Direct and Indirect Effects of Index ETFs on Spot-Futures Pricing and Liquidity: Evidence from the CAC 40 Index*

Laurent Deville,a, b Carole Gresse,c and Béatrice de Séveracd

aCNRS, GREDEG
250 rue Albert Einstein - Batiment 2, 06560 Valbonne, France
laurent.deville@gredeg.cnrs.fr

bEDHEC Business School
400 Promenade des Anglais, BP 3116, 06202 Nice Cedex 3, France

c Corresponding author. Université Paris-Dauphine, DRM
Place du Maréchal de Lattre de Tassigny 75775 Paris cedex 16, France
carole.gresse@dauphine.fr

d Université Paris Ouest Nanterre La Défense,
200, avenue de la République, 92001 Nanterre cedex, France
bseverac@u-paris10.fr

July 2011

JEL classification: G12; G13; G14

Keywords: Futures, Exchange-Traded Fund, ETF, Efficiency, Arbitrage, Liquidity

* The authors gratefully acknowledge the financial support of the Europlace Institute of Finance. We also thank Claudette Babusiaux, Jonathan Dark, Bertrand Jacquillat, Terry Hendershott, Andrea Heuson, Alexander Kurov, Laurence Lescouret, Maureen O’Hara, Patrice Poncet, Christian Rabeau, and participants at the ESSEC seminar, as well as participants at the 2005 EIF meetings in Paris, the 2006 FMA European conference in Stockholm, the 2006 EFMA meetings in Madrid, and the 2006 FMA conference in Salt Lake City, for helpful comments.
Direct and Indirect Effects of Index ETFs on Spot-Futures Pricing and Liquidity: Evidence from the CAC 40 Index

Abstract

This paper investigates how the introduction of an index security directly or indirectly impacts the underlying-index spot-futures pricing. Using intraday data for financial instruments related to the CAC 40 index, we do not find that the spot-futures price efficiency improvement observed after ETF introduction is explained either by the direct effect of ETF shares being used in arbitrage trades or by the indirect effect of ETF trading improving the liquidity of index stocks in the short run. Some of our findings suggest that the efficiency improvement could rather result from a structural change in the way index traders distribute across index markets, with the ETF market absorbing the liquidity demand from some hedgers or passive index traders.
1. Introduction

Exchange-Traded Funds (ETFs) are investment funds designed to replicate the performance of an index or a specified benchmark as closely as possible. Contrary to conventional index mutual funds, ETFs are listed on an exchange and can be traded at any time in the trading day at market prices. Their shares may also be created and redeemed by the issuer in large blocks on a daily basis, either in cash or in kind. ETFs replicating benchmark stock indices have rapidly developed since their first introduction in North America in the 1990s. Their number reached 2,422 funds at the end of November 2010, with 5,413 listings and assets of US$1,231.0 billion from 133 providers on 46 exchanges around the world.¹ Those liquid exchange-traded index securities offer new trading facilities for index portfolio managers, index risk hedgers, and arbitrageurs. They may therefore change trading equilibriums and cross-market pricing relations. In particular, the introduction of ETFs has been shown to tighten the spot-futures no-arbitrage price relation (see Park and Switzer (1995) for the case of the Toronto 35 Index, Switzer, Varson, and Zghidi (2000) for the S&P 500 Index, and Kurov and Lasser (2002) for the NASDAQ-100 Index).² However, previous literature has not yet investigated how this efficiency improvement actually formed. The present article aims to fill this gap and draws on high frequency data to identify the channel(s) by which the spot-futures price relation tightens.

Increased arbitrage trading is the traditional explanation of why the introduction of an ETF would tighten the spot-futures no-arbitrage price relation (Kurov and Lasser, 2002).

¹ Barclays, ETF Landscape Industry Review, November 2010.
² Deville and Riva (2007) also show that ETF introduction significantly improves the joint efficiency of spot and options prices.
2002; Hegde and McDermott, 2004). Because of their low trading costs, it is usually claimed that ETFs are used to establish the cash leg in arbitrage portfolios. With the opening of an ETF market, more arbitrage tools are available to arbitrageurs. Arbitrage trading is thus facilitated, which consequently improves the efficiency of futures prices. This effect stemming from the ETF shares being used in spot-futures arbitrage portfolios will be referred to as the direct effect of ETF trading on price efficiency.

Another explanation for the efficiency improvement following the introduction of an ETF lies in the linkage between liquidity and efficiency. Empirical studies on index spot-futures relations show that liquidity and trading costs play an important role in enforcing no-arbitrage pricing. Arbitrageurs do not trade unless the difference between the theoretical futures price and the market futures price is greater than the transaction costs incurred to implement arbitrage strategies. The higher these costs, or the lower the liquidity, the greater the price inefficiency must be before arbitrageurs trade on it. For example, Roll et al. (2007) show that liquidity plays a significant role in the price reversion process. They provide evidence that the reversion of the basis on S&P 500 futures contracts occurs faster when aggregate NYSE liquidity is high. Due to this linkage between liquidity and price efficiency, if the introduction of an ETF improves the liquidity of underlying stocks, as has been shown by Hegde and McDermott (2004), Madura and Richie (2007), and De Winne et al. (2011), this introduction could therefore

---

3 For instance, De Winne, Gresse, and Platten (2011) show that executing a round-trip trade in an ETF market is substantially less costly than a round-trip trade of the same size executed in the markets for the underlying stocks.

4 Chung (1991) and Miller, Muthuswamy, and Whaley (1994) argue that futures price deviations are more probably the reflection of transaction costs, market non-synchronicity, or market illiquidity, rather than exploitable profits. However, Neal (1996) relates actual S&P 500 arbitrage trades to the predictions of index arbitrage models and observes that price discrepancies do trigger arbitrage trades. Kempf (1996), Tse (2001), and Taylor (2007) show that arbitrage trading in futures markets drives, at least partially, price reversion toward theoretical values.
indirectly improve spot-futures price efficiency even if there is no arbitrage trading in the ETF itself. We refer to this as the indirect effect ETF introduction can have on spot futures price efficiency.

Our contribution is to investigate from which of the direct and indirect effects the efficiency improvement generated by the inception of an ETF arises. Using high-frequency index, futures, and ETF data over two five-month periods surrounding the inception of the first ETF replicating the CAC 40 index, we do not find support for neither a direct effect of ETF trading nor a liquidity indirect effect at the intraday horizon. We rather interpret the post-ETF efficiency improvement as a structural change in the spatial distribution of traders across index related markets. This interpretation is based on the observation that a deterioration of the liquidity of index stocks causes ETF trading to increase and that the causal links between index stock liquidity and futures price deviations significantly change in periods of active ETF trading.

The remainder of this paper proceeds as follows. Section 2 presents the testable hypotheses. Section 3 describes our institutional framework and the data. Section 4 compares the level of mispricing in the pre- and post-ETF periods. Section 5 provides empirical tests of the direct and indirect effects of ETF trading on index spot-futures pricing. Section 6 seeks an alternative explanation for the efficiency improvement evidenced at Section 5. Section 7 sets forth our conclusions.

2. Testable hypotheses

The direct effect of the ETF being used for spot-futures arbitrage relies on the closeness of the ETF portfolio and the CAC 40 index. As evidenced by Blitz, Huij, and Swinkels (2010), ETFs tend to underperform their benchmark index on an annual basis
and this may cast doubt on their closeness to their underlying index. However, in the case of the Lyxor CAC 40, the replication of the index is synthetic, which ensures very low tracking error: every day, the fund exchanges the return of its portfolio, possibly consisting of assets quite different from those constituting the index, against that of the index in the swap market. According to Deville (2002), over the first year of trading, the tracking error is less than 0.35%. Given its low trading costs and its tracking quality, the Lyxor CAC 40 ETF can thus be considered an appropriate cash instrument for index arbitrage. If the improvement of futures price efficiency following ETF introduction results from the direct effect of ETF shares being used in arbitrage portfolios, then we should observe that the more active the ETF market, the tighter the spot-futures pricing. This leads us to posit hypothesis H1:

**H1. spot-futures price deviations negatively correlate with trading volumes in the ETF.**

However, a correlation analysis of daily data is insufficient to conclude as the relation between ETF trading volumes and index spot-futures mispricing may be dual, with (1) spot-futures mispricing inviting arbitrage trading and thus generating ETF trading volumes, and (2) ETF-based arbitrage trade execution making prices revert to no-arbitrage values. For this reason, we complement H1 by hypotheses H2, which will imply Granger-causality tests on intraday time series:

**H2. there exists a two-way causality between index-futures mispricing and ETF trading;**

**H2a. an increase in spot-futures price deviations invites ETF trading volumes;**

**H2b. an increase in ETF trading volumes causes a tightening of spot-futures price deviations.**
Tests of an indirect effect of the ETF improving liquidity in the underlying stocks are motivated by the observation that illiquidity is an obstacle to the convergence of market prices toward no-arbitrage values. Any futures market price that deviates from the no-arbitrage value based on the well-known cost-of-carry model invites arbitrage trading. In practice, transaction costs and illiquidity in any of the cash or futures markets may discourage arbitrage activity and allow temporary price deviations from no-arbitrage values. Conversely, wide price deviations may trigger arbitrage trading, which may, in turn, affect liquidity by creating order imbalances, as noted by Roll, Schwartz, and Subrahmanyam (2007). This implies that there exists a two-way causal relation between the spot-futures joint price efficiency and liquidity, and any factor affecting liquidity is then likely to indirectly affect price efficiency. Therefore, if ETF trading affects the liquidity of index stocks, this change in liquidity caused by ETF trading may then modify the index spot-futures price equilibrium. This indirect effect can be examined by testing the following hypotheses:

**H3.** there exists a two-way causality between index-futures mispricing and index stock liquidity;

**H3a.** an improvement in index stock liquidity causes a decrease in the index-futures mispricing;

**H3b.** index stock liquidity deteriorates following an increase in the index-futures mispricing;

**H4.** an increase in ETF trading volumes causes an improvement in index stock liquidity.

Not rejecting H3a and H4 would validate that ETF trading indirectly cause spot-futures prices to converge towards efficiency by improving the liquidity of index stocks.
We will investigate H2a, H2b, H3a, H3b, and H4 by estimating a trivariate causal model between index stock liquidity, ETF trading volumes, and index spot-futures price deviations.

3. Institutional framework and data

We base our tests of H1, H2a, H2b, H3, and H4 on data relative to the inception of the first ETF replicating the CAC 40 index on NYSE-Euronext, that is the Lyxor CAC 40. In Europe, ETFs emerged in 2000 on the Deutsche Börse and the London Stock Exchange, followed soon thereafter by Euronext Paris, the French subsidiary of NYSE-Euronext, which opened an ETF-dedicated segment, called NextTrack, in January 2001. The Lyxor CAC 40 was one of the first ETFs launched on NextTrack. When it began trading, on 22 January 2001, the CAC 40 index had long served as the underlying asset for futures and options contracts traded on NYSE Liffe, the derivative market of NYSE-Euronext. The characteristics of the CAC 40 index, its futures contracts, and the Lyxor CAC 40 ETF, as well as related descriptive statistics, are presented in Sub-section 3.1. Sub-section 3.2 describes our data.

3.1. The markets for the CAC 40 index

The CAC 40 index consists of the 40 most actively traded stocks listed on the Main Market of Euronext Paris. Components of the CAC 40 are traded in the electronic order book of Euronext on a continuous basis from 9:00 to 17:35. The trading session starts with a batch auction at 9:00, and then switches to continuous trading. A closing auction takes place at 17:35 after a five-minute pre-auction period. Every 30 seconds during the
continuous trading session, Euronext Paris calculates a weighted average of CAC 40 stock prices to determine the value of the index.\(^5\)

The trading of futures contracts on the CAC 40 index (ticker FCE) takes place on NYSE Liffe from 8:00 to 17:30 on the electronic trading system NSC-VF (day session) and from 17:30 to 22:00 on Globex (night session). The size of one contract is equal to the value of the CAC 40 index multiplied by €10 and the tick size is 0.5 index points. Eight maturities (three monthly, three quarterly, and two half yearly) are continuously open with a quotation horizon of 19 to 24 months. Settlement is in cash with a liquidation price equal to the arithmetic average (rounded to one decimal) of each CAC 40 index value calculated and reported on the settlement day between 15:40 and 16:00, the first index value after 16:00 being included. Since its introduction in 1988, the FCE contract has experienced tremendous growth in trading volume and soon became one of the most liquid derivatives contracts trading on NYSE Liffe. In 2000, it reached a daily average of 71,568 contracts traded. Summary statistics in the first panel of Table 1 show that futures trading concentrates on the nearby maturity. Prior to the introduction of the ETF, 7,550 transactions a day are executed for the nearest contract (a figure that increases to more than 9,000 after), against 500 transactions for all other maturities. This research is thus dedicated to the nearby-maturity contract, which is more likely to be subject to arbitrage trading.

**Table 1 about here**

Currently, the CAC 40 index is the benchmark for several ETFs, but the Lyxor CAC 40 faced no competition until March 2005. One unit of the ETF is worth 1/100 of

\(^5\) Its base value was set to 1,000 on 1 December 1987.
the index and the index return is tracked by way of synthetic replication through a daily settled swap, which guarantees a very small tracking error. Management fees equal 0.25% per year and apart from trading costs, no entrance or exit fees are charged by the fund. Share creation and redemption are always possible for a minimum amount of 50,000 units and are charged €10,000 per subscription request. The Lyxor CAC 40 ETF is continuously traded in the Euronext electronic order book in the same way as underlying stocks, but its trading session is delayed by five minutes compared with the cash stock market session, so that the price discovery process on underlying stocks precedes that on ETFs. Parallel to the order book trading, Liquidity Providers act as market specialists in two ways. They are committed to quote two-way bid and ask prices in the limit order book, with a minimum volume and within a maximum spread. In addition, they execute a large portion of the ETF order flow in the OTC market.

The first panel of Table 1 reports Lyxor CAC 40 trading volume during its first year of trading and compares it to the average trading volume in each CAC 40 constituent stock. In terms of daily euro traded volume, the Lyxor CAC 40 ranks 28th among the CAC 40 stocks. The number of trades recorded for the ETF is very small compared to stocks, with an average of 233 transactions per day, but trades in the ETF are much larger. On average, more than €155,000, representing approximately 3,100 shares (31 times the euro-denominated value of the CAC 40 index) are traded on each transaction, whereas the median trade size for a CAC 40 stock amounts to only €27,868. These statistics indicate that the market for Lyxor CAC 40 shares is dominated by institutional traders rather than individuals, and that its trading level in its first year of existence was significant enough to affect market liquidity and arbitrage activity.
3.2. Observation periods and data

Our analysis is based on the comparison of two observation periods surrounding the ETF launch date of 22 January 2001. Although we hold data for the entire year following this inception date, we choose to make the post-ETF observation period start once the Lyxor CAC 40 has gained enough assets and trading volumes, as we need to test the direct impact of ETF trading on other market characteristics. When examining the trading volumes of the ETF over its three first year of trading, we observe that the trading volume of the ETF substantially increases in June 2001. In that month, the average daily trading volume for the Lyxor CAC 40 reached a level comparable to that of 2002 and remains higher than that of 2003 until the end of 2001. In addition, in terms of size, the number of outstanding shares for the ETF substantially increases on the 30th of July to exceed the threshold of ten million for the first time on that date. We therefore set the post-ETF period from 30 July to 31 December 2001. 11 September 2001 is excluded as extremely abnormal market conditions on that day could bias our results. We then set the pre-ETF observation period symmetrically from 30 July to 31 December 2000 in order to avoid intra-year seasonal effects in the comparison of the two periods. Over these two periods, we use high-frequency data for the CAC 40 index, CAC 40 stocks, CAC 40 futures contracts, and the Lyxor CAC 40 ETF. Our calculations also require data on CAC 40 stock dividends and risk-free interest rates.

CAC 40 index values at 30-second intervals, as well as high-frequency data for CAC 40 nearest futures, CAC 40 stocks, and the Lyxor CAC 40 ETF are extracted from the Euronext Paris Market Database.

The CAC 40 futures high-frequency data comprise information for all transactions recorded on the FCE contract and is time-stamped to the nearest second. The data report
expiration month, futures price, and number of contracts traded for each transaction. As it is impossible to match night-session transactions with contemporaneous index values, these are omitted from the analysis.

For CAC 40 stocks, we use the best bid and ask quote data of Euronext Paris. These data are composed of the best limit prices and quantities, as displayed in the Euronext electronic order book. The timestamp frequency is the second and a new row appears in the database each time any characteristic of the best quotes, either price or quantity, changes. Quantities refer to displayed quantities only, but do not include hidden orders. We hold similar data for the ETF security over 2001. We also use ETF tick-by-tick data, which report the price and volume of each trade at a second-by-second frequency.

Theoretically, dividends delivered by the index’s constituent stocks must be accounted for in the derivation of the fair price of the futures contract. Kurov and Lasser (2002) argue that the dividend yield is so low on the NASDAQ 100 Index that it can be neglected in calculations of the theoretical price. Dividends on the French market are usually delivered on an annual basis and are highly concentrated around May and June. It is thus inappropriate to work with a dividend yield since most of the observations concern futures contracts with less than one month to maturity traded during no-dividend periods. Discrete dividends are extracted from Thomson Financial Datastream and expressed in terms of CAC 40 index points.

Finally, Euribor interest rates are used as the risk-free rate in the calculation of cash-futures bases. One-week to one-year Euribor interest rates are retrieved from Thomson Financial Datastream. Then, rates for non-rounded maturities are determined by linear interpolation.
4. Changes in the CAC 40 index-futures pricing efficiency after the introduction of the Lyxor CAC 40 ETF

In a preliminary stage leading to our main empirical work, we check to what extent the price efficiency of CAC 40 futures contracts improves after inception of the Lyxor CAC 40. To do so, we conduct pre/post-ETF univariate comparisons of several mispricing pleasures: the frequency of positive index-futures arbitrage profits, the average value of non-zero index-futures arbitrage profits, and the average duration of arbitrage opportunities.

4.1. Mispricing measures

According to the cost-of-carry model, the theoretical price of an index-futures contract with maturity date $T$ at time $\tau$ on day $t$, denoted $F_{t,T,\tau}^*$, should be such that:

$$B_{t,T,\tau} = F_{t,T,\tau}^* - \left(I_{t,\tau} - D_{t,T}\right)e^{r_{t,\tau}(T-t)} = 0,$$

where $B_{t,T,\tau}$ denotes the theoretical cash-futures basis; $I_{t,\tau}$ is the value of the index at time $\tau$ on day $t$; $r_{t,\tau}$ is the risk-free interest rate on a loan contracted at $t$ and redeemed at $T$; and $D_{t,T}$ is the present value of the dividends delivered by the index stocks in the period $[t;T]$, expressed in index points. Equation (1) defines the fundamental value of the futures contract in the absence of trading costs. When accounting for arbitrage transaction costs, the no-arbitrage cash-futures basis can differ from zero. Let us denote $C_{t,T,\tau}$ as the transaction cost born to implement arbitrage trades at prices prevailing at time $\tau$. The no-arbitrage cash-futures basis fluctuates inside a collar delimited by $-C_{t,T,\tau}$ and $C_{t,T,\tau}$. Let us denote $F_{t,T,\tau}$ and $B_{t,T,\tau}$ as the actual futures price and the actual cash-futures basis, respectively, at time $\tau$ on day $t$ for maturity $T$. If
$B_{t,T,\tau} > C_{t,T,\tau}$ (resp. $< -C_{t,T,\tau}$), the futures contract is overpriced (resp. underpriced) and the mispricing equals:

$$
\Pi_{t,T,\tau} = \left( \left| F_{t,T,\tau} - (I_{t,\tau} - D_{t,\tau}) e^{r_{\tau}(T - t)} \right| - C_{t,T,\tau} \right) / I_{t,\tau}.
$$

(2)

A long (short) arbitrage portfolio\(^6\) would yield a riskless return of $\Pi_{t,T,\tau}$ provided that the trades implemented to build the portfolio are executed at prices $F_{t,T,\tau}$ and $I_{t,\tau}$.

Although in practice the actual arbitrage profit might differ from the observed price deviation, for sake of simplicity, the expressions “mispricing,” “price deviation,” and “arbitrage profit” are used interchangeably henceforth.

To compute arbitrage profit series $(\Pi_{t,T,\tau})$, futures prices are synchronized with spot index values after aggregating futures trades executed within the same second at the same price for a given maturity. Since index-futures markets generally lead cash index markets (see for example, Kavussanos, Visvikis, and Alexakis, 2008; Shyy, Vijayraghavan, and Scott-Quinn, 1996; Stoll and Whaley, 1990), we match futures trade prices with the index value displayed at the time of the futures transaction or immediately following it. This procedure ensures that no more than 30 seconds is elapsed between the two values. Then we determine the direction of futures trades. For each index-futures pairing, profit $\Pi_{t,T,\tau}$ is calculated according to the direction of the futures trade and after transaction cost.

Since the Euronext Paris Market Database does not contain trade directions, estimating price deviations on futures trade prices may result in using buy (resp. sell)

\(^6\) A short or sell arbitrage, also designated reverse cash-and-carry trade, consists in short-selling the index portfolio and buying the futures contract, while a long or buy arbitrage, also known as a cash-and-carry trade, consists in buying the index portfolio and selling the futures contract.
futures trades to compute cash-and-carry (resp. reverse cash-and-carry) profits, even though the strategy consists of selling (resp. buying) the futures contract. This would increase both the frequency and the value of arbitrage opportunities. We thus apply the tick rule to infer the direction of futures trades. A transaction is classified as a buy (sell) if its price is above (below) the price of the preceding trade. If there is no price change, the transaction is classified according to the preceding tick change. Opening trades are unclassified. When more than 10 orders are executed within the same second, the actual trade sequence is unknown. We do not classify such observations and drop them from the final sample. Less than 4% of trades remain unclassified.

Transaction cost $C_{t,T,x}$ in Equation (2) is calculated as follows. Given that futures trade prices are inclusive of implicit trading costs, each futures trade is charged an explicit cost of only 0.01%. Concerning the cash market, it is reasonable to assume that, on average, a one-way CAC 40 basket trade costs a half bid–ask spread of 0.125% plus 2 basis points for explicit fees, for a total cost of 0.145%. Expected transaction costs to be supported at the liquidation of the arbitrage portfolio are estimated on the basis of the initial index value. For short arbitrages, we consider an additional short-selling cost on the cash leg, equal to 0.10% of the index value pro rata temporis. As a result, the total cost charged on an arbitrage strategy may be written:

$$C_{t,T,x} = f \times F_{t,T,x} + (k + 0.02\%) \times I_{t,x} \times \left(1 + e^{-r_{t}(T-t)}\right) + B_{sell} \times I_{t,x} \times 0.10\% \frac{(T-t)}{360} \,,$$

where $f=0.01\%$; $k=0.125\%$; and $B_{sell}$ equals 1 for reverse cash-and-carry trades, 0 otherwise.

---

7 As CAC 40 stocks’ bid–ask spreads are more volatile than futures spreads, we also consider two other levels of transaction costs: 0.10% and 0.15%, i.e., respectively 0.12% and 17% when including explicit costs. Results are qualitatively unchanged.
At each futures trade time, we compute arbitrage profit $\Pi_{t,T,\tau}$ (Equation 2) conditional to a total transaction cost of $C_{t,T,\tau}$ (Equation 3). Negative profits correspond to no-arbitrage prices and are set to zero. Arbitrage profits calculated in this way are stated as ex post because they represent the profitability of an arbitrage trade assuming that observed prices can instantaneously be executed at the observed price. In practice, $\Pi_{t,T,\tau}$ may differ from the actual profit that an arbitrage portfolio would provide because of execution delays. In order to assess the actual profit accessible to an arbitrageur whose trades are triggered by the observation of an ex post price deviation at time $\tau$, we simulate ex ante profits in the manner of Yadav and Pope (1994). An ex ante profit is the profit obtained from an arbitrage strategy executed at prices prevailing a few seconds after the observation of the mispricing signal, i.e., at time $\tau+\delta$. This ex ante simulated profit is positive provided that price deviations persist long enough before prices revert to no-arbitrage values; it is negative when prices revert to fair values before trade execution. We consider two values for lag $\delta$: one minute and two minutes. When no trade occurs in the market after the considered delay and before the close, the observation is omitted from the sample.

We then focus on the durations of ex post arbitrage opportunities. Observing a price deviation at time $\tau$ triggers arbitrage transactions that move prices until they revert to equilibrium or violate the no-arbitrage rule in the opposite direction at trade time $\tau^*$. The time elapsing between $\tau$ and $\tau^*$ is the duration of the arbitrage opportunity and is a measure of price adjustment speed. The shorter $\tau^* - \tau$, the more efficient the markets. Let us assume that a buy arbitrage profit $\Pi_{t,T,\tau}^{\text{buy}}$ is observed on day $t$ at time $\tau$. To determine the time at which the buy arbitrage opportunity vanishes, we seek the nearest following
trade time within day $t$ at which either the price deviation is null or a sell arbitrage profit appears. We follow the same reasoning to determine the durations of sell arbitrages. Profits observed at times between $\tau$ and $\tau^*$ are considered time-$\tau$ opportunity perpetuating and are not taken as new observations for the calculation of arbitrage durations. For this reason, the number of observed durations is much lower than that of sampled arbitrage profits. Finally, the finding of Taylor (2007) that arbitrage activity falls dramatically just before the close suggests that arbitrageurs do not wish to hold arbitrage positions overnight. This leads us not to compute the duration of arbitrage opportunities that do not vanish prior the end of the trading day.8

4.2. Changes in the frequency, magnitude, and persistence of mispricing after ETF introduction

Table 2 presents a complete view of the variation in mispricing frequency and level around the introduction of the Lyxor CAC 40 ETF.

Table 2 about here

Columns (1) and (2) report a highly significant decline in the ex post mispricing frequency consecutive to the introduction of ETFs. The proportion of observations deviating from the no-arbitrage relation falls from 0.58% in the pre-ETF to 0.21% in the after-period. The comparison of ex ante profits presented in columns (3) to (6) of Table 2 shows that the introduction of the ETF reduces arbitrage profit opportunities with respect to any statistic. The proportion of positive profits persisting after a 2-minute delay is divided by 10 after the inception of the ETF, with a decline from 52.63% to

8 While we do not compute durations in these cases, we keep these observations in the sample of arbitrage profits. The percentage of observations dropped from the duration sample is only 0.004%.
5.24%. Furthermore, mean and median profit values decline substantially to become negative in the post-ETF period for any execution lag and any category of arbitrage trades.\textsuperscript{9} Comparison of average and median values of arbitrage durations, reported in columns (7) and (8), confirms those results. The mean of arbitrage durations significantly declines from 15.65 seconds in the pre-ETF period to 4.94 seconds in the post-ETF period.

These findings are all supportive of improved spot-futures price efficiency, which is consistent with the findings of Park and Switzer (1995), Switzer et al. (2000), and Kurov and Lasser (2002) for the introduction of the Toronto 35, the S&P 500, and the NASDAQ 100 ETFs, respectively.

5. Does ETF trading directly or indirectly explain the improvement in spot-futures price efficiency?

In this section, we set out to identify the channel(s) by which the efficiency improvement observed after the introduction of the ETF is formed. Direct and indirect effects of ETF trading on index spot-futures mispricing are tested through regressions of daily aggregates as well as a multivariate vector autoregressive model estimated on intraday data.

\textsuperscript{9} Given that the level of an ex ante profit obviously depends on the value of the initial price deviation, which serves as an arbitrage signal, we also examine ex ante profit values relative to ex post profit values to provide a more accurate picture of the effective impact of ETF inception. We compare differential profits calculated as the ex ante profit minus the initial ex post profit. The results, unreported for the sake of brevity, are in the same direction and even more significant.
5.1. Regression analysis

Our multivariate analysis consists in regressing daily measures of arbitrage profits onto ETF-related variables after controlling for acknowledged determinants of arbitrage trading. The advantage of this procedure is two-fold. First, it allows us to check that the enhancement of joint spot-futures price efficiency measured at Section 4 is due to the inception of the ETF rather than to financial factors that ease or impede arbitrage trading, such as dividends, volatility, liquidity, or maturity.\(^\text{10}\) Second, including a measure of ETF trading in the regressions will provide a test for hypothesis H1.

The first measure of price deviation that we consider is \(\overline{\Pi}_t\), the equally weighted mean of ex post index-futures arbitrage profits measured on day \(t\) assuming no trading costs. We use two ETF-related independent variables: \(ETF_t\), which is a binary variable equal to 0(1) in the pre-ETF (post-ETF) period, and \(ETF\text{turn}_t\), which equals the ETF turnover – calculated as the number of ETF shares traded on date \(t\) in percentage of the number of outstanding shares – when \(t\) belongs to the post-ETF period and 0 otherwise.

On given day \(t\), control factors are measured as follows: volatility is measured as the price range of the futures contract taken in logarithm and is denoted \(F\sigma_t\); the dividend yield is denoted \(d_{t,T}\) and measured as discounted dividends paid by CAC 40 stocks from date \(t\) to futures maturity date \(T\) in percentage of the value of the index; \(F\text{mat}_t\) denotes the futures maturity in number of days taken in logarithm. Liquidity is assessed by two variables: \(CAC\text{turn}_t\), the CAC 40 turnover\(^\text{11}\) on day \(t\), and \(CAC\text{spr}_t\),

\(^{10}\) These factors were proved to explain arbitrage opportunities in futures markets by Switzer et al. (2000).

\(^{11}\) The CAC 40 turnover is the total euro trading volume in CAC 40 stocks reported to the CAC 40 index capitalization.
which denotes the cross-sectional capitalization-weighted mean of CAC 40 stocks’ duration-weighted average quoted bid–ask spreads on date $t$.

The liquidity of the underlying stocks is a factor of particular interest, because the introduction of ETFs is proven to influence the spreads of underlying stocks (Hegde and McDermott, 2004; De Winne et al. 2011). In preliminary regressions of $\Pi_t$ on control variables, the explanatory power of the spread variable appears to be unstable: its coefficient is not significantly different from 0 prior to ETF inception but becomes strongly significant thereafter. This leads us to model the daily average price deviation $\Pi_t$ as follows:

$$
\Pi_t = \gamma_0 + \gamma_1 F\sigma_t + \gamma_2 CAC\text{turn}_t + \gamma_3 F\text{mat}_t + \gamma_4 d_{t,T} + \gamma_5 ETF_t \times CAC\text{spr}_t + \gamma_6 ETF_t + \gamma_7 ETF\text{turn}_t + \eta_t, \\
\eta_t = \phi_1 \eta_{t-1} + \phi_2 \eta_{t-2} + v_t, \ E(v_t) = E(v_t v_{t-1}) = 0.
$$

A 2-order moving average model (MA(2)) model is applied to correct a significant degree of autocorrelation in the error terms.

The daily multivariate analysis is also conducted on daily average deviations after transaction costs calculated according to Equation (3). As the distribution of the average deviations net of trading costs is characterized by a substantial number of values equal to 0, the model is estimated with a censored Tobit methodology. The same independent variables as those of Model (4) are used.

Finding a significantly negative value for $\gamma_6$ in both the OLS regression of price deviations before trading costs and the Tobit regression of price deviations after trading costs would be a robustness check for the univariate tests of Section 4. Finding that $\gamma_7$
is significantly negative would support hypothesis H1 according to which futures price deviations decrease when the ETF is more actively traded.

The results of the regressions are displayed in Table 3. Volatility turns out to have no statistical significance for our sample. Concerning the effect of underlying stock turnover, opposite arguments can be put forward. On the one hand, it may be that the occurrence and magnitude of price deviations increase trading activity by inviting more arbitrage services. On the other hand, higher volumes, if initiated by arbitrageurs, may lead to a tighter spot-futures relation. Active trading would accelerate price reversion and make profits vanish more rapidly. We find a significantly positive coefficient for the CAC 40 turnover and validate the first explanation. Both regressions show that mispricing decreases when approaching the liquidation date, and increases with the payment of dividends by underlying stocks. While these relations have a high level of statistical significance in the MA(2) ordinary least square (OLS) regressions, they are insignificant in the Tobit analysis. Regarding the impact of index stock liquidity, the $\gamma_5$ coefficient is significantly positive in the OLS regression but significantly negative in the Tobit regression. On days when index stock bid-ask spreads are large, price deviations before transaction costs increase because trading costs discourage arbitrage trading (positive $\gamma_5$ in the OLS regression). Simultaneously, trading costs reduce net arbitrage profits as indicated by the negative sign of $\gamma_5$ in the Tobit regression.

**Table 3 about here**

Our main interest lies in the effects of ETF variables. The $\gamma_6$ coefficients are significantly negative at the 5% level in the two regressions, confirming that futures price efficiency improves in the post-ETF without it being driven by arbitrage trading
factors unrelated to the ETF. However, the $ETF_{turn_i}$ coefficients ($\gamma_\gamma$) do not significantly differ from zero in any of the MA(2) OLS or Tobit regressions, which provides no support for H1. The fact that the level of trading in the ETF does not add explanatory power beyond the period binary variable undermines the direct effect of the use of ETF securities in arbitrage strategies on joint price efficiency.

5.2. Vector autoregressive (VAR) analysis

In addition to the regression analysis of daily aggregates, we examined the causal links between joint spot-futures price efficiency, CAC 40 stock liquidity, and ETF trading activity, in a VAR analysis at the intraday level. This not only provides a more refined test of the direct effect of ETF trading but also provides tests for the indirect effect (H3a and H4). To conduct the VAR analysis, we divided the trading day into sixteen periods of 30 minutes from 9:15 to 17:15. For each 30-minute period, indexed by $h$, we calculated: (1) the average of ex post index-futures price deviations assuming no trading costs, denoted $\bar{\pi}_h$; (2) the duration-weighted average relative quoted spread of each component of the CAC 40 index and then the cross-sectional mean of these average spreads, denoted $cacspr_h$; and (3) the turnover of the ETF, denoted $etfurn_h$.

It is well acknowledged that trading volumes and spreads exhibit intraday patterns, and it is likely that spot-futures price deviations exhibit a similar phenomenon. Before performing vector autoregressions, we thus removed intraday seasonalties from the time series. We actually found that average bid–ask spreads of CAC 40 stocks ($cacspr_h$) were greater during the first four and the last 30-minute periods of the day, and that the ETF’s turnover ($etfurn_h$) was higher, on average, in the final 30-minute period. We
therefore adjusted the \( (cacspr_h) \) and the \( (etfturn_h) \) time series by regressing them on dummies as follows:

\[
cacspr_h = a_0 + a_1 I_1 + a_2 I_2 + a_3 I_3 + a_4 I_4 + a_{16} I_{16} + \epsilon_{h}^{cacspr} , \tag{5}
\]

\[
etfturn_h = b_0 + b_{16} I_{16} + \epsilon_{h}^{etfturn} . \tag{6}
\]

In Equations (5) and (6), variables \( I_k \) are binaries that equal 1 when the dependent variable is measured over the \( k^{th} \) 30-minute period of the day, 0 otherwise. \( \epsilon_{h}^{cacspr} \) and \( \epsilon_{h}^{etfturn} \) are residual terms from equations (5) and (6) representing the adjusted average spread and the adjusted ETF turnover, respectively.

Index-futures price deviations \( (\pi_h) \) were found to be greater in the first and last 30-minute periods of the day. In addition, we know from the previous section that price deviations are determined by CAC 40 stock turnover, futures contract maturity, and amounts of dividends paid by index stocks. Average deviations \( (\pi_h) \) were thus controlled for all these effects, as follows:

\[
\pi_h = c_0 + c_1 I_1 + c_{16} I_{16} + d_1 CACturn_h + d_2 Fmat_h + d_3 d_{h,T} + \pi_h , \tag{7}
\]

where:

- \( CACturn_h \) is CAC 40 turnover over 30-minute period \( h \);
- \( Fmat_h \) is futures maturity at period \( h \), in number of days and taken in logarithm;
- \( d_{h,T} \) is dividend yield measured as discounted dividends paid by CAC 40 stocks from the day of period \( h \) to futures maturity date \( T \) in percentage of the value of the index.
Subsequently, residuals from the adjustment regressions ($\varepsilon_h^\pi$, $\varepsilon_h^{cacspr}$, and $\varepsilon_h^{etfturn}$) were related in a trivariate VAR model over the post-ETF observation period:

$$
\begin{align*}
\varepsilon_h^\pi &= \delta_0 + \sum_{i=1}^{q^*} \delta_1^{i} \varepsilon_{h-i} + \sum_{i=1}^{q^*} \delta_2^{i} \varepsilon_{h-i}^{cacspr} + \sum_{i=1}^{q^*} \delta_3^{i} \varepsilon_{h-i}^{etfturn} + v_h^\pi \\
\varepsilon_h^{cacspr} &= \varphi_0 + \sum_{i=1}^{q^*} \varphi_1^{i} \varepsilon_{h-i} + \sum_{i=1}^{q^*} \varphi_2^{i} \varepsilon_{h-i}^{cacspr} + \sum_{i=1}^{q^*} \varphi_3^{i} \varepsilon_{h-i}^{etfturn} + v_h^{cacspr} \\
\varepsilon_h^{etfturn} &= \lambda_0 + \sum_{i=1}^{q^*} \lambda_1^{i} \varepsilon_{h-i} + \sum_{i=1}^{q^*} \lambda_2^{i} \varepsilon_{h-i}^{cacspr} + \sum_{i=1}^{q^*} \lambda_3^{i} \varepsilon_{h-i}^{etfturn} + v_h^{etfturn}.
\end{align*}
$$

(8)

The Akaike criterion was used to set $q^*$. $v_h^\pi$, $v_h^{cacspr}$, and $v_h^{etfturn}$ are error terms. For each pair of variables, the null hypothesis that variable $X$ Granger-causes variable $Y$ was tested by running a Wald test based on a chi-square statistic.

Testing the two-way Granger causality between ETF trading ($\varepsilon^{etfturn}$) and spot-futures price deviations ($\varepsilon^{\pi}$) consists in testing the null hypotheses that: (1) coefficients $\left(\delta_i^1\right)^*_{j}$ do not jointly differ from zero; and (2) coefficients $\left(\lambda_i^1\right)^*_{j}$ do not jointly differ from zero. Rejecting (1) and (2) would be in support of H2a and H2b respectively (i.e. the direct effect), provided that $\left(\lambda_i^1\right)^*_{j}$ are found to be significantly positive and that $\left(\delta_i^3\right)^*_{j}$ are found to be significantly negative. Positive values of $\left(\lambda_i^1\right)^*_{j}$ would indicate that an increase in price deviations invites ETF-based arbitrage trades and is followed by an increase in ETF volumes, while negative values of $\left(\delta_i^3\right)^*_{j}$ would indicate that ETF arbitrage trading contributes to reducing mispricing and is followed by a decrease in price deviations.

The indirect effect of ETF trading at the intraday horizon relies on the existence of a two-way causality between liquidity and efficiency (H3a and H3b). Evidence for this
causality would come from finding a Granger causality between $\epsilon^{cacspr}$ and $\epsilon^\pi$ with positive values for $\left(\phi^*_1\right)_i$ and $\left(\delta^*_2\right)_i$. The null hypothesis (3) that $\epsilon^{etfturn}$ does not Granger-cause $\epsilon^{cacspr}$ combined with the null hypothesis (4) that $\epsilon^{cacspr}$ does not Granger-cause $\epsilon^\pi$ then provides a test for the indirect effect of ETF trading. Rejecting (3) with significantly positive values of $\left(\phi^*_1\right)_i$ and rejecting (4) with significantly positive values of $\left(\delta^*_2\right)_i$ would support H3a and H4 respectively.

**Table 4 about here**

We report the estimated coefficients of Model (8) until the third lag of each exogenous variable, the total number of lags used to estimate the model, and pairwise Granger causality tests in Table 4. According to these estimates and statistics, we did not reject the null hypothesis that price deviations did not Granger-cause the trading activity in the ETF. In other words we failed to prove that an increase in spot-futures mispricing invited ETF trading (rejection of H2a). With respect to the opposite causal link, ETF turnover was found to Granger-cause index-futures price deviations at the 5%-threshold according to the Chi-square statistic. However, coefficients $\delta^3_i$ have signs opposite to what H2b predicts: instead of tightening the spot-futures price relation, ETF trading volumes were followed by increasing price deviations on the sample period. We thus rule out the direct effect of ETF trading.

As for indirect effects, we found evidence for a two-way causal relation between liquidity and price efficiency. A liquidity deterioration over a given 30-minute period significantly caused an efficiency deterioration in the next 30-minute period, with $\delta^2_i$ being significantly positive at the 1% level. The reverse effect of efficiency onto
liquidity was also significant but mixed in directions: an increase in futures price deviations produced tensions on CAC 40 stocks spreads in the next 30-minute period – \( \phi_1^{1} \) being positive with a 5% significance – but was followed by a reduction in stock CAC 40 spreads two 30-minute periods later – \( \phi_2^{1} \) being negative with a 5% significance. This partially supports H3b. Regarding the short-term impact of ETF trading on index stock liquidity, null hypothesis (4) was rejected based on a Wald test significant at the 1% threshold and ETF turnover was found to Granger-cause CAC 40 stock spreads, yet not in the way expected according to H4. The coefficients of the lagged ETF turnover variables appeared to be positive with a strong statistical significance at the third lag (\( \phi_3^{3} \)) and a 10%-level significance at the first lag (\( \phi_1^{3} \)). This led us to also reject the hypothesis that ETF trading has an indirect effect on efficiency by enhancing index stock liquidity at the intraday horizon.\(^{12}\)

6. Interpreting the tightening of the index spot-futures price relation after ETF introduction

In the absence of direct and indirect effects of ETF trading onto index-futures price efficiency at the intraday horizon, how can we then explain the price efficiency improvement observed just after the ETF market has become significantly active? It appears from the statistics displayed in Table 4 that there exists a causal relation between CAC 40 stock spreads and the Lyxor CAC 40 turnover according to which a deterioration of spreads in a given 30-minute period results into an increase in ETF turnover.\(^{12}\)

\(^{12}\) As a robustness check, we conducted the same VAR analysis with 15-minute periods. Results, available upon request, remain qualitatively unchanged.
trading volumes in the next 30-minute period. This suggests that the ETF market could play the role of a second resort market when CAC 40 stocks are less liquid. In addition, the lack of any direct effect of ETF trading on futures price efficiency indicates that the traders who divert their orders to the ETF market are probably not arbitrageurs in their majority but rather hedgers or liquidity traders. Assuming that hedgers and liquidity traders prefer to trade the index in the ETF market when spreads enlarge in the CAC 40 stock markets but that most arbitrageurs remain in the individual stock markets for technical constraints, times of higher volumes in the ETF market should correspond to greater proportions of arbitrageurs – relatively to other categories of traders – in the stock and futures markets. As arbitrage trading is particularly sensitive to trading costs, the greater proportion of arbitrageurs in the stock and futures markets may then result in a tighter causality between spreads and spot-futures price deviations.

To check this hypothesis we divided the post-ETF observation period into two sub-samples of dates: the days on which the total ETF trading volume was higher than the median value of ETF daily trading volumes over the period, and the days on which the ETF trading volume was below the median level. We estimated VAR model (8) on each sub-sample. Results are displayed in Table 5.

Comparing Panel A and Panel B of Table 5 shows that the causal links between liquidity, price efficiency, and ETF trading change dramatically between days of low ETF trading activity (Panel A) and days of high ETF trading activity (Panel B). Panel B

13 One of these constraints could be the low frequency of trading in the ETF market. While long-term position hedgers and long-term liquidity traders care more about immediacy and market depth, arbitrageurs are mainly concerned by execution speed, which is undoubtedly higher in the stock market than in the ETF market (cf. last panel of Table 1).
estimates corresponding to heavy trading in the ETF are similar to those obtained for the whole sample (Table 4), while Panel A estimates differ in several ways. All the causal links involving the ETF turnover that were significant for the whole sample turn out to be insignificant in times of light ETF trading. More unexpectedly, the two-way causality between index stock spreads and price deviations is also modified. It weakens substantially on days when the ETF turnover is low. Price deviations do not Granger-cause spreads any more. Only the opposite-way causality of spreads onto mispricing remains significant; yet the causal impact of spreads on price deviations takes longer to realize: with low ETF trading, the causality is related to the third-lag of spreads while with high ETF trading it is related to the first-lag.

We consider that those differences reflect long-term indirect effects of the creation of the ETF market which cannot be captured at the intraday level. We conjecture that under some market conditions, some group of index traders, most probably those with long-term trading horizon as long-term position hedgers or long-term liquidity traders, shift to the ETF market, leaving other markets with a greater proportion of arbitrageurs. This results in strengthening the dual causality between liquidity and price efficiency and in dampening the liquidity tensions in the stock and futures markets that would be unfavorable to arbitrage and thus price efficiency otherwise. All in all, mispricing is reduced on average.

7. Conclusion

Using high-frequency index, futures, and ETF data over two five-month periods surrounding the introduction of the first ETF tracking the CAC 40 index, we find a significant improvement of the no-arbitrage pricing relation in the post-ETF period.
This finding is consistent with those of Switzer, Varson and Zghidi (2000) and Kurov and Lasser (2002). However, in contrast with Kurov and Lasser (2002), we do not attribute the observed improvement to the increased ease in establishing the cash position in cash-futures arbitrage trades by using ETF shares.

First, in a multivariate analysis that controls for financial factors known to impact the spot-futures price relation, index-futures mispricing was found to decrease following ETF introduction, but ETF trading did not explain this improvement. Second, our VAR analysis shows that index-futures mispricing did not invite ETF trading and that ETF trading did not contribute to reducing index-futures mispricing. Although those two findings do not rule out the use of ETF securities in arbitrage strategies, they fail to support that the efficiency improvement mainly stems from the direct effect of ETF trading. Furthermore, although our VAR analysis provides evidence of a two-way causality between CAC 40 stock liquidity and CAC 40 futures price deviation, it shows that the efficiency improvement following ETF introduction cannot be assigned to an indirect effect of ETF trades improving the liquidity of the underlying index stocks at the intraday level.

Some complementary empirical work suggests that the post-ETF efficiency improvement may rather have arisen from a long-run indirect effect of the creation of the ETF market caused by a structural change in the way index traders distribute across markets. The ETF market is likely to provide a second resort trading venue to some specific categories of traders such as long-term position hedgers or liquidity traders, and this may leave other index markets with a greater proportion of arbitrageurs.
References

Blitz, D., Huij, J. and Swinkels, L., “On the performance of European index funds and ETFs,” *European Financial Management*, forthcoming, 2010.

Chung, P. Y., “A transactions data test of stock index futures market efficiency and index arbitrage profitability,” *Journal of Finance*, Vol. 46, 1991, pp. 1791-1809.

Deville, L., “Coûts de transaction et efficience des marchés d’options : Tests empiriques sur le marché français,” PhD dissertation, Université Louis Pasteur Strasbourg 1, 2002.

Deville, L. and Riva, F., “The determinants of the time to efficiency in options markets: A survival analysis approach,” *Review of Finance*, Vol. 11, 2007, pp. 497-525.

De Winne, R., Gresse, C. and Platten, I., “Liquidity and risk sharing benefits from the introduction of an ETF” working paper, Université Catholique de Louvain and Université Paris-Dauphine, 2011.

Hegde, P. H. and McDermott, J. B., “The market liquidity of DIAMONDS, Q’s and their underlying stocks,” *Journal of Banking and Finance*, Vol. 28, 2004, pp. 1043-1067.

Kavussanos, M. G., Visvikis, I. D. and Alexakis, P. D., “The lead-lag relationship between cash and stock index futures in a new market,” *European Financial Management*, Vol. 14, 2008, pp. 1007-1025.

Kempf, A., “The relation between spot and futures prices: The impact of the early unwind option,” *European Financial Management*, Vol. 2, 1996, pp. 367-368.
Kurov, A. A. and Lasser, D. J., “The effect of the introduction of Cubes on the Nasdaq-100 Index spot-futures pricing relationship,” *Journal of Futures Markets*, Vol. 22, 2002, pp. 197-218.

Madura, J. and Richie, N., “Impact of the QQQ on liquidity and risk of the underlying stocks,” *Quarterly Review of Economics and Finance*, Vol. 47, 2007, pp. 411-421.

Miller, M. H., Muthuswamy, J. and Whaley R. E., “Mean reversion of S&P 500 Index basis changes: Arbitrage induced or statistical illusion?” *Journal of Finance*, Vol. 49, 1994, pp. 479-513.

Neal, R., 1996, “Direct tests of index arbitrage models,” *Journal of Financial and Quantitative Analysis*, Vol. 31, pp. 541-562.

Park, T. H. and Switzer, L. N., “Index participation units and the performance of index futures markets: Evidence from the Toronto 35 index participation units market,” *Journal of Futures Markets*, Vol. 15, 1995, pp. 187-200.

Parkinson, M., “The extreme value method for estimating the variance of the rate of return,” *Journal of Business*, Vol. 53, 1980, pp. 61-65.

Roll, R., Schwartz, E. and Subrahmanyam, A., “Liquidity and the law of one price: The case of the futures-cash basis,” *Journal of Finance*, Vol. 62, 2008, pp. 2201-2234.

Shyy, G., Vijayraghavan, V. and Scott-Quinn, B., “A further investigation of the lead-lag relations between the cash market and stock index futures market with the use of bid–ask quotes: The case of France,” *Journal of Futures Markets*, Vol. 16, 1996, pp. 405-420.
Stoll, H. R. and Whaley, R. E., “The dynamics of stock index and stock index futures returns,” *Journal of Financial and Quantitative Analysis*, Vol. 25, 1990, pp. 441-468.

Subrahmanyam, A., “A theory of trading in stock index futures,” *Review of Financial Studies*, Vol. 4, 1991, pp. 17-51.

Switzer, L. N., Varson, P. L. and Zghidi, S., “Standard and Poor’s depository receipts and the performance of the S&P 500 Index futures market,” *Journal of Futures Markets*, Vol. 20, 2000, pp. 705-716.

Taylor, N., “A new econometric model of index arbitrage,” *European Financial Management,* Vol. 13, 2007, pp. 159-183.

Tse, Y., “Index arbitrage with heterogeneous investors: A smooth transition error correction analysis,” *Journal of Banking and Finance*, Vol. 25, 2001, pp. 1829-1855.

Yadav, P. K. and Pope, P. F., “Stock index futures mispricing: Profit opportunities or risk premia?” *Journal of Banking and Finance*, Vol. 18, 1994, pp. 921-953.
## Table 1. Spot and futures market trading activity around ETF introduction

|                                             | Pre-ETF period | Post-ETF period |
|---------------------------------------------|----------------|-----------------|
| **CAC 40 futures trading activity**         |                |                 |
| Average daily number of trades              | Nearby maturity| 7,496           | 9,232           |
|                                             | Other maturities| 553             | 540             |
|                                             | All maturities  | 8,048           | 9,772           |
| Average daily traded volume in number of contracts | Nearby maturity| 47,997          | 62,235          |
|                                             | Other maturities| 15,085          | 20,635          |
|                                             | All maturities  | 63,082          | 82,870          |
| **Trading activity in the CAC 40 stock basket** |                |                 |
| Average daily total trading volume (in €)    | 3,453,833,669  | 3,459,218,045   |
| Average daily total number of trades         | 91,596         | 94,591          |
| Average daily best limit bid–ask spread (in %)| 0.1892         | 0.1599          |
| Average daily CAC 40-index volatility (in %) | 1.1571         | 1.2575          |
| **Trading activity in the Lyxor CAC 40**     |                |                 |
| Average daily traded volume (in €)           | Mean           | ---             | 36,599,007      |
|                                             | Rank against CAC| ---             | 28 upon 43      |
|                                             | 40 stocks       | ---             | last            |
| Average daily number of trades               | Mean           | ---             | 231             |
|                                             | Rank against CAC| ---             | last            |
|                                             | 40 stocks       | ---             | first           |
| Average trade size (in €)                    | Mean           | ---             | 158,341         |
|                                             | Rank against CAC| ---             | first           |
|                                             | 40 stocks       | ---             |                 |

The first panel of this table reports the average number of trades and the average number of traded contracts per day for the near, far, and all-maturity contracts over the two sample periods. The second panel displays, for the two periods, the average daily euro trading volume in CAC 40 stocks, the corresponding average daily number of trades, the average bid–ask spread computed as the daily mean of the capitalization-weighted average of duration-weighted individual stocks’ bid–ask spreads and the daily mean of the CAC 40 index volatility calculated with intraday values according to Parkinson (1980). The third panel compares trading volumes of the Lyxor CAC 40 security with those of CAC 40 stocks during 2001, on the basis of daily traded volumes in €, daily number of trades and trade sizes in €. It provides the daily average for the Lyxor CAC 40 and the rank of the Lyxor CAC 40 when ordered against CAC 40 securities.
Table 2. Comparing price deviations and arbitrage profits around ETF introduction

| Calculations based on | CAC 40 index-futures price deviations (in %) | CAC 40 index-futures arbitrages (in %) | Duration of arbitrage opportunities (in seconds) |
|-----------------------|---------------------------------------------|---------------------------------------|-----------------------------------------------|
|                       | Signed futures trades                        | Signed futures trades                 | Signed futures trades                          |
|                       | (1)                                         | (2)                                  | (3)                                           |
| Delay before arbitrage | ex post                                     | ex post                              | 1 min                                          |
| Sample period          | pre-ETF                                     | post-ETF                             | 1 min                                          |
|                       |                                              |                                      | 1 min                                          |
|                       |                                              |                                      | 2 min                                          |
|                       |                                              |                                      | 2 min                                          |
| Frequency statistics   |                                             |                                      | ex post                                        |
| Number of pairings     | 846,968                                     | 1,144,025                            | pre-ETF                                        |
| Number of deviations   | 4,941                                       | 2,394                                | post-ETF                                       |
| Frequency of deviations (in %) | 0.58                                        | 0.21                                 | 4,493                                          |
| Z-statistic            | ---                                         | -40.17                               | 1,863                                          |
| Average value statistics |                                           |                                      | 4,482                                          |
| Mean                   | 0.041                                       | 0.163                                | 1,775                                          |
| Student statistic      | ---                                         | 16.95                                | 2,609                                          |
| Median                 | 0.033                                       | 0.069                                | 4,482                                          |
| Mann-Whitney statistic | ---                                         | 15.65                                | 58.07                                          |
|                        | ---                                         | 4.94                                 | 8.48                                           |
|                        | ---                                         | ---                                  | 52.63                                          |
|                        | ---                                         | ---                                  | 5.24                                           |
|                        | ---                                         | ---                                  | ---                                            |
|                        | ---                                         | ---                                  | -51.84                                         |

This table presents the frequencies (upper panel) and average levels (lower panel) of deviations from the no-arbitrage price relation for the nearby CAC 40 index-futures contract around Lyxor CAC 40 introduction. For all columns but (7) and (8), it displays the number of observations, the number and percentage of deviations and the mean and median mispricing value in percentage of the index value. Observations considered in columns (1) and (2) are ex post deviations for which prices revert to no-arbitrage values before the market close. Mean and median deviation values displayed in columns (7) and (8) are those of arbitrage durations reported in seconds. Odd columns correspond to the pre-ETF period, while even columns correspond to the post-ETF period. Pre/post ETF difference statistics are reported in even columns. Ex post results in columns (1) and (2) are based on signed futures trades matched with the contemporaneous index value; ex ante results in columns (3) to (6) for arbitrage strategies triggered by the observation of a cash-futures mispricing (ex post signal) are computed on the basis of signed futures trades matched with contemporaneous index values; duration results in columns (7) and (8) are based on signed futures trades matched with contemporaneous index values. Z-statistics test the significance of the differences in frequency. Student (Mann-Whitney) statistics test the significance of differences in average (median) mispricing. Differences in frequency, mean, and median values are all significant at the 1% level.
Table 3. Regressions of average ex post price deviations
30 July – 31 December

| Dependent variable | Daily average ex post deviation before transaction costs | Daily average ex post deviation net of transaction costs |
|--------------------|--------------------------------------------------------|--------------------------------------------------------|
| **Methodology**    | **MA(2) OLS regressions**                             | **Censored Tobit regressions**                          |
| Intercept          | 0.015786**                                            | -0.003658***                                           |
|                    | (0.0129)                                               | (0.0015)                                               |
| $\sigma_t$         | 0.000975                                               | 0.001063                                               |
|                    | (0.6343)                                               | (0.1563)                                               |
| CACturn$_t$        | 0.017727*                                              | 0.001103                                               |
|                    | (0.0627)                                               | (0.7013)                                               |
| $F_{\text{mat}}_t$| 0.003702***                                            | 0.000197                                               |
|                    | (0.0022)                                               | (0.5086)                                               |
| $d_{t,T}$          | 1.271627***                                            | 0.440659***                                            |
|                    | (0.0082)                                               | (<0.0001)                                              |
| ETF$_t$            | -0.03082***                                            | -0.009161***                                           |
|                    | (0.0044)                                               | (<0.0001)                                              |
| $ETF_t \times CACspr_t$ | 0.11976**                                                 | -0.052495***                                           |
|                    | (0.0136)                                               | (<0.0001)                                              |
| ETFturn$_t$        | -0.0155                                                | -0.007558                                              |
|                    | (0.6158)                                               | (0.1994)                                               |
| $\eta_{t-1}$       | 0.747529***                                            | (<0.0001)                                              |
|                    | (0.1531)                                               |                                                         |
| $\eta_{t-2}$       | 0.105117**                                             |                                                         |

No. of observations 203                         203
Adjusted R² 75.18%                             -297.72
AIC 75.18%                                    -267.99
Schwarz criterion -267.99

This table displays the estimates for regressions of daily average ex post index-futures arbitrage profits calculated upon signed futures trade prices for the nearby maturity. An MA(2) is used to model ex post price deviations before transaction costs. Censored Tobit regressions are implemented to analyze ex post price deviations net of transaction costs. $\sigma_t$ is the price range of the futures contract over day $t$, taken in logarithm. CACturn$_t$ is the trading volume on CAC 40 stocks on day $t$ in percentage of their market value. CACspr$_t$ is the cross-sectional capitalization-weighted mean of CAC 40 stocks’ duration-weighted average quoted bid–ask spreads at date $t$. $F_{\text{mat}}_t$ denotes the futures maturity in number of days taken in logarithm. The dividend yield $d_{t,T}$ is measured as the discounted dividends paid by the underlying stocks from date $t$ to the futures maturity $T$ in percentage of the value of the index. $ETF_t$ equals 0 before the ETF inception date and 1 thereafter. ETFturn$_t$ is ETF turnover on date $t$. $\eta_{t-1}$ and $\eta_{t-2}$ are the lagged variables in the MA(2). ***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. $p$-values are given between brackets.
Table 4. Trivariate VAR analysis in the post-ETF period

|                | $\varepsilon^\pi_{h-1}$ | $\varepsilon^\pi_{h-2}$ | $\varepsilon^\pi_{h-3}$ | $\varepsilon^{\text{cacspr}}_{h-1}$ | $\varepsilon^{\text{cacspr}}_{h-2}$ | $\varepsilon^{\text{cacspr}}_{h-3}$ | $\varepsilon^{\text{etfturn}}_{h-1}$ | $\varepsilon^{\text{etfturn}}_{h-2}$ | $\varepsilon^{\text{etfturn}}_{h-3}$ |
|----------------|--------------------------|--------------------------|--------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| $\varepsilon^\pi_{h}$ Estimate | 0.2912*** | 0.0737*** | 0.0062 | 0.0343*** | 0.0111 | 0.0127 | 0.0391** | 0.0363** | 0.0148 |
| $\varepsilon^\pi_{h}$ p-value | 0.0001 | 0.0069 | 0.8201 | 0.0004 | 0.3081 | 0.2424 | 0.0336 | 0.0487 | 0.4221 |
| Wald test | | | | | | | | | |
| Chi^2 stat. | | | | | | | | | |
| p-value | | | | | | | | | |
| $\varepsilon_{h}^{\text{cacspr}}$ Estimate | 0.1432** | -0.1724** | 0.0227 | 0.5263*** | 0.1230*** | 0.1387*** | 0.0921* | 0.0057 | 0.1515*** |
| $\varepsilon_{h}^{\text{cacspr}}$ p-value | 0.0420 | 0.0184 | 0.7574 | 0.0001 | 0.0001 | 0.0001 | 0.0620 | 0.9077 | 0.0022 |
| Wald test | | | | | | | | | |
| Chi^2 stat. | | | | | | | | | |
| p-value | | | | | | | | | |
| $\varepsilon_{h}^{\text{etfturn}}$ Estimate | -0.0213 | -0.0402 | 0.0340 | 0.0303** | 0.0085 | 0.0085 | 0.0283 | 0.0225 | 0.0728*** |
| $\varepsilon_{h}^{\text{etfturn}}$ p-value | 0.5580 | 0.2868 | 0.3707 | 0.0245 | 0.5729 | 0.5718 | 0.2661 | 0.3777 | 0.0043 |
| Wald test | | | | | | | | | |
| Chi^2 stat. | | | | | | | | | |
| p-value | | | | | | | | | |

This table presents estimates for the trivariate causal model that test causality links between joint cash-futures price efficiency, CAC 40 stock liquidity, and ETF trading activity. $\varepsilon^\pi_{h}$, $\varepsilon_{h}^{\text{cacspr}}$, and $\varepsilon_{h}^{\text{etfturn}}$ are, respectively, average index stock bid–ask spread, ETF turnover, and average index-futures price deviation calculated over 30-minute period $h$ and adjusted for time-of-day effects. The table displays the estimated coefficients of the model until the third lag of each exogenous variable, the number of lags used to estimate the model determined according to the Akaike information criterion, the number of observations, and pairwise Granger causality tests. The null hypothesis that variable $X$ Granger-causes variable $Y$ is tested by running a Wald test based on a chi-square statistic. Chi-square statistics and associated $p$-values are reported. ***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.
Table 5. Trivariate VAR analysis in the post-ETF period: low-trading-volume days vs. high-trading-volume days

| Panel A - Low ETF-volume days | $\varepsilon_{h-1}$ | $\varepsilon_{h-2}$ | $\varepsilon_{h-3}$ | $\varepsilon_{cacspr\ h-1}$ | $\varepsilon_{cacspr\ h-2}$ | $\varepsilon_{cacspr\ h-3}$ | $\varepsilon_{etfturn\ h-1}$ | $\varepsilon_{etfturn\ h-2}$ | $\varepsilon_{etfturn\ h-3}$ |
|------------------------------|----------------------|----------------------|----------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| $\varepsilon_{h}$            | Estimate             | 0.3287***            | 0.0559               | 0.0348                      | 0.0101                     | 0.0037                     | 0.0277**                    | -0.0457                     | 0.0220                     | -0.0472                     |
|                              | p-value              | 0.0001               | 0.1413               | 0.3363                      | 0.4337                     | 0.7936                     | 0.0313                      | 0.2053                     | 0.5418                     | 0.1900                     |
| Wald test                    | Chi² stat.           | 19.63***             | 0.0002               |                            |                            |                            |                            |                            |                            |
|                              | p-value              |                      |                      |                            |                            |                            |                            |                            |                            |
| $\varepsilon_{cacspr\ h}$   | Estimate             | 0.1120               | -0.0672              | -0.0013                     | 0.5202                     | 0.1748                     | 0.1509                      | -0.1039                     | 0.0609                     | 0.0345                     |
|                              | p-value              | 0.2665               | 0.5257               | 0.9894                      | 0.0001                     | 0.0001                     | 0.0001                      | 0.3010                     | 0.5437                     | 0.7306                     |
| Wald test                    | Chi² stat.           | 1.52                 | 0.6766               |                            |                            |                            |                            |                            |                            |
|                              | p-value              |                      |                      |                            |                            |                            |                            |                            |                            |
| $\varepsilon_{etfturn\ h}$  | Estimate             | 0.0387               | -0.0489              | -0.0191                     | 0.0154                     | -0.0116                    | 0.0062                      | -0.0629*                    | -0.0728**                   | -0.0180                    |
|                              | p-value              | 0.2832               | 0.1972               | 0.5960                      | 0.2295                     | 0.4177                     | 0.6309                      | 0.0802                     | 0.0429                     | 0.6154                     |
| Wald test                    | Chi² stat.           | 3.07                 | 0.3817               |                            |                            |                            |                            |                            |                            |
|                              | p-value              |                      |                      |                            |                            |                            |                            |                            |                            |

No. of lags: 3
No. of obs: 795
This table presents estimates for the trivariate causal model that test causality links between joint cash-futures price efficiency, CAC 40 stock liquidity, and ETF trading activity, for two sub-samples. Panel A presents the estimates for the sub-sample of days when the ETF trading is below its median level while Panel B presents those obtained for the sub-sample of days when the ETF trading volume exceeds the median. $\varepsilon_{\pi h}$, $\varepsilon_{\text{cacspr} h}$, and $\varepsilon_{\text{etfturn} h}$ are, respectively, average index stock bid–ask spread, ETF turnover, and average index-futures price deviation calculated over 30-minute period $h$ and adjusted for time-of-day effects. The table displays the estimated coefficients of the model until the third lag of each exogenous variable, the number of lags used to estimate the model determined according to the Akaike information criterion, the number of observations, and pairwise Granger causality tests. The null hypothesis that variable $X$ Granger-causes variable $Y$ is tested by running a Wald test based on a chi-square statistic. Chi-square statistics and associated $p$-values are reported. ***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.