notes. This table records the average across stock-days of quoted (see Equation (1)) and effective (see Equation (2)) half-spreads in bps for the entire market and for those half-spreads observed for each trader account type (HFT-MM, MIX-MM, HFT-MIX-OTHER, and NONHFT) initiating the transaction. Panel A reports summary statistics for the two months before the implementation of the new SLP rules (April 1–June 3, 2013). Panel B reports summary statistics for the two months after the implementation of the new SLP rules (June 3–July 31, 2013). Panel C provides a univariate *t*-test with standard errors clustered by stock \times tick size and by day for the mean difference between pre-SLP and post-SLP periods. The sample comprises 36 stocks traded on NYSE Euronext Paris that belong to the CAC 40 index and 30 stocks that belong to the DAX 30 index. Data for the French and German stocks come from the BEDOFIH and TRTH databases, respectively.

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

over the pre-SLP period, whereas market liquidity does not change for DAX 30 index constituents. This divergence in market liquidity results between the treatment and control groups in the post-SLP period constitutes preliminary evidence that the new SLP rules did improve stock market liquidity for the French market relative to the German market.

Then, for CAC 40 index constituents, we provide information on the quoted and effective half-spreads witnessed for each trader account type while initiating the transaction, averaged across stock-days. In the pre-SLP period, HFT-MM activity faced the smallest quoted and effective half-spreads of 1.83 bps and 1.84 bps, respectively, whereas NONHFT traders faced the largest quoted and effective half-spreads of 2.52 bps and 2.73 bps, respectively. This pattern holds for the post-SLP period.

Figure 3 graphs the weekly moving average of the market-wide residuals of quoted (Panel (a)) and effective (Panel (b)) half-spreads in bps, after controlling for stock and market volatilities, market capitalization, trading volume, and the inverse of the stock price for CAC 40 (solid black line) and DAX 30 (solid gray line) index constituents two months before and after the implementation of the new SLP rules. The dashed horizontal lines represent the pre-SLP (February 1–June 3, 2013) and post-SLP (June 3–September 30, 2013) averages; for ease of comparison, we subtract the pre-SLP average from both time series. The vertical dashed and dotted lines represent the announcement and implementation dates, respectively. Quoted and effective half-spreads for CAC 40 and DAX 30 move together during the pre-SLP period and deviate in the post-SLP period. We verify that the parallel trends assumption is

satisfied, making the DAX 30 an appropriate control group for analyzing the effect of the new SLP rules on the market liquidity of CAC 40 stocks. We refer readers to Internet Appendix IA.7 for the formal test of the parallel trends assumption.

4.2. New SLP Rules: Overall Effect

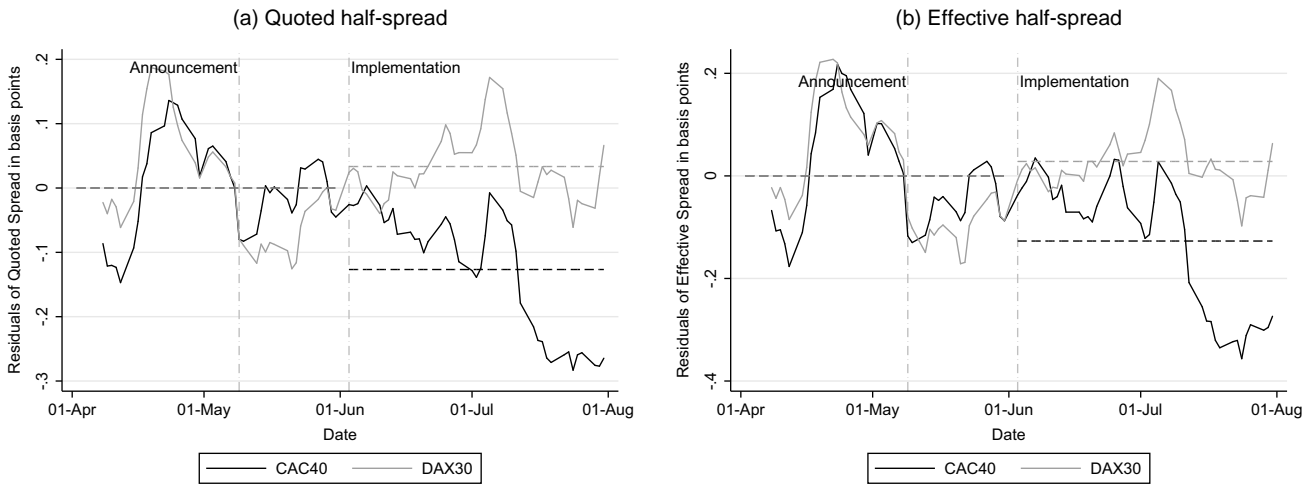
In this section, we begin by asking how the new SLP rules affected market liquidity, namely, the combined change in the rules enforced by the exchange (Rule A and Rule B jointly). We perform a DiD analysis for the various liquidity measures and assign DAX 30 stocks to the control group.

In particular, we regress the different liquidity measures on the dummy variable $SLP_{i,t}$, which is equal to one in the post-event period (June 3–July 31, 2013) and zero in the pre-event period (April 1–June 3, 2013); the dummy variable $CAC40_{i,t}$, which is equal to one if stock i belongs to the CAC 40 index and zero otherwise; and the interaction term between $CAC40_{i,t}$ and $SLP_{i,t}$. We control for stock and market volatilities, trading volume, market capitalization, and the inverse of the stock price.²⁷ We estimate the specifications without fixed effects, with stock \times tick size fixed effects, and with both stock \times tick size and day fixed effects.²⁸ Standard errors are clustered by stock \times tick size and day. Formally, we perform the following regression:

$$Liquidity_{i,t} = \alpha_j^{TickSize} + \lambda_d + \beta_1 SLP_{i,t} + \beta_2 CAC40_{i,t} + \beta_3 SLP_{i,t} \times CAC40_{i,t} + \Gamma Controls + \epsilon_{i,t}. \quad (3)$$

Table 3 presents the results of the regression with the quoted half-spread (Panel A) and the effective half-spread (Panel B) as dependent variables. We anchor our

Figure 3. Quoted and Effective Half-Spreads Around the New SLP Rules



Notes. This figure shows the weekly moving average of the market-wide residuals of quoted (see Equation (1)) and effective (see Equation (2)) half-spreads in bps after controlling for stock and market volatilities, market capitalization, trading volume, and the inverse of the stock price. The solid black (gray) line shows the spread dynamics for stocks that belong to the CAC 40 (DAX 30). For readability, we subtract the pre-SLP average (April 1–June 3, 2013) from both time series. The horizontal dashed lines represent the pre-SLP and post-SLP averages of the half-spreads. The vertical dashed and dotted lines represent the announcement and implementation dates of the new SLP rules, respectively. The period under consideration ranges from April 1, 2013, until July 31, 2013. The sample comprises 36 stocks traded on NYSE Euronext Paris that belong to the CAC 40 index and 30 stocks that belong to the DAX 30 index. Data for the French and German stocks come from the BEDOFIH and TRTH databases, respectively.

Table 3. New SLP Rules: Overall Effect

Independent variables	Panel A: Quoted half-spread			Panel B: Effective half-spread		
	(1)	(2)	(3)	(1)	(2)	(3)
$SLP_d \times CAC40_j$	-0.124*	-0.082	-0.134***	-0.098	-0.054	-0.105**
	(-1.82)	(-1.38)	(-2.72)	(-1.49)	(-0.90)	(-2.11)
SLP_d	-0.008	-0.039		-0.025	-0.058	
	(-0.13)	(-0.70)		(-0.40)	(-1.03)	
$CAC40_j$	-0.427***			-0.783***		
	(-3.67)			(-6.58)		
$Realized\ volatility_{j,d}$	0.202***	0.121***	0.083***	0.197***	0.109***	0.061***
	(5.61)	(7.17)	(5.53)	(5.14)	(5.72)	(3.38)
$Trading\ volume_{j,d}$	-0.077***	-0.022**	-0.034***	-0.064**	0.001	-0.012
	(-2.82)	(-2.32)	(-3.16)	(-2.27)	(0.06)	(-0.81)
$Market\ capitalization_{j,d}$	-0.008***	-0.027	-0.033*	-0.009***	-0.019	-0.023
	(-2.69)	(-1.58)	(-1.91)	(-2.99)	(-1.22)	(-1.54)
$Inverse\ of\ price_{j,d}$	4.151***	-18.743	-19.423	3.921**	-12.509	-13.351
	(2.58)	(-0.95)	(-1.00)	(2.31)	(-0.74)	(-0.81)
$Market\ volatility_d$	0.032***	0.049***		0.034***	0.048***	
	(4.36)	(4.22)		(4.14)	(4.29)	
Constant	1.751***	2.459**	3.468***	2.161***	2.462**	3.412***
	(11.78)	(2.25)	(2.79)	(13.18)	(2.56)	(3.17)
Observations	5,613	5,613	5,613	5,613	5,613	5,613
Adjusted R^2	0.331	0.813	0.837	0.412	0.823	0.849
Stock \times tick size FE	No	Yes	Yes	No	Yes	Yes
Day FE	No	No	Yes	No	No	Yes
Clustered SE	By stock \times tick size and day			By stock \times tick size and day		
p -value $SLP_d \times CAC40_j = \Delta Rebate$	0.13	0.30	0.02**	0.23	0.57	0.09*

Notes. This table shows the results of the SLP regression (see Equation (3)). We regress the quoted (Panel A) and effective (Panel B) half-spreads for stock j , on day d , on the dummy variable SLP_d , which is equal to one in the period after the implementation of the new SLP rules (June 3–July 31, 2013) and zero otherwise (April 1–June 3, 2013); on the dummy variable $CAC40_j$, which is equal to one if stock j belongs to the CAC 40 index and zero if stock j belongs to the DAX 30 index; and on the interaction term $SLP_d \times CAC40_j$. In all regressions, we control for stock and market volatilities, trading volume, market capitalization, and the inverse of the stock price. Standard errors are clustered by stock \times tick size and by day. Spreads are measured in basis points. t -statistics are reported in parentheses. The sample comprises 36 stocks traded on NYSE Euronext Paris that belong to the CAC 40 index and 30 stocks that belong to the DAX 30 index. Data for the French and German stocks come from the BEDOFIH and TRTH databases, respectively. FE, fixed effect; SE, standard error.

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

discussion on the most conservative specification with stock \times tick size and day fixed effects. The quoted (effective) half-spread following the implementation of the new SLP rules decreases for CAC 40 index constituents by 0.134 (0.105) bps, which is a 6.60% (5.02%) decline relative to the pre-SLP level.²⁹ We also reject the notion that the coefficient for $SLP_d \times CAC40_j$ is equal to the change in rebates received by DMMs for passive execution ($\Delta Rebate = 0.02$ bps) at the 10% significance level. It shows that liquidity improves beyond the level one would mechanically observe because of the change in rebate. Overall, our results support Hypothesis 1: the exogenous change of incentives and requirements positively affected market liquidity.

4.3. New SLP Rules: Effect of Competition Among DMMs

To distinguish between the pure effects of increased competition among DMMs and the effects stemming from changes in any other incentives for DMMs, we use a triple DiD methodology to compare the effect of the new SLP rules on baskets of stocks for which competition increased the most (Baskets 1, 2, and 3), relative to baskets of stocks for which competition among DMMs remained largely unchanged (Basket 4), both before and after the new SLP rules were implemented. More formally:

$$\begin{aligned} Liquidity_{j,d} = & \alpha_j^{TickSize} + \lambda_d + \beta_1 SLP_d + \beta_2 CAC40_j + \beta_3 SLP_d \\ & \times CAC40_j + \boldsymbol{\gamma} \times \mathbf{Basket}_j + \\ & + \boldsymbol{\phi} \times SLP_d \times CAC40_j \times \mathbf{Basket}_j \\ & + \Gamma Controls + \epsilon_{j,d}, \end{aligned} \quad (4)$$

where $\boldsymbol{\gamma}$ is a vector of coefficients $\mathbf{Basket}_j = \begin{pmatrix} Basket1_j \\ Basket2_j \\ Basket3_j \end{pmatrix}$, $\boldsymbol{\phi}$

is a vector of coefficients $SLP_d \times CAC40_j \times \mathbf{Basket}_j = \begin{pmatrix} SLP_d \times CAC40_j \times Basket1_j \\ SLP_d \times CAC40_j \times Basket2_j \\ SLP_d \times CAC40_j \times Basket3_j \end{pmatrix}$, and $Basket1_j$, $Basket2_j$,

and $Basket3_j$ are dummy variables equal to one if the stock belongs to Baskets 1, 2, and 3, respectively (we use Basket 4 as the reference) and zero otherwise.³⁰

We use the estimation results from Equation (4) to disentangle the effect of changes in other incentives due to the new SLP rules from the pure effect of competition among DMMs by exploiting heterogeneity in the change in competition across the different baskets. $\beta_3 + \boldsymbol{\phi}$ represents the overall effect of the implementation of the new SLP rules, $\boldsymbol{\phi}$ represents the heterogeneous effects of the new SLP rules across baskets of stocks due to differences in the changes in competition among DMMs, and β_3 represents the effect of changes in other incentives due to the implementation of the new SLP rules for market liquidity. Therefore, the coefficient of greatest interest for testing Hypothesis 2 is $\boldsymbol{\phi}$, that is, the coefficient that captures whether for the various baskets of stocks, the new

SLP rules increase competition and whether market liquidity improves as a consequence.

Table 4 presents the results of the regression with the quoted half-spread (Panel A) and the effective half-spread (Panel B) as dependent variables and the same controls and standard error clustering as before. Our findings are consistent across all our specifications. In our discussion of the results below, we focus on the most conservative specification that includes both stock \times tick size and day fixed effects.

We observe the negative and significant effect of the new SLP rules for baskets that exhibit a substantial increase in competition among DMMs, as manifested by the negative and significant interaction coefficients for $SLP_d \times CAC40_j \times Basket123_j$ (i.e., the coefficient $\boldsymbol{\phi}$ in Equation (4)). In particular, we show that the quoted (effective) half-spread decreases by 0.131 (0.122) bps, or 6.45% (5.84%) of the pre-SLP level, because of the effect of increased competition among DMMs. This implies that competition among DMMs is responsible for 79.87% of the improvement in quoted half-spread (i.e., $0.131 / (0.131 + 0.033)$) and 91.73% of the improvement in effective half-spread (i.e., $0.122 / (0.122 + 0.011)$) because of the implementation of the new SLP rules, with the rest stemming from the changes in incentives in our setup.³¹

We further check whether the improvement in market liquidity due to the new SLP rules is different across Baskets 1, 2, and 3. In particular, in the last specification in each panel of Table 4 we show that an increase in the number of DMMs is monotonically related to liquidity improvement, in line with Hypothesis 2. That is, Basket 4 has the smallest (and statistically insignificant) decrease in effective half-spreads ($\Delta\#$ of DMMs = 1), followed by Basket 2, with an effective half-spread decrease of 0.111 bps ($\Delta\#$ of DMMs = 2), and Baskets 1 and 3 with an effective half-spread decrease of 0.127 bps and 0.131 bps, respectively ($\Delta\#$ of DMMs = 3). We conclude that the effect of the new SLP rules on market liquidity is largely driven by increased competition among DMMs (i.e., we cannot reject Hypothesis 2).³²

On average, the trading volume per day for all CAC 40 stocks is EUR 1.384 billion; hence, in economic terms, the decrease in the effective half-spread of 0.122 bps due to the pure effect of competition among DMMs (based on specification (3) of Table 4) corresponds to a decrease in transaction costs of EUR 4.25 million per year. These findings highlight the key result that the increase in competition among DMMs significantly improves the trading conditions (roughly 90% of the overall liquidity improvement) in both statistical and economic terms. We note that the exact magnitude of market liquidity improvement due to competition among DMMs with respect to other incentives is case specific. However, our results suggest that other limit order book markets might be able to benefit from increasing competition among DMMs.

Table 4. New SLP Rules: Effect of Competition Among DMMs

Independent variables	Panel A: Quoted half-spread				Panel B: Effective half-spread			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
$SLP_d \times CAC40_j$	-0.020 (-0.31)	0.021 (0.27)	-0.033 (-0.50)	-0.033 (-0.49)	-0.001 (-0.01)	0.041 (0.57)	-0.011 (-0.18)	-0.011 (-0.18)
$SLP_d \times CAC40_j \times Basket123_j$	-0.135*** (-4.90)	-0.134** (-2.48)	-0.131** (-2.45)		-0.126*** (-5.28)	-0.123*** (-2.58)	-0.122** (-2.51)	
$SLP_d \times CAC40_j \times Basket1_j$				-0.140** (-2.13)				-0.127** (-2.01)
$SLP_d \times CAC40_j \times Basket2_j$				-0.125** (-2.08)				-0.111** (-2.02)
$SLP_d \times CAC40_j \times Basket3_j$				-0.131* (-1.87)				-0.131** (-1.98)
SLP_d	-0.009 (-0.13)	-0.039 (-0.71)			-0.025 (-0.41)	-0.058 (-1.04)		
$CAC40_j$	-0.266* (-1.72)				-0.629*** (-3.83)			
$Basket123_j$	-0.211 (-1.52)				-0.202 (-1.37)			
$Realized\ volatility_{j,d}$	0.206*** (5.76)	0.121*** (7.19)	0.082*** (5.54)	0.082*** (5.47)	0.201*** (5.24)	0.108*** (5.71)	0.060*** (3.37)	0.060*** (3.33)
$Trading\ volume_{j,d}$	-0.082*** (-3.29)	-0.022** (-2.29)	-0.034*** (-3.11)	-0.034*** (-3.11)	-0.069*** (-2.61)	0.001 (0.08)	-0.011 (-0.79)	-0.011 (-0.80)
$Market\ capitalization_{j,d}$	-0.008*** (-2.85)	-0.026 (-1.51)	-0.032* (-1.84)	-0.031* (-1.85)	-0.009*** (-3.15)	-0.018 (-1.15)	-0.022 (-1.46)	-0.022 (-1.47)
$Inverse\ of\ price_{j,d}$	3.998*** (2.66)	-19.209 (-0.98)	-19.877 (-1.03)	-19.890 (-1.02)	3.775** (2.35)	-12.938 (-0.77)	-13.773 (-0.84)	-13.730 (-0.83)
$Market\ volatility_d$	0.032*** (4.45)	0.050*** (4.26)			0.034*** (4.20)	0.048*** (4.33)		
Constant	1.757*** (12.09)	2.434** (2.24)	3.442*** (2.78)	3.440*** (2.79)	2.166*** (13.44)	2.438** (2.55)	3.387*** (3.17)	3.387*** (3.17)
Observations	5,613	5,613	5,613	5,613	5,613	5,613	5,613	5,613
Adjusted R^2	0.355	0.814	0.839	0.839	0.430	0.824	0.850	0.850
Stock \times tick size FE	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Day FE	No	No	Yes	Yes	No	No	Yes	Yes
Clustered SE	By stock \times tick size and day				By stock \times tick size and day			
p -value								
$SLP_d \times CAC40_j + SLP_d \times CAC40_j \times Basket123_j = \Delta Rebate$	0.05*	0.11	<0.01***		0.12	0.30	0.02**	
$SLP_d \times CAC40_j \times Basket123_j = \Delta Rebate$	<0.01***	0.03**	0.04**		<0.01***	0.03**	0.04**	

Notes. This table shows the results of the SLP regression (see Equation (4)). We regress quoted (Panel A) and effective (Panel B) half-spreads for stock j on day d on the dummy variable SLP_d , which is equal to one in the period after the implementation of the new SLP rules (June 3–July 31, 2013) and zero otherwise (April 1–June 3, 2013); on the dummy variable $CAC40_j$, which is equal to one if stock j belongs to the CAC 40 index and zero if stock j belongs to the DAX 30 index; on the dummy variable $Basket123_j$, which is equal to one if stock j belongs to Basket 1, 2, or 3 (the baskets for which DMM activity increases) in the pre-SLP period and zero otherwise; on the dummy variables for each of the three baskets $Basket1_j$, $Basket2_j$, and $Basket3_j$, respectively (see the Internet Appendix for basket composition details); and on the interaction terms $SLP_d \times CAC40_j$ and $SLP_d \times CAC40_j \times Basket123_j$, $SLP_d \times CAC40_j \times Basket1_j$, $SLP_d \times CAC40_j \times Basket2_j$, and $SLP_d \times CAC40_j \times Basket3_j$. In all the regressions, we control for stock and market volatilities, trading volume, market capitalization, and the inverse of the stock price. Standard errors are clustered by stock \times tick size and by day. Spreads are measured in bps. t -statistics are reported in parentheses. The sample comprises 36 stocks traded on NYSE Euronext Paris that belong to the CAC 40 index and 30 stocks that belong to the DAX 30 index. Data for French and German stocks come from the BEDOFIH and TRTH databases, respectively.

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Our findings complement those of Bessembinder et al. (2020), who report that the tightened market-making requirements of DMMs, together with increased rebates for liquidity provision, substantially improve market liquidity. At the same time, we observe that in our setup, the improvement in market liquidity is driven mainly by the competition among DMMs. Several potential explanations clarify the lesser role of incentives in our results. First, the empirical setup of

Bessembinder et al. (2020) does not include the *simultaneous* increase in competition among DMMs that appears in our analysis. Second, Bessembinder et al. (2020) look at the dynamic contract of DMMs, when requirements would be loosened again if trading volume surpasses a specified threshold; therefore, in their context, DMMs had a *direct* incentive to fulfill such requirements not only de jure but also de facto, given the exchange response. Third, the ultimate effect of the

change in requirements depends on the original level and tightness of the requirements already in place and the magnitude of the changes imposed.

Moreover, we perform an *F*-test to ascertain whether the improvement in liquidity due to the increased competition among DMMs as a result of the implementation of the new SLP rules is different from the change in the rebate DMMs receive for passive execution (see Table 4). We confirm that the market liquidity improvement stemming from competition among DMMs is significantly larger than the rebate change ($\Delta \text{Rebate} = 0.02$ bps). If the environment among DMMs were already fully competitive before the new SLP rules were implemented, one would expect the half-spread to improve only by the size of ΔRebate , provided that the new requirements were not binding.

To sum up, our specific setting, which includes multiple DMMs in place, also allows for clarifying the different policy options that an exchange has with respect to a single DMM per stock. For the latter, a single DMM does not have any incentive to transfer the rebate back to the market, at least for the type of requirements we are considering for NYSE Euronext Paris. In Section 5.2, we show that although the requirements on quoting were already satisfied by the DMMs as a group, the fact that, after the change, they were shared among different DMMs is what matters. Hence, for instance, increasing the number of DMMs from five to eight or increasing the quantity that a single DMM is required to quote by a factor of 8/5 would have very different empirical consequences. If the single DMM were already quoting 8/5 times more than required, there would be no difference in total quoting activity. On the other hand, if quoting activity were split among eight rather than five DMMs, the competition among them would be much stronger, with resultant effects on spreads and liquidity provision, even if overall quoting activity does not change. In addition, it is worth remembering the classical advantage of competition, that is, it allows the exchange to exploit market mechanisms rather than set exogenous requirements in order to improve market quality.

5. Robustness Analysis

In this section, we perform several robustness tests. First, we repeat the analysis of the new SLP rules for different transaction sizes (see Section 5.1). Second, we show that the requirements enforced by the new SLP rules were not binding on DMMs as a group (see Section 5.2). Third, we demonstrate that small changes in rebates for DMMs do not affect market liquidity (see Section 5.3).³³

5.1. New SLP Rules: Different Transaction Sizes

In this section, we examine whether the improvement in market liquidity after the implementation of the new

SLP rules is present across different transaction sizes or is concentrated on the smallest transactions. To do so, we split all the aggressive transactions for the sample stocks into quintiles, based on the number of shares traded using the data for the whole of the year 2013, with quintile 1 (quintile 5) containing the smallest (largest) transactions.

Table 5 shows the results of the regression (see Equation (4)) of different transaction size quintiles. For brevity, we report only the coefficients for $SLP_d \times CAC40_j$ and $SLP_d \times CAC40_j \times Basket123_j$, for the specification that includes both stock \times tick size and day fixed effects.

We draw several conclusions from this analysis. First, we note that, in line with the main analysis, the main effect can be observed in those baskets that underwent a large increase in competition among DMMs, which can be seen from the negative and statistically significant coefficients for $SLP_d \times CAC40_j \times Basket123_j$ for all transaction sizes. The effect is decreasing while moving from small transactions to large transactions. More specifically, the market-wide effective half-spread decreases by 0.155 bps for the smallest transactions and by 0.096 bps for the largest, because of the pure effect of increased competition among DMMs.

Overall, we observe the largest effect of competition among DMMs on the smallest transactions; nevertheless, increased competition among DMMs also significantly diminishes transaction costs for larger transactions.³⁴

5.2. New SLP Rules: DMM Behavior

In this section, we show that the new requirements introduced by the new SLP rules were not binding on DMMs as a group in the pre-SLP period. To do so, we compute several variables that reflect the requirements that DMMs have to fulfill and then check whether the new requirements introduced by the new SLP rules were binding.³⁵ As described in Section 3, these requirements involve restrictions on the minimum presence at the BBO level (10% of the continuous session for each stock and 25% of the continuous session on average for CAC 40 stocks), the minimum presence on both sides of the market (95% of the continuous session on average for stocks included in the basket), the minimum value displayed at the BBO level (at least EUR 5,000 on average for stocks included in the basket), and the liquidity provision ratio (the share of passive execution of 0.10% for each stock relative to the total trading volume).

Table 6 shows the average of these measures for all stocks in the CAC 40 index and for each basket of stocks that DMMs could choose from prior to June 3, 2013, for the pre-SLP (Panel A) and post-SLP (Panel B) periods, separately for HFT-MM and MIX-MM. Unfortunately, we cannot track the behavior of individual DMMs and thus can only confirm whether the requirements were fulfilled by DMMs as a group. Table 6 shows that the new requirements were already satisfied in the pre-SLP

Table 5. New SLP Rules: Liquidity by Transaction Sizes

Independent variables	Quintile 1 (small)	Quintile 2	Quintile 3	Quintile 4	Quintile 5 (large)
$SLP_d \times CAC40_j$	-0.070 (-0.92)	-0.048 (-0.64)	-0.007 (-0.10)	0.028 (0.39)	-0.015 (-0.26)
$SLP_d \times CAC40_j \times Basket123_j$	-0.155** (-2.52)	-0.149** (-2.39)	-0.145** (-2.52)	-0.154*** (-2.61)	-0.096** (-2.27)
Realized volatility $_{j,d}$	0.059*** (3.21)	0.055*** (3.25)	0.055*** (3.18)	0.061*** (3.62)	0.059*** (3.13)
Trading volume $_{j,d}$	-0.030** (-2.12)	-0.023* (-1.69)	-0.025* (-1.84)	-0.026** (-2.01)	-0.014 (-1.03)
Market capitalization $_{j,d}$	-0.039** (-2.03)	-0.035* (-1.94)	-0.031* (-1.71)	-0.026 (-1.55)	-0.014 (-1.11)
Inverse of price $_{j,d}$	-20.781 (-0.94)	-22.196 (-1.08)	-21.526 (-1.02)	-19.640 (-1.02)	-9.481 (-0.76)
Constant	4.034*** (2.87)	3.916*** (2.97)	3.751*** (2.77)	3.600*** (2.91)	3.173*** (3.75)
Observations	5,613	5,613	5,613	5,613	5,613
Adjusted R ²	0.818	0.834	0.835	0.837	0.839
Stock × tick size FE	Yes	Yes	Yes	Yes	Yes
Day FE	Yes	Yes	Yes	Yes	Yes
Clustered SE	By stock × tick size and day				

Notes. This table shows the results of the SLP regression (see Equation (4)) for transaction size quintiles (based on transactions in 2013). We regress the effective half-spread for stock j on day d on the dummy variable SLP_d , which is equal to one in the period after the implementation of the new SLP rules (June 3–July 31, 2013) and zero otherwise (April 1–June 3, 2013); on the dummy variable $CAC40_j$, which is equal to one if stock j belongs to the CAC 40 index and zero if stock j belongs to the DAX 30 index; on the dummy variable $Basket123_j$, which is equal to one if stock j belongs to Basket 1, 2, or 3 (the baskets for which DMM activity increases) in the pre-SLP period and zero otherwise (see the Internet Appendix for basket composition details); and on the interaction terms $SLP_d \times CAC40_j$ and $SLP_d \times CAC40_j \times Basket123_j$. In all regressions, we control for stock volatility, trading volume, market capitalization, and the inverse of the stock price. For brevity, we report only the specifications with both stock × tick size and day fixed effects. Standard errors are clustered by stock × tick size and by day. Spreads are measured in bps. t -statistics are reported in parentheses. The sample comprises 36 stocks traded on NYSE Euronext Paris that belong to the CAC 40 index and 30 stocks that belong to the DAX 30 index. Data for French and German stocks come from the BEDOFIH and TRTH databases, respectively.

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

period and are thus unlikely to result in any changes in market liquidity after the new SLP rules were implemented. We now move on to discussing each of the requirements in greater detail.

The liquidity provision ratio was well above 0.10%, the minimum required by the new SLP rules. Moreover, the liquidity provision ratio improves in the post-SLP period, for both HFT-MM and MIX-MM groups, for

Table 6. New SLP Rules: DMM Behavior

Requirements of DMMs	HFT-MM					MIX-MM				
	CAC 40	Basket 1	Basket 2	Basket 3	Basket 4	CAC 40	Basket 1	Basket 2	Basket 3	Basket 4
Panel A: Pre-SLP period										
Gross liquidity provision (%)	24.2%	23.7%	22.7%	22.0%	29.1%	6.4%	7.2%	6.7%	6.2%	5.4%
Displayed order at value at BBO	34,818	35,879	33,868	37,941	31,549	14,360	12,132	14,313	13,962	17,101
Time presence five best prices	99.3%	99.4%	99.2%	99.3%	99.4%	99.7%	99.4%	99.8%	99.5%	99.8%
Time presence at BBO	59.3%	58.8%	56.1%	61.5%	61.5%	27.2%	19.8%	30.8%	23.9%	33.6%
Panel B: Post-SLP period										
Gross liquidity provision (%)	35.5%	37.5%	35.3%	34.2%	35.1%	6.9%	8.1%	6.8%	6.5%	6.5%
Displayed order at value at BBO	23,266	24,519	19,427	28,769	21,102	16,023	14,559	13,249	18,777	18,200
Time presence five best prices	99.6%	99.7%	99.4%	99.7%	99.6%	99.8%	99.7%	99.8%	99.8%	99.8%
Time presence at BBO	56.7%	55.5%	50.7%	62.8%	59.1%	27.9%	27.0%	25.4%	29.6%	30.5%

Notes. This table shows the average across stock-days for the requirements of DMMs. In particular, we show the average time presence at the BBO level and at the first five best-price levels (the amount of seconds present at the BBO level or at the first five best-price levels relative to the total number of seconds during a continuous trading session), the order value in EUR displayed at the BBO level, and liquidity provision (the number of shares executed passively by trader account type relative to the total trading volume per stock-day) separately for HFT-MM and MIX-MM. We report the results for all stocks in the CAC 40 and separately for each basket of stocks as defined in the pre-SLP period (see the Internet Appendix for basket composition details). The sample comprises 36 stocks traded on NYSE Euronext Paris that belong to the CAC 40 index. The period under consideration is April 1–June 3, 2013 (Panel A: Pre-SLP period), and from June 3–July 31, 2013 (Panel B: Post-SLP period). Data for French stocks come from the BEDOFIH database.

CAC 40 stocks as a whole, and for each of the four baskets of stocks. In particular, at the market level, we observe an increase in liquidity provision by HFT-MM from 24.2% to 35.5%, and by MIX-MM from 7.2% to 8.1%. This suggests that the new SLP rules shifted the liquidity provision activity from voluntary liquidity providers to DMMs, given that a larger share of the gross liquidity provision is now provided by DMMs.

The time presence at the first-five best prices of the limit order book levels slightly increases for both HFT-MM and MIX-MM and is above 99% in the pre-SLP period for the CAC 40 index and for each basket of stocks. The time presence at the BBO level increases slightly for MIX-MM (from 27.2% to 27.9% for CAC 40) and decreases for HFT-MM (from 69.3% to 56.7% for CAC 40), with a similar pattern present for the displayed quantity at the BBO level. The displayed order value at the BBO offer level increases for MIX-MM (from EUR 14.36 to 16.02 thousand) and decreases for HFT-MM (from EUR 34.82 to 23.27 thousand).

We note that in the pre-SLP and post-SLP periods, HFT-MM and MIX-MM as a group comply with the new SLP rules (including those that remained unchanged). More specifically, the time presence at the first-five best prices is above 95%, the displayed order value at the best price is far above 5,000 EUR, and the liquidity provision is above 0.1% of the total passive execution volume. DMMs also satisfy the requirement of being present for at least 10% of the continuous session at the BBO level for each stock. The newly introduced Rule B3.2 requires that DMMs are, on average across all CAC 40 stocks, present at least 25% of the time at the best level of the limit order book. Both HFT-MM and MIX-MM traders also comply with this requirement.

Therefore, we conclude that none of the aforementioned requirements was binding on DMMs as a group.³⁶ The observed difference in DMM behavior in the pre- and post-SLP periods is unlikely to be caused by these small changes in the requirements but rather to result from increased competition among DMMs.

5.3. Rebate Reversal: Market Liquidity

NYSE Euronext Paris increased the rebate for DMMs' passive execution from 0.20 bps to 0.22 bps when implementing new SLP rules on June 3, 2013; however, on November 1, 2013, the exchange reverted the rebate to the pre-June level. Ex ante, we would expect that such small changes (approximately 1% of the quoted half-spread in the pre-SLP period) in rebates should have at most a marginal effect on market liquidity, especially given that the reversal took place several months after the rebate level was initially increased. We focus our attention on the time window two months before and two months after November 1, 2013, the implementation date of the rebate reversal.

We start by examining whether non-SLP stocks or DAX 30 stocks are the more appropriate control group. We note that the parallel trends assumption for the CAC 40 and DAX 30 quoted and effective half-spreads is not satisfied around the rebate reversal event, whereas it is satisfied for the CAC 40 and non-SLP quoted and effective half-spreads.³⁷ Therefore, we perform an analysis of the rebate reversal using non-SLP stocks as the control group. We regress the different liquidity measures on the dummy variable $Rebate_d$, which is equal to one in the post-event period (November 1–December 31, 2013) and zero in the pre-event period (September 1–October 31, 2013); on the dummy variable $CAC40_j$, which is equal to one if stock j belongs to the CAC 40 index and zero otherwise; and on the interaction term between $CAC40_j$ and $Rebate_d$. As noted above, we control for stock and market volatilities, trading volume, market capitalization, and the inverse of the stock price in all regressions. We estimate the specifications without fixed effects, with stock \times tick size fixed effects, and with both stock \times tick size and day fixed effects. Again, in all our regressions, we cluster standard errors by stock \times tick size and by day. More formally, we perform the following regression:

$$Liquidity_{j,d} = \alpha_j^{TickSize} + \lambda_d + \delta_1 Rebate_d + \delta_2 CAC40_j + \delta_3 Rebate_d \times CAC40_j + \Gamma Controls + \epsilon_{j,d}. \quad (5)$$

Table 7 provides the regression results (see Equation (5)) for the changes in market liquidity that occur around the rebate reversal to the pre-SLP level from -0.22 bps to -0.20 bps, which occurred on November 1, 2013, with the usual dummy variables, fixed effects, controls, and clustering of errors. We observe that the coefficients for the interaction term $CAC40_j \times Rebate_d$ are statistically insignificant for the quoted and effective half-spreads across all specifications.

To conclude, our findings confirm our ex ante expectation that tiny changes in the DMM rebate (0.02 bps, or approximately 1% of the quoted half-spreads in the pre-SLP period) do not materially affect market liquidity. Given that the change in the rebate that occurred on November 1, 2013, exactly offsets the change in rebate that occurred on June 3, 2013 (the same time as the change in SLP rules), we argue that any effect observed around the change in SLP rules is attributable to sources other than the change in the maker-taker fee structure. We emphasize that our analysis does not offer any conclusion about large changes in the rebate, which we believe would materially affect market liquidity.

6. Conclusion

The evolving trading environment has reshaped the market-making business in global equity markets. Traditional market makers were crowded out by

Table 7. Rebate Reversal: Market Liquidity

Independent variables	Panel A: Quoted half-spread			Panel B: Effective half-spread		
	(1)	(2)	(3)	(1)	(2)	(3)
$Rebate_d \times CAC40_j$	-0.044 (-0.86)	-0.029 (-0.42)	-0.030 (-0.43)	-0.032 (-0.62)	-0.016 (-0.21)	-0.016 (-0.21)
$Rebate_d$	0.010 (0.34)	0.070 (1.02)		-0.020 (-0.90)	0.046 (0.63)	
$CAC40_j$	-2.324*** (-7.61)			-2.539*** (-7.37)		
$Realized\ volatility_{j,d}$	0.649*** (4.72)	0.242*** (10.30)	0.231*** (8.91)	0.727*** (4.49)	0.272*** (10.63)	0.264*** (9.26)
$Trading\ volume_{j,d}$	-0.275*** (-4.17)	-0.090*** (-5.05)	-0.094*** (-5.27)	-0.301*** (-3.97)	-0.092*** (-4.92)	-0.094*** (-5.14)
$Market\ capitalization_{j,d}$	0.018* (1.81)	-0.005 (-0.81)	-0.001 (-0.09)	0.021* (1.88)	-0.004 (-0.57)	-0.001 (-0.09)
$Inverse\ of\ price_{j,d}$	7.705** (2.20)	14.688** (2.34)	13.007** (2.27)	8.512** (2.08)	15.004** (2.41)	13.644** (2.38)
$Market\ volatility_d$	-0.008 (-0.67)	0.018** (2.05)		-0.017 (-1.29)	0.012 (1.39)	
Constant	3.299*** (11.04)	7.558*** (35.77)	7.913*** (55.77)	3.586*** (10.62)	8.449*** (43.05)	8.700*** (64.29)
Observations	5,968	5,968	5,968	5,968	5,968	5,968
Adjusted R^2	0.582	0.922	0.925	0.564	0.924	0.926
Stock \times tick size FE	No	Yes	Yes	No	Yes	Yes
Day FE	No	No	Yes	No	No	Yes
Clustered SE	By stock \times tick size and day			By stock \times tick size and day		

Notes. This table shows the results of the rebate reversal estimation (see Equation (5)). We regress the quoted (Panel A) and effective (Panel B) half-spreads for stock j on day d on the dummy variable $Rebate_d$, which is equal to one in the period after the implementation of the rebate reversal rules (November 1–December 31, 2013) and zero otherwise (September 1–October 31, 2013); on the dummy variable $CAC40_j$, which is equal to one if stock j belongs to the CAC 40 index and zero if stock j belongs to the 36 largest non-SLP stocks; and on interaction term $Rebate_d \times CAC40_j$. In all regressions, we control for stock and market volatilities, trading volume, market capitalization, and the inverse of price. Standard errors are clustered by stock \times tick size and by day. Spreads are measured in basis points. t -statistics are reported in parentheses. The sample is composed of 36 stocks traded on NYSE Euronext Paris that belong to the CAC 40 index and the 36 largest non-SLP stocks. Data for French stocks come from the BEDOFIH database.

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

algorithmic liquidity providers, often operating voluntarily and without any obligation to maintain stable markets. The “Flash Crash” in the U.S. market on May 6, 2010, is one episode that raised serious doubts among academics and regulators about the efficacy of voluntary liquidity provision by algorithmic traders (and especially its subset of HFTs) in modern financial markets, particularly in times of market stress. Thus, it is not surprising that high-frequency market making has drawn close scrutiny from regulators whose obligation is to ensure the continuous participation of traders in market making. For example, the recently implemented MiFID II regulation explicitly focuses on requirements for such market makers and has made written contracts between high-frequency market makers and stock exchanges mandatory. In this paper, we empirically address the issue of such an optimal contract design between DMMs and stock exchanges to facilitate better liquidity provision.

Our findings allow us to conclude that specifying the requirements that DMMs have to fulfill and providing them with an attractive fee structure might improve liquidity provision in equity markets, but the outcome

could be even better if market forces such as competition among DMMs are used. We emphasize that exchanges could improve liquidity provision if in addition to the requirements and fee structures applied to DMMs, they explicitly introduce competition among DMMs for providing liquidity for the same stock.

This broad conclusion is robust to controlling for several other effects, including basket composition, the fee rebate offered, and transaction size. These conclusions are likely to be of interest to securities market regulators and exchanges that seek to improve liquidity provision in the face of rapid changes in trading technology and execution speed.

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Endnotes

¹ We use the term “designated market makers” in this context to emphasize the fact that such traders enter into written agreements with the exchange, although their exact role in the market and the details of such agreements may vary across time and exchanges.

² Clearly, the degree of competition that prevails in the market is also determined by the actions of traders other than DMMs whose actions may be indirectly influenced by the exchanges.

³ We acknowledge that we are unable to analyze the effect of the shift from a single monopolistic DMM to a fully competitive environment, but we can evaluate the effect on market liquidity of switching from a few oligopolistic DMMs to a more competitive environment.

⁴ NYSE Paris Euronext was fifth in the world in terms of market capitalization as of 2013, based on information from the World Federation of Exchanges. NYSE Paris Euronext exhibits a level of HFT activity similar to the one in U.S. equity markets. For example, Carrion (2013) reports HFT trading to be 68% of dollar trading volume on the NASDAQ (sample periods: January 2008–December 2009 and February 22–February 26, 2010), whereas we show in our sample that HFTs are responsible for around 82%. Overall, these aspects suggest that the results from NYSE Paris Euronext can be generalized to other limit order book markets.

⁵ We note that on NYSE Euronext Paris during the period under consideration (i.e., 2013) the only nonvoluntary liquidity providers among CAC 40 index constituents were members of the SLP program. Therefore, in this study, we refer to members of the SLP program as DMMs. By contrast, the NYSE has several tiers of nonvoluntary liquidity providers: one DMM per stock plus SLP members, with the latter facing less strict obligations than DMMs.

⁶ The German stock market index, the DAX, consisted of 30 stocks during the period of our investigation. On September 20, 2021, the index was broadened to 40 stocks.

⁷ The reported magnitudes are based on a difference-in-difference regression with DAX 30 stocks used as the control group. The period under consideration is two months before and two months after the implementation of the new SLP rules. We control for stock and market volatilities, trading volume, market capitalization, and the inverse of the stock price. In addition, the regression specification includes stock \times tick size and day fixed effects.

⁸ We acknowledge that increasing the number of DMMs per stock might not necessarily lead to an improvement in market liquidity, because the ultimate effect depends on *all* aspects of a DMM’s contract with the exchange (competitive environment, requirements of and economic benefits for DMMs) and on the interaction between the different aspects involved, such as the extent to which market obligations are binding on DMMs, the balance between the strength

of these obligations and benefits received, and so on. Nevertheless, we believe that regulators and exchanges should not ignore the competition tool at their disposal.

⁹ NEEQ is a quote-driven market where investors can transact only through market makers; that is, direct transactions between two investors are not possible.

¹⁰ Other studies offering evidence for the value of DMMs are largely based on voluntarily negotiated contracts between the DMM and the firm itself (e.g., Venkataraman and Waisburd 2007, Anand et al. 2009, Menkveld and Wang 2013, Bessembinder et al. 2015, Skjeltorp and Ødegaard 2015). However, these studies are likely to provide an upward-biased estimate of the DMM’s value, because only firms that find hiring a DMM beneficial will do so.

¹¹ Theissen and Westheide (2023) show that the voluntary entry of additional DMMs improves liquidity for small-cap stocks that experience negligible HFT activity. Using an Instrumental Variables approach, the authors conclude that for such firms it can be beneficial to hire more than one DMM.

¹² Several studies explore the role of maker-taker fees in incentivizing DMMs to provide liquidity (e.g., Colliard and Foucault 2012, Malinova and Park 2015, Cardella et al. 2017, El Euch et al. 2018, Lin et al. 2018, Clapham et al. 2021, Black 2022). Most of these studies zero in on the case in which maker-taker fees are uniformly applied to all market participants across all stocks, rather than specifically to DMMs to incentivize their liquidity provision. In a closely related recent paper on this issue, Bessembinder et al. (2020) examine the joint effect of making-taking fees specific to DMMs and the requirements of DMMs.

¹³ Hasbrouck and Sofianos (1993) describe the specialist’s role on the NYSE; Venkataraman and Waisburd (2007) provide a historical overview of “animateurs” in the French stock market.

¹⁴ See Hagströmer and Norden (2013), Menkveld (2013), Budish et al. (2015), Bongaerts and Van Achter (2021), and Menkveld and Zoican (2017) for both theoretical and empirical evidence of HFTs taking on the role of de facto market makers. Anecdotal evidence also confirms this view; for example, since January 2016, DMMs’ duties on the NYSE are all managed by HFT firms (see Bullock 2016).

¹⁵ Baron et al. (2019) show that HFTs compete with the fastest trader among them on speed to secure the largest profit. Because of this relative speed advantage, the HFT industry does not typically witness a deterioration in profits over time. Shkillo and Sokolov (2020) show that when speed differentials among HFTs become less prominent, liquidity improves, whereas Brogaard and Garriott (2019) study the entry of new HFTs into the market and show that HFTs are quantity competitors (as modeled by Biais et al. 2000) rather than price competitors (as modeled by Budish et al. 2015 and Menkveld and Zoican 2017).

¹⁶ Because of the many ownership changes of NYSE Euronext Paris and website design changes in recent years, some earlier documents are not easy to find. Therefore, we provide all the relevant SLP documents at the end of the Internet Appendix.

¹⁷ Please see Internet Appendix IA.1 for basket composition details.

¹⁸ Megarbane et al. (2017) use the same database, enhanced with trader ID numbers, to identify 13 firms as SLP members for the sample period from November 2015 through July 2016.

¹⁹ In Internet Appendix IA.1, we examine whether there are any stock characteristics (e.g., closing bid-ask spread, trading volume, and volatility) that are ex ante different across the four baskets of stocks that could explain the selective endogenous choices made by DMMs. However, it appears from the statistical analysis that the baskets are very similar, so we cannot shed light on the choices made by DMMs based on these ex ante stock characteristics.

²⁰ We argue that traders that were part of the SLP program were present across all CAC 40 stocks before the new rules were implemented. However, in some baskets of stocks they acted as DMMs, whereas in other baskets of stocks they acted as proprietary traders. In Internet Appendix IA.2, we provide empirical evidence consistent with the fact that competition among HFTs remained unchanged, whereas competition among DMMs increased. In other words, some HFTs shifted their role from proprietary traders to DMMs. This fact distinguishes our analysis from the literature studying changes in competition among HFTs.

²¹ We note that these *modest* changes in the size of the rebate did not materially affect market liquidity (see Section 5.3).

²² Four components are not included in the database, because their main trading venue is not NYSE Euronext Paris: ArcelorMittal, Gemalto, Solvay, and Unibail-Rodamco.

²³ In order to avoid any bias from intraday patterns, we exclude the first and last 30 minutes of the continuous trading session from our analyses.

²⁴ We refer to Internet Appendix IA.3 for the analysis that includes all SLP stocks as a treatment group. Our main findings hold in this extended sample.

²⁵ The tick size on NYSE Euronext Paris and Xetra depends on the stock price: if the stock price is below EUR 10, then the tick size is 1/1,000; if it is between EUR 10 and EUR 50, the tick size is 5/1,000; if it is between EUR 50 and EUR 100, then the tick size is 1/100; and if it is above EUR 100, the tick size is 5/100.

²⁶ As a robustness check, we repeat the main analysis with non-SLP stocks as the control group (see Internet Appendix IA.5) and without any control group (see Internet Appendix IA.6). The results are qualitatively similar to the results using DAX 30 as the control group.

²⁷ We note that trading volume itself may be affected by the new SLP rules and may thus be endogenous. Therefore, we repeat our main analysis but drop trading volume from the list of control variables. We also repeat our main analysis using the share of trading volume, instead of the trading volume, executed on NYSE Euronext Paris alone as a control variable. Our findings remain qualitatively unchanged. Internet Appendix IA.8 presents the results of these alternative specifications.

²⁸ Given that tick size directly affects the cost and potential magnitude of spread improvement, we use stock \times tick size fixed effects to accommodate for its dynamic nature; that is, tick size is adjusted automatically depending on the current price level. Internet Appendix IA.1 provides summary statistics for the number of stock-days with a particular tick size during our sample period.

²⁹ As a comparison, Bessembinder et al. (2020) report a decrease of quoted (effective) spread of 7.4%–8.1% (8.2%–9.3%) relative to the spread before the change in the DMM contracts. This decrease stemmed from substantial tightening of the market-making requirements for DMMs, along with increased rebates for liquidity provision.

³⁰ We note that all stocks in Basket 1, 2, or 3 also belong to the CAC 40 index. Consequently, the interaction terms $SLP_d \times Basket1_j$ and $CAC40_j \times Basket1_j$ are exactly the same as the interaction term $SLP_d \times CAC40_j \times Basket1_j$ and $Basket1_j$ and are thus omitted from the estimation to avoid multicollinearity. The same consideration applies to the interaction terms with $Basket2_j$ and $Basket3_j$.

³¹ One might argue that this decrease in spreads does not translate into a decrease in overall transaction costs and not simply for trades of small size. By rerunning the analysis for different transaction sizes (see Section 5.1), we show that our results are robust and that our conclusion does not change.

³² In Internet Appendix IA.9, we repeat our analysis for the components of the effective spread: price impact (i.e., adverse selection costs) and realized spread (i.e., revenue of liquidity providers). We

show that the main source of the reduction in effective spread is the decrease in realized spread consistent with increased competition among DMMs. In addition, in Internet Appendix IA.10, we analyze gross and net profits of DMMs as a group and show that their profits decreased after the implementation of the new SLP rules, which is also consistent with the increased competition among DMMs.

³³ We also analyze whether implementation of the new SLP rules had an effect on the market share of NYSE Euronext Paris (see Internet Appendix IA.11), on the market liquidity on alternative trading venues (namely, Chi-X [see Internet Appendix IA.12]), and on the spreads faced by different trader categories (see Internet Appendix IA.13). In addition, we analyze whether market liquidity improved most for stocks in which DMMs improve BBOs or are present at the BBO level more often under the new SLP rules (see Internet Appendix IA.14 and IA.15).

³⁴ The improvement in the effective spread for larger transactions implicitly suggests an improvement in dimensions of liquidity such as market depth.

³⁵ For the purpose of this analysis, we use the data from the entire continuous session because the requirements are defined on the basis of the overall activity during the continuous session.

³⁶ We note that this conclusion is valid, on average, across stock-days for HFT-MM and MIX-MM as a group. We implicitly assume that each individual DMM also complies with the requirements, but we cannot categorically exclude the possibility that the requirements become more binding for some DMMs than for others. Unfortunately, our data do not allow us to track individual DMMs and thus make it impossible to address this issue.

³⁷ We refer to Internet Appendix IA.7 for a formal test of the parallel trends assumption between CAC 40, DAX 30, and non-SLP quoted and effective half-spreads around the rebate reversal event.

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