# Direct and Indirect Effects of Index ETFs on Spot-Futures Mispricing and Illiquidity♣

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## Abstract

Our article investigates how the introduction of an index security directly and indirectly impacts the links between the underlying-index spot-futures mispricing. Using intraday data for financial instruments related to the CAC 40 index, we show that the efficiency improvement consequent to the inception of the Lyxor CAC 40 Exchange-Traded Fund (ETF) is not a direct effect of arbitrage trading using the ETF as the cash asset, as argued in previous literature. Indeed, ETF trading does not Granger-cause futures price reversion. However, there is a strong causal relation between index-futures mispricing and illiquidity in the underlying stocks after the introduction of the ETF, suggesting that the ETF introduction indirectly improves spot-future price linkage by enhancing the liquidity of the underlying stocks.

## 1. Introduction

Illiquidity has long been recognized as an obstacle to the convergence of market prices toward no-arbitrage values. According to the well-known cost-of-carry model, the no-arbitrage value of a futures contract equals the price of the underlying asset in the cash market, plus the cost of a risk-free loan contracted to buy and hold the asset until the futures maturity date, minus any coupon paid by the asset up to that date. Any futures market price that deviates from this value invites arbitrage trading. In practice, transaction costs and illiquidity in any of the cash or futures markets may discourage arbitrage activity and cause 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 coined by Roll, Schwartz, and Subrahmanyam (2007). Indeed, the link between cash-derivative joint price efficiency and liquidity is often thought of as a two-way causal relation, and the introduction of a new cash market for the underlying asset may well modify this relation, as evidenced by Deville and Riva (2007).

Our analysis addresses this issue in the case of a stock index, on which a futures contract is traded, and for which an Exchange-Traded Fund (ETF) is created. An ETF is an exchange-traded security that accurately replicates the index of consideration. Its inception thus offers a new cash market for index traders. Our study uses high frequency data to understand how the introduction of the index security (1) changes the structural magnitude of the index cash-futures basis and, more importantly, (2) impacts the efficiency-liquidity two-way relation governing cash and futures prices. Our findings link the literatures examining the spot-futures relations and the ETF-constituent relations by carefully examining the channel by which ETFs affect the underlying-futures price linkages.

Empirical tests on the index spot-futures relation[1] commonly agree that significant deviations from the no-arbitrage pricing rule with potential profits for arbitrageurs exist in index futures markets, even once transaction costs are accounted for (e.g., Modest and Sundaresan, 1983; Figlewski, 1984; MacKinlay and Ramaswamy, 1988; Yadav and Pope, 1994). Whether observed deviations are actual arbitrage opportunities or merely the result of market imperfections, such as delayed incorporation of new information into prices, noise trading, liquidity risk,[2] institutional constraints, etc. is still an open question. Indeed, arbitrageurs do not trade unless the difference between the theoretical futures price and the market futures price is larger than the transaction costs and risk incurred to implement arbitrage strategies. Chung (1991), Klemkosky and Lee (1991), and Miller, Muthuswamy, and Whaley (1994) argue that futures price deviations are more probably the reflection of transactions 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. Garrett and Taylor (2001), Tse (2000), and Alphonse (2007) show that arbitrage trading in futures markets drives, at least partially, price reversion toward theoretical values. Roll et al. (2007) also show that illiquidity 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.

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[1] For an extensive review on stock index futures studies, see Sutcliffe (1997).

Among the market frictions that impede index cash-futures arbitrage execution, the major obstacle to arbitrageurs is index-tracking risk. Implicit transaction costs, non-synchronicity, and price risk due to intra-day volatility when trading the stock basket are some factors that may considerably reduce arbitrage profits. The introduction of index-tracking securities such as ETFs is likely to mitigate those frictions in several respects. First, when trading an ETF, non-synchronicity is totally avoided. Second, implicit trading costs are generally reduced. De Winne, Gresse, and Platten (2009) 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. Further, as evidenced by Hegde and McDermott (2004) and Madura and Richie (2007) for the Diamonds and the QQQ funds, respectively, index stock spreads decrease after ETF introduction. For all those reasons, index derivative price efficiency may be expected to improve when an ETF replicating the index is introduced. Ackert and Tian (1998), Deville (2005), and Deville and Riva (2007) showed that ETF introduction significantly improved the joint efficiency of spot and option prices. Park and Switzer (1995), Switzer, Varson, and Zghidi (2000), and Kurov and Lasser (2002) found a tightening of the cash-futures price relation after ETF inception in the case of the Toronto 35, the S&P 500, and the NASDAQ 100 indices, respectively. Kurov and Lasser (2002) not only documented lower price deviations but also faster market reactions to observed deviations in the post-ETF period.

The main argument put forward to explain those findings in past research is that ETF securities provide the direct channel by which the spot-futures linkage becomes

[2] There is a risk of adverse price movements between the detection of an opportunity by arbitrageurs and the moment when their arbitrage portfolios are actually established.

tighter because ETFs are used to build arbitrage portfolios. This argument will thus be called the *ETF-arbitrage-trading argument* in the remainder of the article. Arbitrageurs would use index-tracking securities to establish the cash leg in arbitrage portfolios when trading the stock basket is too costly or risky. In particular, it is often argued that an ETF is easier to short-sell than its underlying basket of stocks, and that ETF shares would be particularly useful in reverse cash-and-carry arbitrage trades. The introduction of ETFs would therefore result in increased arbitrage activity and tighten the spot-futures price relation. This hypothesis based on the ETF-arbitrage-trading argument is commonly referred to as the *arbitrage hypothesis* in the literature and implies the following testable hypotheses: (a) index cash-futures price deviations should be lower in level and in frequency after ETF inception, even when determinants of futures mispricing are controlled for; (b) this effect should be greater for price deviations generating short arbitrage opportunities; (c) the ETF-futures price relation should be as tight as that linking the index and the futures contract; (d) there should be a two-way causality between index-futures mispricing and ETF trading.

An alternative to the *arbitrage hypothesis* is that the introduction of an ETF improves liquidity in the underlying stocks and that ETF trading may be used for both hedging and arbitrage. If hedging demands in the ETFs is sufficiently large, it could overwhelm the arbitrage trading in the ETFs attenuating evidence of (b)-(d). However, the introduction of an ETF could indirectly improve the linkage between the spot and futures prices by improving liquidity in the underlying stocks.

Using high frequency index, futures, and ETF data over two years surrounding the inception date of the first ETF replicating the CAC 40 index, we find evidence in support of (a) as other researchers, but we do not find support for (b), (c), and (d). Our lack of support for (c) is consistent with Roll et al. (2007) on their finding relative to ETF Spider. They show that the causality between the S&P 500 futures basis and liquidity weakens when the Spider rather than the index is used as the cash instrument in the computation of the basis. Failing to find support for (b), (c), and (d) undermines the direct ETF-arbitrage-trading argument. Our study shows that ETF trading does not sufficiently explain the cash-futures basis decline after the ETF inception, but that this decline is also related to indirect liquidity effects. By examining Granger causality between stock liquidity, futures mispricing, and ETF trading volumes, we find that ETF trading does not cause futures price reversion but that a strong two-way causality between futures price efficiency and index stock liquidity appears after the introduction of the ETF.

The remainder of the article is organized as follows. Section 2 describes our institutional framework and the data. The calculation of deviations from no-arbitrage prices and other related variables are detailed in Section 3. Section 4 compares mispricing values and arbitrage profits in the pre- and post-ETF periods. Section 5 provides a multivariate analysis which aims to determine whether trading in the ETF explains the results obtained in Section 4. Section 6 investigates causality links between futures mispricing, index stock liquidity, and ETF trading, and examines how the efficiency-liquidity two-way causality changes with the ETF creation. Section 7 concludes.

## 2. Institutional framework and data

ETFs are investment funds designed to replicate an index or, more generally, a specified benchmark. Those funds are open ended in the sense that their shares may be created and redeemed, at any time, in very large blocks at a price equal to their net asset value (NAV). The number of ETFs has exploded since their first introduction in US equity markets in the nineties. Their popularity is assignable to the ease with which they allow any category of investors to obtain portfolio diversification benefits at low trading costs. Their relatively low price per share gives the opportunity to small investors to take positions in an entire index.

They emerged in Europe in 2000 when the Frankfort and the London stock exchanges opened their ETF segments, and their number has considerably increased ever since. Euronext Paris, the French subsidiary of Nyse-Euronext, opened an ETF-dedicated segment, called NextTrack, in 2001. One of the first ETFs to be launched on NextTrack is the Lyxor CAC 40, which replicates the CAC 40 index. When the Lyxor CAC 40 security started trading, on 22 January 2001, the CAC 40 index had long served as the underlying asset for futures 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 a first sub-section. The second sub-section describes the data used in the study.

### 2.1. 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 9:00am to 17:35pm. The trading session starts with a batch auction at 9:00am, and then switches to continuous trading. A closing auction takes place at 17:35pm 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.[3]

Several derivative contracts are written on the CAC 40 index. Among those derivatives, futures contracts are probably the most liquid. The trading of the futures contracts on the CAC 40 index (ticker FCE) takes place on Nyse Liffe from 8:00am to 5:30pm on the electronic trading system NSC-VF (day session) and from 5:30pm to 10:00pm 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 1 decimal) of each CAC 40 index value calculated and reported on the settlement day between 3:40pm and 4:00pm, the first index value after 4:00pm being included. Since its introduction in 1988, the FCE contract has experienced tremendous growth in trading volume. In the year 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. Before 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. The research will thus be dedicated to the nearby-maturity contract, which is more likely to be subject to arbitrage trading.

**Table 1 about here**

[3] Its base value was set to 1,000 on 1 December 1987.

At the current date, several ETFs replicate the CAC 40 index. The first one to be launched on NextTrack was the Lyxor CAC 40. It was introduced by Lyxor, a subsidiary of Société Générale, on 22 January 2001. One unit of the ETF is worth 1/100 of the index and the index return is tracked by way of synthetic replication, which guarantees a tracking error of less than 1%. Management fees equal no more than 0.25% per year and no entrance or exit fees are charged. 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 manners. 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 the 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 28$^{th}$ within the CAC 40 stocks. The number of trades recorded for the ETF is very small compared to genuine stocks, with an average of 233 transactions a day, but trades in the ETF are much larger. On average, more than €155,000, representing approximately 3,100 units of ETFs (that is 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 only amounts to €27,868. These statistics indicate that the market for the Lyxor CAC 40 shares is dominated by institutional traders rather than individuals, and that its trading level in its first year of existence has been significant enough to affect market liquidity and arbitrage activity.

### 2.2. Data

We select a 2-year observation period surrounding the ETF launch date of 22 January 2001. We remove the first week of trading for the ETF from the observation period so as to avoid temporary effects. The post-ETF period therefore spreads from 1 February 2001 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 1 February 2000 to 31 December 2000. Over those two periods, we use high frequency data for the CAC 40 index, the CAC 40 stocks, the 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.

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

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

As for CAC 40 stocks, we use the best bid and ask quote data of Euronext Paris for from 1 February 2000 to 31 December 2001. 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 a price or a quantity, changes. Quantities refer to displayed quantities only, but do not include hidden orders. We hold similar data for the ETF security from 1 February to 31 December 2001. We also use the 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 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 the 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 and 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 have been 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 have been retrieved from Thomson Financial Datastream. Then rates for non-rounded maturities were determined by linear interpolation.

## 3. 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:

$$B^{*}_{t,T,\tau} \equiv F^{*}_{t,T,\tau} - \left(I_{t,\tau} - D_{t,T}\right) e^{r_{t,T}(T-t)} = 0\,, \tag{1}$$

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 $t$; $r_{t,T}$ 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 a long (short) arbitrage portfolio[4] will yield a riskless return of:

$$\Pi_{t,T,\tau} = \left( \left| F_{t,T,\tau} - \left( I_{t,\tau} - D_{t,T} \right) e^{r_{t,T}(T-t)} \right| - C_{t,T,\tau} \right) \Big/ I_{t,\tau}\,. \tag{2}$$

[4] 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.

To compute arbitrage profit[5] series $(\pi_{t,T,\tau})$, futures prices are synchronised 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[6], 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 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) futures trades to compute cash-and-carry (resp. reverse cash-and-carry) profits although the strategy consists in 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 ten orders are executed within the same second, the actual trade sequence is unknown. We do not classify those observations and drop them from the final sample. Less than 4% of the trades remain unclassified.

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[5] In the rest of the article, the expressions "price deviation" and "arbitrage profit" will be used interchangeably.

[6] Kawaller, Koch and Koch (1988), Stoll and Whaley (1990) or Fleming, Ostdiek and Whaley (1996) show that the S&P 500 futures returns lead the cash index returns by 5 to 45 minutes. On the French market, Shyy, Vijayraghavan and Scott-Quinn (1996) and Alphonse, Capelle-Blancard and Vandelanoite (2001) find evidence that the FCE futures contract leads the CAC 40 index. Besides, Sofianos (1993) shows that the futures leg precedes the cash leg when both legs are not established simultaneously.

Transaction cost $C_{t,T,\tau}$ in Equation (2) is calculated as follows. Given that futures trade prices are inclusive of implicit trading costs, each futures trade is only charged an explicit cost of 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, that is a total cost of 0.145%.[7] 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:

$$C_{t,T,\tau} = f \times F_{t,T,\tau} + (k + 0.02\%) \times I_{t,\tau} \times \left(1 + e^{-r_{t,T}(T-t)}\right) + B_{sell} \times I_{t,\tau} \times 0.10\% \, (T-t)/360\,, \qquad (3)$$

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

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 this way are said 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

[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 time $\tau$, we simulate an ex-ante profit, that 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 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 will move prices until they revert to equilibrium or violate the no-arbitrage rule in the opposite direction at a trade time $\tau^*$. The time elapsing between observation time $\tau$ and execution time $\tau^*$ 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 $\Pi_{t,T,\tau}^{buy}$ 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 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 as being time-$\tau$ opportunity perpetuating and are not taken as new observations for the calculation of arbitrage durations. When an arbitrage opportunity does not vanish before the end of the day, its duration is not computed. For those reasons, the number of observed durations is much lower than that of sampled arbitrage profits.

## 4. Changes in the frequency, magnitude, and persistence of mispricing around the ETF introduction

In a preliminary stage to our main empirical work, we check to what extent the price efficiency of the CAC 40 futures contracts improved after the inception of the Lyxor CAC 40. To do so, we conduct pre/post-ETF univariate comparisons of 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. We also conduct basic tests of the ETF-arbitrage-trading argument by examining the next two hypotheses: (1) the mean value and frequency of price deviations triggering short arbitrage trades decrease more than those of deviations triggering long arbitrage trades; (2) the cash-futures no-arbitrage price relation is tighter when the ETF rather than the basket of stocks is used as the cash instrument. 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, with no striking discrepancy between buy and sell arbitrage opportunities. The proportion of observations deviating from the no-arbitrage relation falls from 1.54% in the pre-ETF to 0.15% in the after-period. This is consistent with previous evidence by Kurov and Lasser (2002) for the Nasdaq 100 futures, although the CAC 40 index-futures price relationship seems tighter than that of the Nasdaq 100. Concerning the level of deviations, their average (or median) values before trading costs significantly increase in the post-ETF period.

When trading costs are accounted for, deviations become scarcer but greater in value, which means that only the largest deviations persist in the post period.

The comparison of ex-ante profits is presented in columns 5 to 8 of Table 2. The pre-ETF statistics show that the futures market was already well monitored before the launch of the ETF. Yet, 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 1.9 after the inception of the ETF, with a decline from 48.39% to 25.32%. Results are similar for buy (Panel B) and sell (Panel C) arbitrage trades. 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.[8]

The comparison of average and median values of arbitrage durations, reported in columns 9 and 10, confirms those results. The market quickly reverts to no arbitrage values, suggesting that the market is highly monitored. We can denote a significant decrease in arbitrage durations after the ETF introduction, the mean duration declining from 13.64 seconds in the pre-ETF period to 6.07 seconds in the post-ETF period. The magnitude of the decline is slightly greater for sell arbitrages as can be seen in Panels B and C of the table.

We complement the comparison analysis with a test of the ETF-futures price relation over the first year of trading of the ETF. To that end, trade prices of the near

[8] Given that the level of an ex-ante profit obviously depends on the value of the initial price deviation that 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 the 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 unchanged. On the contrary, they exhibit a higher degree of significance.

contract are matched either with ETF signed trade prices (column 3 of Table 2) or with bid and ask ETF best limit prices (column 4 of Table 2). Sell (buy) futures prices are combined both with buy (sell) ETF prices and ETF ask (bid) prices. Ex-post price deviations are computed according to Equation (2), in which the index value is replaced by the relevant ETF price. The formulas are modified to account for the fact that the ETF delivers one dividend per year. This dividend, usually paid in September, equals the sum of the dividends received on a portfolio replicating the CAC 40 and held since the last ETF dividend date minus annual management fees.[9] Explicit fees on the ETF are the same as those on the index stocks. Since we use either bid or ask quotes or signed trades for the ETF, no additional implicit cost is charged. Short-selling the ETF costs a 1.50% rate instead of 0.10% for the stock basket.

The results, reported in column 3 (signed ETF trades) and 4 (ETF bid and ask quotes) of Table 2, show that the ETF and the futures markets are jointly efficient as average values of arbitrage profits are rather small. However, in comparison with the results obtained with index values, the ETF-futures price relation is not tighter than the basket-futures price relation.

For a robustness check, we excluded the months of May and June during which the highest level of dividend payments is observed and re-ran the tests. Results were strictly equivalent. To conclude on this section, the univariate comparison of arbitrage profits around the ETF-inception date is supportive of increased arbitrage activity,

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[9] Lyxor CAC 40 management fees are accrued between dividend dates in the following manner: $fee_t = fee_{t-1} + NAV_{t-1} \times 0.30\% \times \frac{n_{t-1,t}}{360}$, where $fee_t$ are the fees accrued at date $t$, $NAV_t$ is the ETF's net asset value at date $t$, and $n_{t-1,t}$ is the number of calendar days elapsing from trading day $t$ to trading day $t-1$.

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&P500, and the Nasdaq 100, respectively.

Nevertheless, we cannot interpret the tightening of the CAC 40 index-futures price relation as resulting from additional spot-futures arbitrages that use the ETF security as the cash asset. Indeed, we do not find that the frequency and level of short arbitrage profits decrease more than those of long arbitrage profits, and we fail to prove that the ETF-futures price relation is as tight as that of the index-futures prices. These two findings call the ETF-arbitrage-trading argument into question and lead us to examine the effective role of the basket security in two manners. First, we conduct a multivariate analysis that tests the impact of ETF-trading variables after controlling for other financial factors known as impacting spot-futures price relations (Section 5). Among those factors, special attention is given to the liquidity factor. Second, we test the causality relations between futures price deviations, liquidity, and ETF trading volumes, in a VAR analysis (Section 6).

## 5. Does ETF trading really explain the improvement in the spot-futures price efficiency?

A variety of factors, such as dividends, volatility, liquidity, or maturity as documented by MacKinlay and Ramaswamy (1988), Bhatt and Cakici (1990), Klemkosky and Lee (1991) and Switzer et al. (2000) have been found to explain arbitrage opportunities in futures markets. Differences in the values of those factors may thus explain the comparative results of Section 3. In particular, according to the descriptive statistics of Table 1, the post-introduction period is associated with higher trading volumes and smaller spreads, which suggest that trading the CAC 40 stock basket is easier in the second period. Therefore, we test whether the enhancement of the joint price efficiency is due to the ETF inception rather than to other financial factors that ease arbitrage trading.

The liquidity of the underlying stocks is a factor of particular interest because the introduction of ETFs has been proved to influence the spreads of underlying stocks (Subrahmanyam, 1991; Hegde and McDermott, 2004). In order to control for it, we compute relative quoted bid-ask spreads for each component of the CAC 40 index.

As a preliminary step, we look at the correlations between $\overline{\Pi}_t$, the equally-weighted mean of ex-post index-futures arbitrage profits measured on day *t* assuming no trading costs ($C_{t,T,\tau} = 0$), with daily measures of various factors as follows:

$F\sigma_t$, the price range of the futures contract over day *t*;

$CACturn_t$, the CAC 40 turnover on day *t*;

$CACspr_t$, which denotes the cross-sectional capitalisation-weighted mean of CAC 40 stocks' duration-weighted average quoted bid-ask spreads at date *t*;

$Fmat_t$, the futures maturity in number of days taken in logarithm;

and $d_{t,T}$, the dividend yield measured as the discounted dividends paid by the CAC 40 stocks from date *t* to the futures maturity *T* in percentage of the value of the index.

$\overline{\Pi}_t$ is significantly correlated with any of those factors except the futures price range $F\sigma_t$, which will thus be dropped from the control variable set. In preliminary regressions of $\overline{\Pi}_t$ on remaining control variables, all control variable exhibit a significant explanatory power which remains stable over the two-year observation period surrounding the ETF introduction. The exception to the rule is the spread variable, whose coefficient is not significantly different from 0 before the ETF inception, but becomes strongly significant afterward. Those observations lead us to model the daily average price deviation $\overline{\Pi}_t$ in the following way:

$$\overline{\Pi}_t = \gamma_0 + \gamma_1 CACturn_t + \gamma_2 Fmat_t + \gamma_3 d_{t,T} + \gamma_4 ETF_t + \gamma_5 ETF_t \times CACspr_t + \gamma_6 ETFturn_t + \eta_t,$$
$$\eta_t = \varphi_1 \eta_{t-1} + \varphi_2 \eta_{t-2} + v_t, \quad E(v_t) = E(v_t v_{t-1}) = 0, \tag{4}$$

where $ETF_t$ is a binary variable equal to 0(1) in the pre-ETF (post-ETF) period, and $ETFturn_t$ [I deleted text here] equals the ETF turnover on date *t* when *t* belongs to the post-ETF period and is set to 0 otherwise. A 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 in Model (4) are used.

With each methodology, we test the following economic hypotheses.

***H1***. *Index-futures price deviations are lower in the post-ETF period even after controlling for market frictions.* Statistically, this means testing whether $\gamma_4$ is significantly negative.

***H2***. *The value of index-futures price deviations significantly relates to the level of trading in the ETF.* Finding that $\gamma_6$ significantly differs from 0 would support that.

The results of the regressions are displayed in Table 3.

**Table 3 about here**

Concerning the effect of turnover, opposite arguments can be put forward. On the one hand, it can be considered that the occurrence and the magnitude of price deviations increase trading activity by inviting more arbitrage services. On the other hand, higher volumes, if initiated by arbitragers, 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 turnover and validate the first explanation. $\gamma_5$ coefficients in the MA(2) OLS regressions are significantly positive, confirming that price efficiency improves with liquidity in the stock market in the post-ETF period. All regressions show that mispricing decreases when approaching the liquidation date, and increases with the payment of dividends by underlying stocks. While those relations have a high level of statistical significance in the MA(2) OLS regressions, they are insignificant in the Tobit analysis.

Our main interest lies in the effects of ETF variables. $\gamma_4$ coefficients are significantly negative at the 5% level in all regressions. We therefore fail to reject H1. However, the $ETFturn_t$ coefficients ($\gamma_6$) do not significantly differ from zero in any of the MA(2) OLS or Tobit regressions, which provides no support for H2. The fact that the level of trading in the ETF does not add explanatory power beyond the period binary variable undermines the argument according to which joint price efficiency improves because ETF securities are used in arbitrage strategies when single stocks cannot be.

In order to check whether the changing regime in the liquidity-efficiency relation may explain the efficiency improvement consequent to the ETF inception, we explore the causality links between liquidity and efficiency in the next section.

## 6. Causal relations between index cash-futures arbitrage opportunities and illiquidity before and after the ETF inception

The causality links between the joint cash-futures price efficiency, the CAC 40 stocks' liquidity, and the ETF trading activity are examined in a VAR analysis. To conduct this analysis, we divide the trading day into sixteen periods of 30 minutes from 9:15am to 5:15pm. For each 30-minute period referred to with an index *h*, we calculate: (1) the average of ex-post index-futures price deviations assuming no trading costs, denoted $\overline{\pi}_h$; (2) the duration-weighted average relative quoted spread of each component of the CAC 40 index and then the cross-sectional mean of those average spreads, denoted $cacspr_h$; and (3) the turnover of the ETF, denoted $etfturn_h$.

It is well acknowledged that trading volumes and spreads exhibit intraday patterns, and it is likely that cash-futures price deviations exhibit a similar phenomenon. Before performing vector autoregressions, we thus remove intraday seasonalities from the time series. We actually find that average bid-ask spreads of CAC 40 stocks ($cacspr_h$) are larger during the first four and the last 30-min periods of the day, and that the ETF's turnover ($etfturn_h$) is higher, on average, in the last 30-min period. We therefore adjust the ($cacspr_h$) and the ($etfturn_h$) time series by regressing them on dummies in the following way:

$$cacspr_h = a_0 + a_1 I_1 + a_2 I_2 + a_3 I_3 + a_4 I_4 + a_{16} I_{16} + \varepsilon_h^{cacspr}, \quad (5)$$

$$etfturn_h = b_0 + b_{16} I_{16} + \varepsilon_h^{etfturn}. \quad (6)$$

In Equations (5) and (6), variables $I_k$ are binaries that equal 1 when the dependent variable is measured over the $k^{\text{th}}$ 30-min period of the day, 0 otherwise. $\varepsilon_h^{cacspr}$ and

$\varepsilon_h^{etfturn}$ are residual terms from equations (5) and (6) representing the adjusted average spread and the adjusted ETF turnover respectively.

Index-futures price deviations ($\overline{\pi}_h$) are found to be greater in the first and last 30-min periods of the day. In addition, we know from the previous sub-section that they are determined by the CAC 40 stock turnover, the futures contract maturity, and the amount of dividends paid by the index stocks. Average deviations ($\overline{\pi}_h$) are thus not only adjusted for start-of-the-day and end-of-the-day effects, but are also controlled for those factors:

$$\overline{\pi}_h = c_0 + c_1 I_1 + c_{16} I_{16} + d_1 CACturn_h + d_2 Fmat_h + d_3 d_{h,T} + \varepsilon_h^{\overline{\pi}} . \qquad (7)$$

where:

$CACturn_h$ is the CAC 40 turnover over 30-min period *h*;

$Fmat_h$ is the futures maturity at period *h*, in number of days and taken in logarithm;

and $d_{h,T}$ is the dividend yield measured as the discounted dividends paid by the CAC 40 stocks from the day of period *h* to the futures maturity *T* in percentage of the value of the index.

Subsequently, residuals from the adjustment regressions ($\varepsilon_h^{\overline{\pi}}$, $\varepsilon_h^{cacspr}$, and $\varepsilon_h^{etfturn}$) are related in vector autoregressions. We first investigate the causal relations between adjusted price deviations ($\varepsilon_h^{\overline{\pi}}$) and adjusted bid-ask spreads ($\varepsilon_h^{cacspr}$), and examine how stable these relations are from the pre-ETF period to the post-ETF period. The motivation for this first analysis is that a bivariate causality between spot-futures mispricing and illiquidity was previously documented, namely by Roll et al. (2007), and that a structural change in the offer for cash assets may well change the parameters of these causalities. The following VAR model,

$$\begin{cases} \varepsilon_h^{\overline{\pi}} = \alpha_0 + \sum_{i=1}^{p^*} \alpha_i^1 \varepsilon_{h-i}^{\overline{\pi}} + \sum_{j=1}^{p^*} \alpha_j^2 \varepsilon_{h-j}^{cacspr} + u_h^{\overline{\pi}} \\ \varepsilon_h^{cacspr} = \beta_0 + \sum_{i=1}^{p^*} \beta_i^1 \varepsilon_{h-i}^{\overline{\pi}} + \sum_{j=1}^{p^*} \beta_j^2 \varepsilon_{h-j}^{cacspr} + u_h^{cacspr}, \end{cases} \tag{8}$$

is estimated over two periods: the pre-ETF period from 1 February 2000 to 31 December 2000, and the post-ETF period from 1 February 2001 to 31 December 2001, from which 11 September 2001 is excluded. For each period, the optimal number of lags, *p**, is determined according to the Akaike information criterion. $u_h^{\overline{\pi}}$ and $u_h^{cacspr}$ are zero-mean uncorrelated error terms.

We then estimate a trivariate VAR model that relates the adjusted average price deviations, the average bid-ask spreads, and the ETF turnover, during the post-ETF observation period:

$$\begin{cases} \varepsilon_h^{\overline{\pi}} = \alpha_0 + \sum_{i=1}^{q^*} \delta_i^1 \varepsilon_{h-i}^{\overline{\pi}} + \sum_{j=1}^{q^*} \delta_j^2 \varepsilon_{h-j}^{cacspr} + \sum_{k=1}^{q^*} \delta_k^3 \varepsilon_{h-k}^{etfturn} + v_h^{\overline{x}} \\ \varepsilon_h^{cacspr} = \beta_0 + \sum_{i=1}^{q^*} \varphi_i^1 \varepsilon_{h-i}^{\overline{\pi}} + \sum_{j=1}^{q^*} \varphi_j^2 \varepsilon_{h-j}^{cacspr} + \sum_{k=1}^{q^*} \varphi_k^3 \varepsilon_{h-k}^{etfturn} + v_h^{cacspr} \\ \varepsilon_h^{etfturn} = \beta_0 + \sum_{i=1}^{q^*} \lambda_i^1 \varepsilon_{h-i}^{\overline{\pi}} + \sum_{j=1}^{q^*} \lambda_j^2 \varepsilon_{h-j}^{cacspr} + \sum_{k=1}^{q^*} \lambda_k^3 \varepsilon_{h-k}^{etfturn} + v_h^{etfturn}. \end{cases} \tag{9}$$

Again, the Akaike criterion is used to set *q**. $v_h^{\overline{\pi}}$, $v_h^{cacspr}$, and $v_h^{etfturn}$ are error terms.

Model (9) aims to test the causal interactions between ETF trading and index-futures price deviations. More precisely, the null hypotheses we test can be written as follows:

***H3***. *ETF trading does not Granger cause index-futures price deviations, that is,* $\left(\delta_k^3\right)_{k=1}^{q*}$ *do not jointly differ from zero.*

***H4***. *Index-futures price deviations does not Granger cause index ETF trading, that is,* $\left(\lambda_i^1\right)_{i=1}^{q*}$ *do not jointly differ from zero.*

For all VAR models, we report the estimated coefficients 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. Panel A and Panel B of the table report the results for Model (8) in the pre-ETF period and the post-ETF period, respectively. Panel C is dedicated to the results obtained for model (9). For 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. This consists in testing whether the coefficients of variable *X* lags are jointly zero when *Y* is the dependent variable. Chi-square statistics are reported in Table 4. *p*-values of all coefficients or test statistics are also provided in the table.

**Table 4 about here**

We also calculate the Impulse Response Functions (IRFs) for Model (8). IRFs trace the impact of a one-time, unit standard-deviation, positive shock to one independent variable to the current and future values of the endogenous variable of interest. Figure 1 depicts the response of index-futures price deviations to a shock in liquidity in the pre-ETF and post-ETF periods. Symmetrically, Figure 2 compares the response of liquidity to a shock in price deviations over the two periods. Those responses are traced forward over 16 30-min periods, representing one trading day.

**Figure 1 about here**

**Figure 2 about here**

Comparing Panel A and B of Table 4 shows a dramatic change in the causal links between liquidity and price efficiency after the ETF inception. While adjusted bid-ask spreads of the index stocks do not Granger-cause adjusted index-futures price deviations, and vice versa before the ETF introduction, those two causal relations become highly significant after the inception of the ETF. During 2001, a one standard-deviation increase in the adjusted bid-ask spreads produced a significant increase in future price deviations, whereas it produced a non-significant decrease during 2000 (cf. Figure 1). In the reverse direction, the response of bid-ask spreads to a one standard-deviation increase in price deviations is much greater in 2001 than in 2000 (cf. Figure 2).

According to the estimates and statistics of Panel C in Table 4, the causality links between spreads and price deviations are not substantially affected when the ETF turnover variable is introduced in the VAR analysis. The null hypothesis that price deviations do not influence the trading activity in the ETF (H4) is not rejected. Reversely, the ETF turnover is found to Granger-cause index-futures price deviations at the 5% threshold (Rejection of H3). However, this causality relation is weak. The estimated coefficients of lagged ETF turnovers indicate that the economic impact of ETF volume variations on index-futures price deviations is low, and none of those coefficients is significantly different from zero when considered individually. As a robustness check, we conduct the same VAR analysis with 15-minute periods. Results remain unchanged.

Consistent with the ETF introduction indirectly strengthening the spot-future price linkage, we find that a new regime in causality between liquidity and index-futures price efficiency appears after the ETF introduction, but we fail to prove that index-futures mispricing invites arbitrage activity using ETF shares in the cash leg.

## 7. Conclusion

ETFs are generally found to improve the link between the associated cash and futures markets. Using high frequency index, futures, and ETF data over two years surrounding the introduction of the first ETF tracking the CAC 40 index, we find a significant improvement of the no-arbitrage pricing relationship 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 the literature, we consider that the observed improvement does not necessarily stem directly from the use of ETFs in cash-futures arbitrage trades. Two facts raise question about the ETF-arbitrage-trading argument: (1) the improvement is not greater for price deviations generating short arbitrage opportunities; (2) the ETF-futures price relation does not appear as tight as that linking the index and the futures contract. Furthermore, in a multivariate analysis that controls for financial factors known to impact the spot-futures price relation, we show that index-futures mispricing does decrease after the introduction of the ETF, but the ETF turnover poorly explains that improvement. This last finding again fails to support the conventional argument according to which ETFs are used in arbitrage portfolios when trading the basket of individual stocks is too risky or costly.

In order to understand which factor actually produces the spot-futures price tightening, we investigate the causality links between the joint cash-futures price deviations, the spreads of the CAC 40 stocks, and the ETF trading activity. Our VAR analysis shows that the ETF turnover Granger-causes index-futures price deviations but the economic and statistical significance of this relation is weak. In addition, index-futures mispricing does not Granger-cause ETF trading. More importantly, the causality links between stock illiquidity and index-futures price deviations change dramatically after the ETF inception. While no causal relation between those two variables is found to be significant in the pre-ETF period, a strong two-way Granger causality between price efficiency and liquidity appears in the post-ETF period. We therefore conclude that the post-ETF efficiency improvement is not directly related to ETF trading but is rather formed through the mediation of indirect liquidity effects. Our results shed light on the importance of the linkage between price efficiency and liquidity and suggest that this linkage is probably insufficiently examined in academic research.

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## Table 1. Spot and futures markets' trading activity around the 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 40 stocks | --- | 28 upon 43 |
| Average daily number of trades | Mean | --- | 231 |
| | Rank against CAC 40 stocks | --- | last |
| Average trade size (in €) | Mean | --- | 158,341 |
| | Rank against CAC 40 stocks | --- | first |

The first panel of this table reports the average number of trades and the average number of traded contracts per day for the near, the far, and all-maturity contracts over our 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 capitalisation-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 the ETF introduction

| | CAC 40 Index-futures arbitrages | | ETF-futures arbitrages | | CAC 40 Index-futures arbitrages | | | | Duration of arbitrage opportunities (in seconds) | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Calculations based on** | **Signed futures trades** | | **Signed ETF trades** | **ETF bid-ask quotes** | **Signed futures trades** | | | | **Signed futures trades** | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| **Delay before arbitrage** | *Ex-post* | *Ex-post* | *Ex-post* | *Ex-post* | *1mn* | *1mn* | *2mn* | *2mn* | *Ex-post* | *Ex-post* |
| **Sample period** | Pre-ETF | Post-ETF | Post-ETF | Post-ETF | Pre-ETF | Post-ETF | Pre-ETF | Post-ETF | Pre-ETF | Post-ETF |
| **Panel A - All arbitrages** | | | | | | | | | | |
| ***Deviation frequency*** | | | | | | | | | | |
| Number of pairings | 1,769,068 | 2,211,960 | 37,157 | 2,166,565 | 24,594 | 2,589 | 24,467 | 2,468 | | |
| Number of deviations | 27,181 | 3,293 | 3,531 | 60,875 | 13,373 | 730 | 11,840 | 625 | 7,433 | 685 |
| Percentage of deviations | 1.54 | 0.15 | 9.50 | 2.81 | 54.38 | 28.20 | 48.39 | 25.32 | | |
| Z-statistic | --- | -144.48 | 61.48 | 230.93 | --- | -27.86 | --- | -24.75 | | |
| ***Deviation values (in %)*** | | | | | | | | | | |
| Mean | 0.046 | 0.159 | 0.061 | 0.064 | 0.003 | -0.173 | -0.009 | -0.188 | 13.64 | 6.07 |
| Student statistic | --- | 21.45 | -17.94 | -18.00 | --- | -36.10 | --- | -36.08 | --- | -20.47 |
| Median | 0.033 | 0.084 | 0.041 | 0.028 | 0.007 | -0.267 | -0.003 | -0.274 | 7 | 3 |
| **Panel B - Buy arbitrages** | | | | | | | | | | |
| ***Deviation frequency*** | | | | | | | | | | |
| Number of pairings | 893,297 | 1,115,882 | 21,435 | 1,093,185 | 20,970 | 1,273 | 20,853 | 1,225 | | |
| Number of deviations | 23,168 | 1,578 | 1,377 | 22,501 | 11,264 | 470 | 9,950 | 428 | 6,253 | 261 |
| Percentage of deviations | 2.59 | 0.14 | 6.42 | 2.06 | 53.71 | 36.92 | 47.71 | 34.94 | | |
| Z-statistic | --- | -142.66 | 37.51 | 136.55 | --- | -12.03 | --- | -9.09 | | |
| ***Deviation values (in %)*** | | | | | | | | | | |
| Mean | 0.045 | 0.159 | 0.047 | 0.056 | 0.003 | -0.130 | -0.009 | -0.135 | 13.44 | 6.23 |
| Student statistic | --- | 11.98 | -11.66 | -10.77 | --- | -17.47 | --- | -16.42 | --- | -14.05 |
| Median | 0.032 | 0.097 | 0.036 | 0.027 | 0.006 | -0.261 | -0.004 | -0.262 | 7 | 4 |
| **Panel C - Sell arbitrages with short-selling costs** | | | | | | | | | | |
| ***Deviation frequency*** | | | | | | | | | | |
| Number of pairings | 875,771 | 1,096,078 | 15,722 | 1,073,380 | 3,624 | 1,316 | 3,614 | 1,243 | | |
| Number of deviations | 4,013 | 1,715 | 2,154 | 38,374 | 2,109 | 260 | 1,890 | 197 | 1,180 | 424 |
| Percentage of deviations | 0.46 | 0.16 | 13.70 | 3.58 | 58.20 | 19.76 | 52.30 | 15.85 | | |
| Z-statistic | --- | -37.05 | 49.38 | 186.66 | --- | -28.06 | --- | -27.45 | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Deviation values (in %)*** | | | | | | | | | | |
| Mean | 0.049 | 0.159 | 0.070 | 0.068 | 0.003 | -0.215 | -0.012 | -0.240 | 14.69 | 5.97 |
| Student statistic | --- | 21.13 | -16.09 | -17.67 | --- | -36.24 | --- | -37.96 | --- | -12.02 |
| Median | 0.037 | 0.079 | 0.045 | 0.030 | 0.014 | -0.271 | 0.004 | -0.291 | 8 | 3 |

This table presents a complete view of average levels and frequencies of deviations from the no-arbitrage price relation for the nearby CAC 40 index futures contract around the Lyxor CAC 40 introduction. Panel A provides statistics for all categories of arbitrage strategies. Panel B and C perform the analysis separately for buy arbitrages and sell arbitrages (with short-selling costs) respectively. Each panel displays, for each column but columns (9) and (10), 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 (9) and (10) are ex-post deviations for which prices return to levels compatible with no-arbitrage before the market close. In this case, mean and median deviation values are durations reported in seconds. Z-statistics test the difference in violation frequency before and after Lyxor-ETF-CAC 40 inception. Student statistics test the difference in average mispricing between the pre- and the post-ETF period. Differences in median values are all significant at the 1% level. We do not report the Mann-Whitney statistics for the sake of brevity. Ex-post results in columns (1) and (2) are based on signed futures trades matched with the contemporaneous index value; ex-post results in column (3) are based on signed ETF trades matched with the closer relevant futures trade; ex-post results in column (4) are based on futures trades matched with the prevailing bid or ask ETF quote; ex-ante results in columns (5) to (8) 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 (9) and (10) are based on signed futures trades matched with contemporaneous index values.

## Table 3. Regressions of average ex-post price deviations

| **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 | 0.019938*** | -0.003913*** |
| | (0.0019) | (0.0083) |
| $CACturn_t$ | 0.023216*** | 0.005074 |
| | (0.0018) | (0.1223) |
| $Fmat_t$ | 0.003365*** | 0.000098 |
| | (0.0018) | (0.7938) |
| $d_{t,T}$ | 0.034481*** | 0.004813** |
| | (0.0062) | (0.0211) |
| $ETF_t$ | -0.03796*** | -0.015971*** |
| | (0.0020) | (<0.0001) |
| $ETF_t \times CACspr_t$ | 0.128059** | 0.076413*** |
| | (0.0144) | (<0.0001) |
| $ETFturn_t$ | -0.009750 | -0.005924 |
| | (0.7147) | (<0.5035) |
| $\eta_{t-1}$ | 0.765302*** | |
| | (<0.0001) | |
| $\eta_{t-2}$ | 0.127667** | |
| | (0.0112) | |
| Nb of observations | 440 | 440 |
| Adjusted R² | 76.64% | |
| AIC | | -670.71 |
| Schwarz criterion | | -638.14 |

This table displays the estimates for regressions of the daily average ex-post index-futures arbitrage profits calculated upon signed futures trade prices for the nearby maturity. A 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. $CACturn_t$ 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*. $Fmat_t$ 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 afterward. $ETFturn_t$ is the ETF turnover on date *t*. $\eta_{t-1}$ and $\eta_{t-2}$ are the lagged variables in the MA(2). ***, **, * indicates statistical significance at the 1%, 5% and 10% level, respectively. *p*-values are given between brackets.

## Table 4. VAR analysis

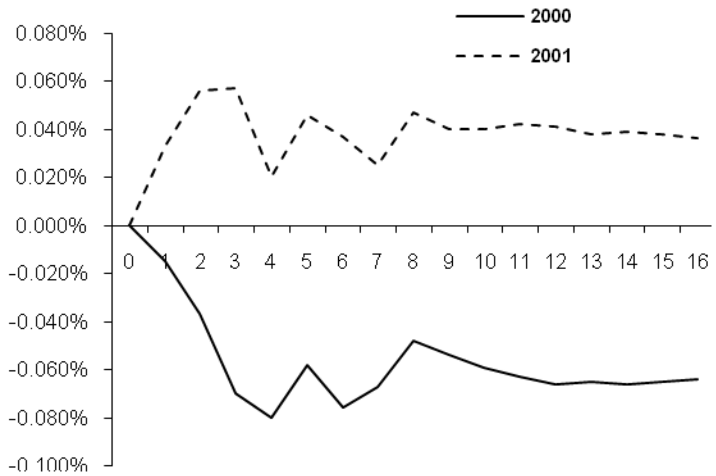
| Panel A - Bivariate VAR analysis in the pre-ETF period | | Intercept | $\varepsilon_{h-1}^{\bar{\pi}}$ | $\varepsilon_{h-2}^{\bar{\pi}}$ | $\varepsilon_{h-3}^{\bar{\pi}}$ | $\varepsilon_{h-1}^{cacspr}$ | $\varepsilon_{h-2}^{cacspr}$ | $\varepsilon_{h-3}^{cacspr}$ |
|---|---|---|---|---|---|---|---|---|
| $\varepsilon_{h}^{\bar{\pi}}$ | **Estimate** | 0.0000 | 0.5717*** | 0.1293*** | 0.0462** | -0.0079 | -0.0111 | -0.0175 |
| | ***p*-value** | 0.9815 | 0.0001 | 0.0001 | 0.0198 | 0.5946 | 0.4969 | 0.2870 |
| | | | | | | **Wald test** | **Chi-2 stat.** | 7.27 |
| | | | | | | | ***p*-value** | 0.5077 |
| $\varepsilon_{h}^{cacspr}$ | **Estimate** | 0.0000 | 0.0355* | -0.0095 | -0.0039 | 0.4727*** | 0.0844*** | 0.1217*** |
| | ***p*-value** | 0.9913 | 0.0716 | 0.6772 | 0.8652 | 0.0001 | 0.0001 | 0.0001 |
| | | | **Wald test** | **Chi-2 stat.** | 12.00 | | | |
| | | | | ***p*-value** | 0.1510 | | | |
| **# of lags** | 8 | | | | | | | |
| **# of obs.** | 3,448 | | | | | | | |

| Panel B - Bivariate VAR analysis in the post-ETF period | | Intercept | $\varepsilon_{h-1}^{\bar{\pi}}$ | $\varepsilon_{h-2}^{\bar{\pi}}$ | $\varepsilon_{h-3}^{\bar{\pi}}$ | $\varepsilon_{h-1}^{cacspr}$ | $\varepsilon_{h-2}^{cacspr}$ | $\varepsilon_{h-3}^{cacspr}$ |
|---|---|---|---|---|---|---|---|---|
| $\varepsilon_{h}^{\bar{\pi}}$ | **Estimate** | -0.0001 | 0.3647*** | 0.1166*** | 0.0482*** | 0.0197*** | 0.0163** | 0.0036 |
| | ***p*-value** | 0.6381 | 0.0001 | 0.0001 | 0.0097 | 0.0076 | 0.0478 | 0.6618 |
| | | | | | | **Wald test** | **Chi-2 stat.** | 58.15*** |
| | | | | | | | ***p*-value** | <0.0001 |
| $\varepsilon_{h}^{cacspr}$ | **Estimate** | 0.0000 | 0.1958*** | -0.0971** | 0.0297 | 0.5077*** | 0.1022*** | 0.1216*** |
| | ***p*-value** | 0.9980 | 0.0001 | 0.0259 | 0.4996 | 0.0001 | 0.0001 | 0.0001 |
| | | | **Wald test** | **Chi-2 stat.** | 32.26*** | | | |
| | | | | ***p*-value** | 0.0002 | | | |
| **# of lags** | 9 | | | | | | | |
| **# of obs.** | 3,404 | | | | | | | |

| Panel C - Trivariate VAR analysis in the post-ETF period | | Intercept | $\varepsilon_{h-1}^{\overline{\pi}}$ | $\varepsilon_{h-2}^{\overline{\pi}}$ | $\varepsilon_{h-3}^{\overline{\pi}}$ | $\varepsilon_{h-1}^{cacspr}$ | $\varepsilon_{h-2}^{cacspr}$ | $\varepsilon_{h-3}^{cacspr}$ | $\varepsilon_{h-1}^{etfturn}$ | $\varepsilon_{h-2}^{etfturn}$ | $\varepsilon_{h-3}^{etfturn}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\varepsilon_{h}^{\overline{\pi}}$ | **Estimate** | -0.0001 | 0.3656*** | 0.1181*** | 0.0505*** | 0.0191*** | 0.0168** | 0.0045 | 0.0060 | 0.0140 | 0.0186 |
| | ***p*-value** | 0.6804 | 0.0001 | 0.0001 | 0.0067 | 0.0097 | 0.0422 | 0.5848 | 0.6139 | 0.2353 | 0.1142 |
| | | | | | | **Wald test** | **Chi-2 stat.** | 60.72 | **Wald test** | **Chi-2 stat.** | 15.56 |
| | | | | | | | ***p*-value** | <0.0001 | | ***p*-value** | 0.0295 |
| $\varepsilon_{h}^{cacspr}$ | **Estimate** | 0.0000 | 0.1937*** | -0.0968** | 0.0319 | 0.5069*** | 0.1052*** | 0.1228*** | 0.0145 | -0.0023 | 0.0929*** |
| | ***p*-value** | 0.9965 | 0.0001 | 0.0262 | 0.4673 | 0.0001 | 0.0001 | 0.0001 | 0.6031 | 0.9342 | 0.0008 |
| | | | **Wald test** | **Chi-2 stat.** | 29.41 | | | | | | |
| | | | | ***p*-value** | 0.0001 | | | | | | |
| $\varepsilon_{h}^{etfturn}$ | **Estimate** | 0.0000 | -0.0086 | -0.0068 | 0.0125 | 0.0134 | -0.0116 | 0.0073 | 0.0168 | 0.0028 | 0.0428** |
| | ***p*-value** | 0.8984 | 0.7329 | 0.8014 | 0.6446 | 0.2131 | 0.3340 | 0.5453 | 0.3274 | 0.8697 | 0.0129 |
| | | | **Wald test** | **Chi-2 stat.** | 3.13 | | | | | | |
| | | | | ***p*-value** | 0.8723 | | | | | | |
| **# of lags** | 7 | | | | | | | | | | |
| **# of obs.** | 3,404 | | | | | | | | | | |

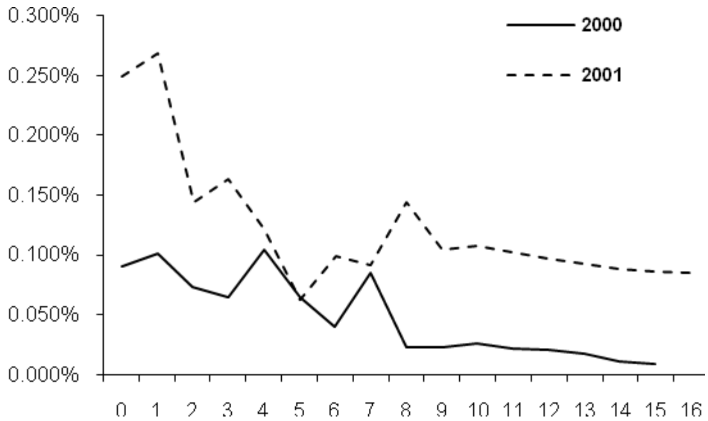
This table presents the estimates for the VAR analysis that test the causality links between the joint cash-futures price efficiency, the CAC 40 stocks' liquidity, and the ETF trading activity. Panel A and Panel B report the results for the bivariate causality model between spot-futures mispricing and illiquidity in the pre-ETF and the post-ETF observation period, respectively. Panel C reports the results obtained for the trivariate causality model between the adjusted average price deviations, the average bid-ask spreads, and the ETF turnover during the post-ETF observation period. $\varepsilon_{h}^{cacspr}$, $\varepsilon_{h}^{etfturn}$ and $\varepsilon_{h}^{\overline{\pi}}$ are respectively the average index stock bid-ask spread, the ETF turnover, and the average index-futures price deviation calculated over 30-min period *h* and adjusted for time-of-the-day effects.. We report both Chi-square statistics and *p*-values of the Wald-tests for Granger causality between the variables, the number of lags used to estimate the model determined according to the Akaike information criterion and the number of observations. ***, **, * indicates statistical significance at the 1%, 5% and 10% level, respectively.

**Figure 1. Impact of a 1-standard-deviation increase in bid-ask spreads on price deviations before and after the ETF introduction**




Impulse response functions of index-futures price deviations to index stock bid-ask spreads are presented for the pre-ETF period before (full line) and the post-ETF period (dotted line).

**Figure 2. Impact of a 1-standard-deviation increase in price deviations on bid-ask spreads before and after the ETF introduction**




Impulse response functions of index stock bid-ask spreads to index-futures price deviations are presented for the pre-ETF period before (full line) and the post-ETF period (dotted line).