

Efficient Price Discovery in Stock Index Cash and Futures Markets

Pascal ALPHONSE *

ABSTRACT. – This study is concerned with the aggregation of information in the French stock index cash and futures markets. The results indicate that deviations from the equilibrium relationship linking cash and futures prices originate mainly from information arrivals in the futures market and that at least 95 % of the price discovery is achieved in this market. Finally, the results appear relatively independent of the particular choice of price measurement, transaction prices *versus* quotes.

Découverte du prix efficient dans les marchés au comptant et à terme d'indice boursier

RÉSUMÉ. – Ce travail analyse l'agrégation d'informations nouvelles dans les prix au comptant et à terme de l'indice boursier CAC 40. Les résultats indiquent que l'information nouvelle arrive essentiellement sur le marché de futures et est, ensuite, transmise sur le marché des actions. Il apparaît qu'environ 95 % de la découverte du prix est réalisé sur le marché de futures. Ces résultats apparaissent relativement indépendants du choix de la mesure indicielle retenue, derniers prix négociés *versus* dernières cotations disponibles.

* P. ALPHONSE: GERME-ESA, Université de Lille 2, 1 place Déliot, BP 381, 59020 Lille Cedex, France.

I thank B. BIAIS, C. GOURIÉROUX (the Editors), A. FRANÇOIS-HEUDE and an anonymous referee for valuable comments. All remaining errors are mine.

1 Introduction

Besides the traditional role of risk sharing assigned to futures markets, these markets play an important role in the aggregation of information (see, for example, GROSSMAN [1977], BRAY [1981] and BRANNEN and ULVELING [1984]). The case of stock index futures is analyzed in SUBRAHMANYAM [1991] and in KUMAR and SEPP [1994]. Futures and cash markets contribute to the discovery of a unique and common unobservable price that is the efficient price. The contribution of each market to the price discovery depends, at least in part, on the microstructure of these markets, including the level of transparency, the liquidity supply mechanism, the rules governing the priority of orders, the constraints on short sales and the settlement mechanism.

Special features of the French stock index cash and futures markets may play a non-trivial role in the price discovery process. The major French stock market, the “*Règlement Mensuel*” (hereafter, the RM) is based on a fixed date settlement that operates once a month. Thus, the RM works like a futures market with delivery at the end of the month. This feature reduces the traditional difference between stock and futures markets. As a consequence, and contrary to most of the US studies, the empirical results presented in this paper are much more related to differences in the assets traded, a single asset versus a basket of securities (in the spirit of the papers of SUBRAHMANYAM [1991], CHAN [1993] and KUMAR and SEPP [1994]) than to differences induced by the settlement schedules.

Furthermore, stocks and futures are traded in different market structures, a pure limit order market for the stocks and a floor market for the futures.¹ As suggested by BIAIS, FOUCAULT and SALANIÉ [1998], this difference affects the liquidity suppliers’ behavior and has an impact on the level of liquidity of the market. In particular, it appears that the cost of liquidity is larger in the floor market than in the limit order market due to the absence of incentive to undercut on large ask prices (overbid on low bid prices) in the floor market. On the contrary, limit order markets appear to entail efficient risk sharing and competitive pricing. This may affect the order submission behavior of informed traders in a way that is favorable to the stock market. As a consequence, traditional results indicating that information is first aggregated in the futures market (e.g. STOLL and WHALEY [1990]) may in fact reflect, at least partially, differences in market microstructure. In this paper, we provide evidence of price discovery by stocks and futures traded in market architectures that differ significantly from the ones analyzed in other large market places.

On the empirical ground, most of the studies emphasize some kind of causality between futures and cash markets returns (e.g. STOLL and WHALEY [1990]) and/or between futures and cash markets return volatility (e.g. CHAN, CHAN and KAROLYI [1991]). While these analyses provide some evidence about

1. Since 1998, the financial futures exchange is also organized as a limit order market.

the relationship between the cash and futures markets, they do explicitly take into account neither the equilibrium relationship between cash and futures prices nor the price discovery process. A more satisfactory specification may be built on the observation that these two characteristics are linked to two particular forms of the cointegration property of futures and cash prices, the error correction form (hereafter, ECM) and the common trend form. WAHAB and LASHGARI [1993] provide an in-depth analysis of the relationship between stock index cash and futures markets using an ECM framework. Nevertheless, the evidence presented in their paper should be interpreted with caution due to the use of non-synchronous daily closing prices. The analysis of SHYY, VIJAYRAGHAVAN and SCOTT-QUINN [1996] is more closely related to our work because it deals with the French market and uses intraday data. Furthermore, the empirical analysis presented in their paper suggests that traditional results concerning the lead-lag relationship between cash and futures markets may be caused by a stale price effect due to non-synchronous trading among stocks.² While this result is appealing, it should also be considered with caution because SHYY, VIJAYRAGHAVAN and SCOTT-QUINN [1996] use data on the second nearest contract which is characterized by a very low level of activity.³ As far as the choice of the data is concerned, part of our work may be viewed as an extension and analysis of the robustness of the results of SHYY, VIJAYRAGHAVAN and SCOTT-QUINN [1996] to the case of the first nearest contract which is characterized by a high level of activity. Finally, HASBROUCK [1995] uses the common trends representation of a set of cointegrated variables to measure the contribution to the efficient price innovation from a particular market.

A cointegration analysis based on intraday data from the French stock index cash and futures markets is developed in this paper. The main results indicate that the futures leads the spot and contributes largely to the price discovery, suggesting that news are first aggregated in the prices of the futures and then transferred to the stock market. An analysis of the price adjustment to past disequilibrium supports this view.

The remainder of the paper is organized as follows. Section 2 presents a simple model of price discovery. The data are presented in section 3 and the results are presented in section 4. Section 5 concludes the study.

2. This stale price effect results in index autocorrelation. In order to analyse this effect, SHYY, VIJAYRAGHAVAN and SCOTT-QUINN [1996] use quotes from the futures and cash markets in addition to transaction price data. Nevertheless, several studies argue that the role of infrequent trading should be limited. For example, LO and MACKINLAY [1990] show that the level of infrequent trading that would be consistent with the level of index autocorrelation is much larger than the observed level of infrequent trading that characterizes most stock indexes. STOLL and WHALEY [1990] and DE JONG and NIJMAN [1998] show that the infrequent trading effect could be identified and eliminated without altering the lead/lag results. Finally, BOSSAERT [1993] and CHAN [1993] suggest that informational effects as well as infrequent trading may cause the index autocorrelation.

3. Activity data provided by MATIF SA, the futures exchange, show that the trading volume of the second nearest contract considered by SHYY, VIJAYRAGHAVAN and SCOTT-QUINN [1996] is about twenty times lower than the trading volume of the first nearest contract.

2 A Simple Model of Price Discovery

It is well known that prices of related securities like prices in spot and futures markets cannot diverge without bound because they are linked by an arbitrage relationship. The link between this arbitrage relationship (and the associated cost-of-carry pricing model) and the existence of a cointegration relationship between the spot and futures prices has been extensively presented in the literature (e.g. WAHAB and LASHGARI [1993]). This literature suggests that inference concerning the spot and futures price dynamics should be based on Error Correction Models (ECM) where the error-correction components indicate i) the proportion of disequilibrium from one period that is corrected in a later period and ii) the relative magnitude of adjustments in each market towards equilibrium.⁴ Another important insight from this literature states that the spot and futures prices should share a common stochastic trend because spot and futures markets are essentially two different places to trade the same underlying commodity. Based on this feature, HASBROUCK [1995] proposes a measure of price discovery that is used in this study. In the following, the ECM and the common trend model is presented in the context of a very simple model of price dynamics inspired from HASBROUCK [1995].

Suppose, first, that a claim on some future cash flows is traded in two different markets, a cash market and a futures market. Obviously, it exists only one true value for this claim and we call this value the efficient price. As standard in the finance literature, we assume that the efficient price follows a random walk:

$$(1) \quad \mu_t = \mu_{t-1} + \eta_t$$

where the increments η_t are assumed to reflect new information about the future cash-flows.

The actual cash and futures price dynamics is driven by this common random walk and it may be specified by an unobservable component model:

$$(2) \quad P_t = K + \mu_t \mathbf{1} + \epsilon_t$$

where $P_t = (S_t \ F_t)'$ is a (2×1) price vector, S_t and F_t are the spot and the futures prices observed at time t , K is a (2×1) vector of means, $\mathbf{1}$ is a unit vector and ϵ_t is a vector of disturbances which is assumed to be a zero-mean covariance stationary stochastic process. The process ϵ_t allows spot and futures prices to deviate from the efficient price due to market specific phenomenon such as a liquidity pressure. Price discovery refers to the impounding of (new) information into spot and futures prices and is related to the contributions to the efficient price increments from the spot and futures markets.

Suppose, for example, that the informational content of orders and trades (other than arbitrage-based orders and trades) in one market is larger than the

4. See BANERJEE, DOLADO, GALBRAITH and HENDRY [1993] or LÜTKEPOHL [1993], chap. 13 for a general analysis of cointegration and see BRENNER and KRONER [1995] for an analysis of the link between arbitrage and cointegration.

informational content of orders and trades (other than arbitrage-based orders and trades) in the other market. These asymmetric contributions to the common efficient price discovery create a price discrepancy between the two markets that causes some investors to submit arbitrage orders. Therefore, arbitrage appears as an error-correction mechanism that prevents the spot and futures prices from diverging without bound. Furthermore, in our informational framework, the deviation from the cash and carry relationship disappears only when all the relevant information is shared by the two markets and impeded in the spot and the futures prices. As a result, cash and futures prices ultimately reflect the same information, as suggested by the common (unobservable) efficient price model.

Inference concerning the error correction mechanism may be obtained from an ECM for price changes and inference concerning the common (unobservable) efficient price may be obtained from the vector moving average (VMA) representation for the actual data. Additional motivation for these models is that ECM and VMA are alternative forms of a cointegrated system. In our bivariate framework, and due to the arbitrage constraint, S_t and F_t are expected to be cointegrated of order one, yielding a unique cointegrating vector. Following JOHANSEN [1988], the ECM for price changes is given by:

$$(3) \quad \Delta P_t = \sum_{i=1}^{p-1} \pi_i \Delta P_{t-i} + \alpha(\beta' P_{t-p} - \beta' K) + e_t$$

where the π_i are (2×2) coefficient matrices, α is a (2×1) vector of coefficients for the cointegrating vector, β is the (2×1) cointegrating vector and e_t is a (2×1) vector of serially-uncorrelated disturbances with $\text{Cov}(e_t) = \Omega$. Note that in our spot-futures framework β should be equal to $(1 - 1)'$. Furthermore, the coefficients of the vector α should indicate the proportion of the mispricing observed in a given period that is corrected in a later period as well as the relative magnitude of the adjustments in the spot and futures markets. The VMA specification is directly obtained from the ECM and is given by:

$$(4) \quad \Delta P_t = \sum_{i=0}^{\infty} \psi_i e_{t-i}$$

Assuming that $e_t = 0$ for $t < 0$, the cumulative price impact to an innovation arriving at time $t = 0$ may be obtained as:

$$(5) \quad \Delta P_0 + \Delta P_1 + \Delta P_2 + \dots = (\psi_0 + \psi_1 + \psi_2 + \dots)e_0$$

In the present case, the matrix sum $(\psi_0 + \psi_1 + \psi_2 + \dots)$ forms a (2×2) matrix whose rows must be identical because the long term response of each price to an innovation must be identical if the prices are not to diverge. Denoting ψ one of these (identical) rows, the variance of the efficient price may be obtained as:

$$(6) \quad \sigma_{\eta}^2 = \psi \Omega \psi'$$

In order to measure the contribution of each market to the price discovery, HASBROUCK [1995] proposes to compute the quantities S_i given by:

$$(7) \quad S_i = \frac{\psi_i^2 \Omega_{ii}}{\psi \Omega \psi'}$$

where i refers to the relevant market ($i = s, f$ for the spot and the futures markets, respectively). Due to the possibility of cross-correlation in price innovations, the matrix Ω may not be diagonal and may be replaced by its Cholesky factor. In this case, the price contribution of the market i is obtained by the quantity:

$$(8) \quad S_i = \frac{(\psi F)^2}{(\psi F) I (\psi F)'}$$

where F is the Cholesky factor (F is the lower triangular matrix such that $\Omega = F F'$) and where σ_{η}^2 is now given by $(\psi F) I (\psi F)'$.

Note that the Cholesky decomposition forces a potential important asymmetry on the system since a shock to the first variable affects the first variable initially, while a shock to the second variable has a contemporaneous effect on both variables. Then, the ordering of the variables matters and the price contributions will be computed for the two different orderings of the variables. The index contribution is maximized when index price is placed first and the futures contribution is maximized when the futures price is placed first.

3 The Data

Intraday transaction prices for the CAC 40 futures were obtained from MATIF SA for the period from January 3rd, 1995 to March 31st, 1995. Intraday stock quotes and prices were extracted for the same period from the CDs supplied by the Paris Bourse. We used the TMP and PIBOR of various maturities to evaluate the cost of carry of the futures. These rates are from DATASTREAMtm. The daily number of shares issued by each firm and the dividend data were also extracted from the CDs. Contrary to SHYY, VIJAYRAGHAVAN and SCOTT-QUINN [1996] who use data on the second nearest contract, we chose to use data related to the contract with the highest volume of trading which is, except for the few days preceding the expiration-day, the nearest contract. In order to sample the data, we retained the last transaction price and the last available bid and ask quotes at the end of each thirty-second length interval. Finally, data referring to the first and last five minutes of trading have been ignored due to specific behavior of prices at the opening and closing periods. Thus, the final time series include 50,020 price observations.

Two values of the index were computed, the first from the last transaction prices and the second from the mid-quote points. The rationale for the second index measure lies in the fact that transaction price index may induce mean-

reversion in the basis that would reflect stale price effect due to infrequent trading (e.g. MILLER, MUTHUSWAMY and WHALEY [1994]). Furthermore, the analysis of SHYY, VIJAYRAGHAVAN and SCOTT-QUINN [1996] suggests that this infrequent trading effect affects the results. Of course, staleness may also affect the mid-quote index, but quotes reflect more recent information than trades (we took into account the quotes available at the end of each interval while trades refer to previous market conditions). Furthermore, the transaction price index may be affected by the bid-ask bounce effect (e.g. ROLL [1984]) although this effect should be reduced due to the number of stocks in the index (e.g. STOLL and WHALEY [1990]).

The index value is corrected with the estimated cost of carry. The traditional formula is adapted to take into account the main features of the French market structure, the monthly settlement and the dividend tax-credit mechanism. A discussion of these features and an analysis of the mispricings is provided in ALPHONSE [1999].

4 Results

The tests of stationarity developed by DICKEY and FULLER [1981], PHILLIPS and PERRON [1988] and KWIATKOWSKI, SCHMIDT, PERRON and SHIN [1993] have been performed for the series. Results are presented in table 1 and indicate that stationarity is rejected for the level of the variables.

The results of the cointegration tests of JOHANSEN [1988] have also been performed for a VAR (variables in level) of order three and are reported in table 2.⁵ They indicate that one cointegration relationship exists between the cash and the futures markets, whatever the measure of the index retained.

Results of a likelihood test indicate that in each case the (normalized) cointegrating vector is not different from the expected value of $(1 - 1)$, the values of the χ^2 statistics being equal to 35.41 and to 29.33 for the transaction price index data and for the mid-quote index data, respectively. The estimates of the cointegration relationships are given in table 3. Note first that the estimates based on the transaction-price index (panel A) do not appear qualitatively different from the estimates based on the mid-quote index (panel B). Contrary to SHYY, VIJAYRAGHAVAN and SCOTT-QUINN [1996], this result indicates that the noise induced by the infrequent trading and the bid-ask bounce cannot be considered as a source of some misleading inference. This may be due to the difference in the maturity of the contract used in each study, essentially the second nearest contract in SHYY, VIJAYRAGHAVAN and SCOTT-QUINN [1996] and

5. Various lag selection tests have been performed indicating that about twenty lags may be considered in the estimated model. While such a long lag structure may be satisfactory on a pure statistical ground, it appears i) that a long lag structure decreases the economic appeal of considering the error correction term as a measure of the true market price correction, ii) that it makes little difference in the residuals estimates. Furthermore, estimates of π_{t-i} for $i > 2$ do not appear significantly different from zero. Then, the results retained and presented here are based on a VAR model with 3 lags.

the first nearest contract in the present paper. The negative sign of the estimates of $\pi_{f,f}$ is consistent with the bid-ask bounce effect suggested by ROLL [1984]. Still, note that the autocorrelation at lag one of the index is not significant, suggesting that the index returns are not affected by an infrequent trading effect. Taken as a whole, the estimates of the cross-autoregressive part of

TABLE 1
Unit Root Tests

Constraints	ADF	PP	KPSS
Panel A – Futures Prices			
Intercept and Trend	– 1.3277	– 1.5438	53.3252
Intercept	– 1.8681	– 1.8388	379.9463
None	– 0.0492	– 0.0229	–
Panel B – Transaction Price Index Value			
Intercept and Trend	– 1.3936	– 0.6615	54.3463
Intercept	– 1.9108	– 1.7877	382.9000
None	0.0077	0.0274	–
Panel C – Mid-Quote Index Value			
Intercept and Trend	– 1.0543	– 0.1064	54.4032
Intercept	– 1.7065	– 1.5271	382.8612
None	0.0103	0.0289	–

Note: ADF is for the Augmented Dickey-Fuller test (DICKEY and FULLER [1981]), PP is for the Phillips-Perron test (PHILLIPS and PERRON [1988]) and KPSS is for the KWIATKOWSKI-SCHMIDT-PERRON-SHIN test (KWIATKOWSKI, SCHMIDT, PERRON and SHIN [1992]). Critical values for the ADF and the PP statistics are equal to – 3.41, – 2.86 and – 1.95 for a 5 % risk and are equal to – 3.96, – 3.43 and – 2.58 for a 1 % risk for the model with intercept and time trend, the model with intercept only and the model with no intercept and no time trend, respectively. Critical values for the KPSS statistics are equal to 0.146 and 0.464 for a 5 % risk and are equal to 0.216 and 0.739 for a 1 % risk for the model with intercept and time trend and the model with time intercept only, respectively.

TABLE 2
Cointegration Tests of JOHANSEN [1988]

Eigen-value	Trace statistics	λ -max statistics
Panel A – The Transaction Price Index and the Futures		
0.0343	1690.93	1694.29
0.0001	3.35	3.35
Panel B – The Mid-Quote Index and the Futures		
0.0363	1789.59	1793.40
0.0001	3.51	3.51

Note: The critical values for the trace statistics are 15.197 and 3.962 for the first eigenvalue and the second eigenvalue, respectively. The critical value for the λ -max statistics are 14.036 and 3.962 for the first eigenvalue and the second eigenvalue, respectively.

the ECM indicate that it exists a feedback effect between the cash and the futures markets, but that the lead of the futures market on the cash market is much stronger than the reverse.

TABLE 3

The Error Correction Models

Estimates are based on the following specification of the ECM:		
$\Delta S_t = \pi_{0,S} + \sum_1^2 \pi_{i,S,S} \Delta S_{t-i} + \sum_1^2 \pi_{i,S,F} \Delta F_{t-i} + \alpha_S (S_{t-3} - F_{t-3}) + e_{S,t}$		
$\Delta F_t = \pi_{0,F} + \sum_1^2 \pi_{i,F,S} \Delta S_{t-i} + \sum_1^2 \pi_{i,F,F} \Delta F_{t-i} + \alpha_F (S_{t-3} - F_{t-3}) + e_{F,t}$		
	ΔS_t	ΔF_t
Panel A – The Transaction Price Index and the Futures		
$\pi_{0,i}, i = S, F$	- 1.0980 (- 37.0120)	0.1760 (4.8780)
ΔS_{t-1}	0.0070 (1.4200)	0.0370 (6.2410)
ΔF_{t-1}	0.0770 (18.3150)	- 0.0480 (- 9.3380)
ΔS_{t-2}	- 0.0100 (- 2.1040)	0.0070 (1.1430)
ΔF_{t-2}	0.0910 (22.0020)	- 0.0020 (- 0.3280)
$\alpha_i, i = S, F$	- 0.0570 (- 37.1130)	0.0090 (4.9610)
Panel B – The Mid-Quote Index and the Futures		
$\pi_{0,i}, i = S, F$	- 0.7780 (- 34.8070)	0.1740 (5.1460)
ΔS_{t-1}	0.0030 (0.6280)	.0520 (7.1360)
ΔF_{t-1}	0.0610 (17.6950)	- 0.0500 (- 9.7780)
ΔS_{t-2}	- 0.0150 (- 3.0480)	0.0080 (1.1130)
ΔF_{t-2}	0.0770 (22.3150)	- 0.0020 (- 0.3570)
$\alpha_i, i = S, F$	- 0.0420 (- 34.8770)	0.0090 (5.2370)

Note: t-stat in parenthesis.

Inspection of the estimates of the adjustment factor coefficients (the elements of the vector α) indicates that each market adjusts to the new equilibrium price following a price discrepancy, with a clear dominance for the futures market. This is true because of the value of the coefficients, but also because of the sign of the estimates. To see this, consider the two following polar cases. If new information is first aggregated in the futures prices, then, *ceteris paribus*, the futures dynamics drives the basis dynamics and induces a positive contemporaneous correlation between the two.⁶ Due to arbitrage activity, the movement in the basis induces a spot market price adjustment, which in turn induces a positive correlation of order p between the basis and the index price dynamics. Opposite to this view, if the information flow reaches the spot market first, it must be the case that the basis and the spot price dynamics are contemporaneously negatively correlated, and that the basis and the futures price dynamics are characterized by a negative correlation of order p .

Recalling now that the index is first listed in the vector P_t and that the cointegrating vector is not statistically different from $(1 - 1)$, it is straightforward to see that $\alpha\beta'P_{t-3} = \alpha(Index_{t-3} - Futures_{t-3})$ where the difference $Index_{t-3} - Futures_{t-3}$ is just $(-1) \times$ the basis evaluated at time $t - 3$. Then, in the current model, a negative correlation of order 3 should be observed between the index return and the correction term if the information is first aggregated in the futures price, and a positive correlation of order 3 should be observed between the futures return and the correction term if the information is first

TABLE 4
Contribution to the Price Discovery

The price contributions are obtained from the VMA specification and are given by $\frac{\psi_i^2 \Omega_{ii}}{\psi \Omega \psi'}$ and by $\frac{(\psi F)^2}{(\psi F) I (\psi F)'}$ for the cases of no-orthogonalization and Cholesky orthogonalization, respectively. Ω is the covariance matrix of ϵ_t , ψ_i is one of the (identical) rows of the matrix sum $(\psi_0 + \psi_1 + \psi_2 + \dots)$ and F is the Cholesky factor. The subscript i refers to the relevant market ($i = S, F$ for the spot and the futures markets, respectively). The index contribution is maximized when the index price is placed first and the futures contribution is maximized when the futures price is placed first.				
	Transaction Price Index		Mid-Quote Index	
Orthogonalization	Spot	Futures	Spot	Futures
Max. the index contribution	5.21	94.79	5.11	94.89
Max. the futures contribution	1.25	98.75	1.13	98.87
No orthogonalization	1.27	96.14	1.14	96.32

6. The traditional measure of the basis is the futures price minus the spot price.

aggregated in the index value. The empirical evidence suggests that although the two markets contribute to the price discovery, the major part of the price discovery is in fact achieved in the futures market.

The evaluation of the contributions to the price discovery is presented in table 4. The orthogonalization of residuals is obtained by the method of Cholesky. Because in this case the ordering of the variables matters, we report the evaluation that maximize the contribution of the index and the evaluation that maximize the contribution of the futures (line 1 and line 2 of table 4, respectively). We also report in the third line of the table 4 the results of the variance decomposition based on unorthogonalized residuals.

Taken as a whole, the results indicate that at least ninety-five percent of the price discovery is achieved in the futures market (the maximum of the index contribution is 5.21 percent and the minimum is 1.13 percent) and is consistent with the previous results of HASBROUCK [1995].

5 Conclusions

This study is concerned with the aggregation of information in stock index cash and futures markets. It has been recalled that the efficient price discovery process is well related to two specifications of a set of cointegrated variables, the error correction form and the common trend form. The empirical evidence, based on French CAC40 index intraday data, is consistent with the fact that mispricings originate mainly from information arrivals in the futures markets, and that in turn these mispricings induce stock price adjustments related to information transmission from the futures to the spot market. The price discovery process has been shown to be dominated by the futures market in that at least ninety-five percent of the price discovery is achieved in the futures market. Taken as a whole, these results indicate that the arrival and the aggregation of new information into prices is achieved primarily through futures trading and that the stock market adjusts quickly to the new equilibrium price. ■

• References

- ALPHONSE P. (1999). – « Dividend Tax Credit, Monthly Settlement and the Pricing of Stock Index Futures », *Working Paper*, ESA-University of Lille 2.
- BANERJEE A., DOLADO A.J., GALBRAITH J.W., HENDRY D.F. (1993). – *Co-integration, Error-correction, and the Econometric Analysis of Non-Stationary Data*, Oxford University Press.
- BIAIS B., FOUCAULT T., SALANIÉ F. (1998). – « Floors, Dealer Markets and Limit Order Markets », *Journal of Financial Markets*, 1, pp. 253-284.
- BOSSAERT P. (1993). – « Transaction Prices when Insiders Trade Portfolios », *Finance*, 14, pp. 43-60.
- BRANNEN P.P., ULVELING E.F. (1984). – « Considering an Informational Role for a Futures Market », *Review of Economic Studies*, 51, pp. 33-52.
- BRAY M. (1981). – « Futures Trading, Rational Expectations, and the Efficient Market Hypothesis », *Econometrica*, 49, pp. 575-596.
- BRENNER R.J., KRONER K.F. (1995). – « Arbitrage, Cointegration, and Testing the Unbiasedness Hypothesis in Financial Markets », *Journal of Financial and Quantitative Analysis*, 30, pp. 23-42.
- CHAN K., CHAN K. C., KAROLYI G. A. (1991). – « Intraday Volatility in the Stock Index and Stock Index Futures Markets », *Review of Financial Studies*, 4, pp. 657-684.
- CHAN K. (1993). – « Imperfect Information and Cross-Autocorrelation among Stock Prices », *Journal of Finance*, 48, pp. 1211-1230.
- DE JONG F., NIJMAN T. (1997). – « High Frequency Analysis of Lead-Lag relationships between Financial Markets », *Journal of Empirical Finance*, 4, pp. 259-277.
- DICKEY D.A., FULLER W.A. (1981). – « Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root », *Econometrica*, 49, pp. 1057-1072.
- GROSSMAN S. J. (1977). – « The Existence of Futures Markets, Noisy Rational Expectations, and Informational Externality », *Review of Economic Studies*, 44, pp. 431-449.
- HASBROUCK J. (1995). – « One Security, Many Markets: Determining the Contributions to Price Discovery », *Working Paper*, Stern School of Business, New York University.
- JOHANSEN S. (1988). – « Statistical Analysis of Cointegration Vectors », *Journal of Economics Dynamics and Control*, 12, pp. 231-254.
- KUMAR P., SEPPI D. (1994). – « Information and Index Arbitrage », *Journal of Business*, 67, pp. 481-509.
- KWIATKOWSKI D., SCHMIDT P., PERRON P., SHIN Y. (1992). – « Testing the Null Hypothesis of Stationarity Against the Alternative of a Unit Root: How Sure are we that Economic Time Series have Unit Root », *Journal of Econometrics*, 54, pp. 159-178.
- LO A., MACKINLAY A.G. (1990). – « An Econometric Analysis of Non-Synchronous Trading », *Journal of Econometrics*, 45, pp. 181-211.
- LÜTKEPOHL H. (1993). – *Introduction to Multiple Time Series Analysis*, Second edition, Springer-Verlag.
- MILLER H.M., MUTHUSWAMY J., WHALEY R.E. (1994). – « Mean Reversion of S&P 500 Index Basis Changes: Arbitrage Induced or Statistical Illusion », *Journal of Finance*, 49, pp. 479-513.
- PHILLIPS P.C.P., PERRON P. (1988). – « Testing for a Unit Root in Time Series Regression », *Biometrika*, 75, pp. 335-346.
- ROLL R. (1984). – « A Simple Implicit Measure of the Effective Bid-Ask Spread in an Efficient Market », *Journal of Finance*, 39, pp. 1127-1139.
- SHYY G., VIJAYAGHAVAN V., SCOTT-QUINN B. (1996). – « A Further Investigation of the Lead-Lag Relationship between the Cash Market and the Stock Index Futures Markets with the use of Bid/Ask Quotes: the Case of France », *Journal of Futures Markets*, 16, pp. 405-420.
- STOLL H., WHALEY R. (1990). – « The Dynamics of Stock and Stock Index Futures Returns », *Journal of Financial and Quantitative Analysis*, 25, pp. 441-468.
- SUBRAHMANYAM A. (1991). – « A Theory of Trading in Stock Index Futures », *Review of Financial Studies*, 4, pp. 17-51.
- WAHAB M., LASHGARI M. (1993). – « Price Dynamics and Error Correction in Stock Index and Stock Index Futures Markets », *Journal of Futures Markets*, 13, pp. 711-742.