BANCA D'ITALIA
EUROSISTEMA

Temi di Discussione

(Working Papers)

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Number 1083

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ISSN 1594-7939 (print)
ISSN 2281-3950 (online)

Printed by the Printing and Publishing Division of the Bank of Italy

BTP FUTURES AND CASH RELATIONSHIPS: A HIGH FREQUENCY DATA ANALYSIS

by Onofrio Panzarino*, Francesco Potente** and Alfonso Puorro***

Abstract

The paper analyses the interactions between the 'cash' market (MTS Cash) and the futures market (Eurex) of Italian government bonds in terms of liquidity, price correlation and volatility. Based on daily data, the growth of the Eurex market seems to support the tightening of the bid-ask spread of MTS Cash, all things being equal, thus confirming a healthy and efficient link between cash and futures markets. Against this backdrop, a high frequency analysis highlights some episodes of partial divergence between price developments of futures and cash markets, which might be related to differences in the microstructures of the two markets. The futures market is order driven while the cash market is quote driven; furthermore different types of participants are active in each market. At higher frequencies, episodes of unidirectional propagation of volatility shocks from BTP futures to the MTS Cash market materialize, with potential spillovers on cash market liquidity conditions. In this regard, it is also important to consider the role played by High Frequency Traders, whose activity in futures markets may well contribute to explaining the peculiarities in price dynamics highlighted by high frequency data.

JEL Classification: G12, G13, G14
Keywords: market liquidity, HFT, volatility spillover, government bonds.

Contents

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1. Introduction[1]

The MTS market, introduced in Italy in 1988, is a regulated market where Italian Government securities are negotiated. It is a quote driven market and it is characterized by the presence of players with market making obligations, committed to quote on a continuous basis on both sides of the market. Participating dealers could conclude transactions only by matching market makers' proposals. An average daily turnover of 4.8 blns was negotiated during 2015 on the MTS, which continues to play a dominant role as an interdealer platform on the Italian Government Bond secondary market.

BTP futures were re-introduced on the German Eurex market on September 14th 2009[2], when the financial crisis broke the strong correlation among euro denominated sovereign bonds. The Eurex is an order driven market: it allows for direct booking, amendment and cancellation of orders on dealers' negotiation books; transactions derive from the interaction of participating dealers' orders.

Trading volumes negotiated on the BTP futures market were initially extremely low (see Bank of Italy, 2010), but they gradually increased up to a daily turnover in line with other futures on European Government bonds[3]. Improved liquidity conditions of BTP futures market, which came along with the increase in trading activity, also made BTP futures contracts a very valuable instruments for market making activity, thus significantly strengthening interconnections between BTP futures and MTS Cash market (Bank of Italy, 2015) [4].

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[1] Any views expressed in this paper are the authors and do not necessarily represent those of the Bank of Italy. We thank Claudio Impenna and Roberto Violi for sharing their experience, insights and continuous feedback. Special thanks go to Gioia Cellai and Gaetano Marseglia for their great contribution, helpful discussions and for giving us the time and the opportunity to cooperate and investigate this topic. We also would like to thank anonymous referees for their precious suggestions to the text.

[2] Between 1991 and 1999, the BTP futures on ten-year maturity was traded on the LIFFE market in London and the Italian Mif. With the introduction of the euro, the convergence of several European countries yields reduced spreads between government bonds, thereby removing the need for different futures for different countries.

[3] In terms of open interest, the open positions of BTP, OAT and Bund futures, are respectively equal to 223,714, 188,239 and 1,356,000 (as of 28 April 2015). Furthermore, in April the average number of daily contracts traded amounted respectively to 88,000, 63,000 and about 476,000.

[4] As an example, on July 20th 2015 the activity on the MTS Cash market deeply suffered from the late opening of the BTP futures market, due to technical problems on the EUREX platform. The future market opened around 10:30 and until then only 15 mln contracts were concluded on the MTS Cash, compared with an average turnover of around 1 bln; average bid-ask spreads was particularly large as well.

In addition, a mature and efficient future market may well contribute to the liquidity of the secondary market by facilitating price discovery. Futures support operational flexibility and allow for a large number of trading strategies that would be hardly viable through cash market only (see Annex A).

Liquidity and efficiency of the MTS Cash market are crucial for a smooth and effective placement of Italian Government bonds. Therefore, it is important to analyze the relationship between the two markets, in a view to assess whether and to what extent the BTP futures market really affects the efficiency of the MTS Cash. The relationships between spot and futures market were widely analyzed in market microstructure studies. Garbade and Silber (1983) show that in commodities markets, in most cases, futures lead spot markets in terms of price discovery and they argue that such relationship is directly affected by liquidity and market size. Furthermore, the authors highlight that the efficiency of the futures market as well as the consistency of prices on the spot and futures market are extremely important for hedging activity. Koontz et al. (1990) also investigate the spatial price discovery mechanism in the livestock market pointing that price discovery process is dynamic and directly influenced by the structure of the market. Other several works investigate this topic and generally support a significant bidirectional information flows between the two markets (see Scalia, 1998) or document a dominant role usually played by futures contracts, above all in commodity markets (Moosa, 2002; Zapata et al., 2005; Fu and Qing, 2006) and treasury bond market as well (Brandt et al., 2007).

More recent studies, based on high frequency data and specifically focused on the BTP futures and MTS Cash markets, confirm the leading role of the futures market compared to the cash market in terms of price discovery. Pelizzon et al. (2014) highlight the impact of credit risk premia on MTS Cash liquidity conditions, while Darbha and Dufour (2015) analyze the implications of liquidity on yield spreads. Rittler (2009), with regard to a completely different market (CO2 emission rights in the EU), shows that - based on high frequency data - the future market leads the spot market in terms of transmission of volatility shocks (volatility discovery). With regard to spillover analysis on other markets, the work of Prasad et al. (2014) has to be mentioned, as well as Conefrey and Cronin (2013) on European bond markets. Such papers are based on a spillover index, first introduced by Diebold and Yilmaz (2009, updated in 2012);

however, such indicator is not easily adaptable to high frequency analyses[5]. Frijns et al. (2013) work elaborates on the causal relationship between an equity volatility index (VIX[6]) and the related future (VXF) within an econometric framework based on Granger Causality test. Such framework was also applied to very high frequency data (15 seconds). This work highlights a bi-directional causality relationship between the two volatility indices.

Frino et al. (2015) highlight the relationship between bid/ask spreads on the equity market, traded volumes and volatility. The methodological framework developed in their paper is the starting point of the analysis carried out in the first part of our Study. Such framework was broadened and adapted so as to include a proxy of the development of the BTP future market as an explanatory variable of bid/ask spreads on BTPs traded on the MTS Cash market.

The results of the first part of the Study, based on daily data, suggest that - in general - the development of the BTP future market may support the compression of MTS bid-ask spreads, with a potentially positive impact on hedging and market making activity. The second part of the Study, based on high frequency data, shows peculiar developments in the correlation between BTP futures and the *cheapest-to-deliver*[7] bond (as correlation decreases along with increase in data frequency) and a leading role of futures volatility on cash volatility. Such peculiarities, which start to emerge at higher frequency, might reflects different market technological characteristics and different players behavior. In this regard the presence of some specific traders (High Frequency traders - HFT), that operates at such high frequencies, may idiosyncratically affects assets prices dynamics on markets where they operate.

Against this backdrop, it can be argued that the presence of high frequency traders may on its turn affect market efficiency as well. Several analysts highlight that HFTs may positively

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[5] The time series adopted for the estimation of the parameters used for the construction of the indicator are mostly daily or drafted to this frequency, although based on intraday data. At this regard, in our work, we also tried to implement the Diebold and Yilmaz indicator for high frequencies analysis, but it provides no clear guidance. Analysis are underway in order to get a proper fitting of indicator for further research.

[6] The VIX index is a measure of the implied volatility of the US stock market.

[7] In general futures contract provides a list of bond that the seller (*short-position*) can deliver to the buyer (*long-position*) at maturity. This list, called *deliverable list*, is usually provided by the market where the futures contract is listed. At the delivery date of a futures contract the agent with the short position in the BTP futures contract has the right to choose the specific bond to deliver and usually the cheapest bond to purchase in the market is most likely to be considered: the *cheapest-to-deliver* (CTD) bond. For the Long-Term Euro-BTP Futures contract the contract terms specify that the underlying instrument is a coupon-bearing debt security issued by the Republic of Italy (BTP), with a remaining life of 8.5 to 11 years and an original maturity no longer than 16 year.

contribute to market liquidity, supporting the compression of bid/offer spreads and reducing transaction costs. In addition, according to some authors, HFTs would contribute to better price discovery (Angel et al., 2010). On the other hand, specialized press as well as non-high frequency traders argue that the most aggressive practices applied by HFTs may even generate situations encompassing a high probability of market inefficiency, aimed at increasing their profit opportunities. In this regard, adverse selection, shadow liquidity, information asymmetries and front running phenomena (Puorro, 2013) are often mentioned among the negative effects of a massive HFT presence. From a different perspective, the recent paper by Caivano (2015) shows that, at least on the Italian equity market, a significant growth in HFTs' activity may bring about a non-negligible increase in yields intraday volatility. Jiang et al. (2014) show that HFTs activity in the US Treasury market may contribute to an increase in volatility in the immediate aftermath of the release of economic news.

In this regard, empirical results of our study highlight risks that - in times of market turmoil - an increase in HFTs activity on the BTP futures market may favor the transmission of volatility spikes to the spot segment, with negative consequences on the liquidity conditions of Italian Government bond secondary market.

Section 2 introduces the data-set employed in the empirical analysis. Section 3 illustrates how the growth of the BTP futures market contributed to MTS market liquidity. Section 4 focuses on correlation developments between selected securities prices traded on the two markets. Section 5 compares volatilities on various frequencies and it analyses volatility spillover risks across markets. Section 6 considers the potential implications of volatility spillover for the liquidity of BTP secondary market, and Section 7 concludes.

2. Dataset and descriptions of methodologies

2.1. The dataset

We rely on two different data-sets, one for a longer term analysis (daily observations) and another for the high-frequency analysis (based on *tick-by-tick* quoting price information). The long-term analysis aims to assess if the introduction of BTP futures market and its development helped in improving the Italian BTP secondary market liquidity conditions. The data-set used includes daily observations covering the time span between 20th September 2006 to 21st august

2015 for: 10-year Italian sovereign bond benchmark *bid-ask* spread, 10-year German Bund yields and the daily turnover traded on MTS Cash and BTP futures market. Table 1 provides main descriptive statistics for above mentioned time series.

High-frequency analysis regards the quoting activity observed on MTS Cash market and BTP futures market (*Eurex*). In order to study their interactions, quoted *Bid* and *Ask* prices are collected from: Long-term (10-year) BTP future contract with maturity September 2015[8] and the related *cheapest-to-deliver* (CTD), that in the period considered in our analysis it turned out to be the BTP 5% March 2025 (shown as *cash 1*). In addition, a similar analysis on two different cash securities with maturity similar to CTD were carried out: BTP 3.75% 09/24 (*cash 2*) and BTP 2.5% 12/24 (*cash 3*), both included in the basket of the deliverable future during the period under review.

The initial dataset consists of intraday tick-by-tick observations regarding 41 contiguous trading days between June 29 until August 28 2015 (an average is calculated when several price changes occur within a single second). A data re-sampling process was subsequently carried out across several time frequencies, from 1 second to 15 minutes. In order to preserve the information content of the data used, in the re-sampling process we always consider the last observation available in the original dataset. In this way we obtain several distinct dataset, one for each frequency considered, and all characterized by equally-spaced observations. The criteria adopted is slightly different from the more common *"fill-in"*[9] technique usually adopted in case of missing observation or when dealing with not regularly spaced datasets. In place to consider the closest available observation (regardless if the previous or next one available), we employ the last observed one indeed, because (dealing with quoting prices) representative of the effective, still available proposal. Finally, for each business day is considered only the time window that concentrate almost the whole trading activity (from 9:30 AM to 5:00 PM). Table 2 presents summary statistics for the *log-returns* of the considered assets.

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[8] IKU5 instrument on Bloomberg. Italian government bond futures are quoted on four different delivery months (March, June, September and December) and are written on a theoretical 10 year bond with a coupon of 6%; each contract has a notional value of 100.000€ and a minimum price change (tick) of 0.01€; therefore one contract position exposes the owner to +/- 10€ changes in values for every price tick.

[9] The "fill-in" technique is largely adopted in literature in order to deal with missing data in time series analysis (see Girardi and Impenna, 2013; Upper and Werner, 2002).

In the following sections we describe the econometric tools used to investigate correlations, volatilities and liquidity transmissions in the Italian *spot* and *futures* markets.

2.2. Bivariate GARCH with BEKK specification

Economic literature developed a large variety of univariate GARCH-type models that properly capture time series volatility dynamics. Because more interested in modeling the mutual relationship between two markets, we adopt a multivariate GARCH model. In such a way we had the possibility to simultaneously estimate both volatility and correlation of the two considered time series. In the context of VECH-like[10] model we employ the GARCH-BEKK specification introduced by Engle and Kroner (1995) and largely adopted in literature because of the advantage of a relatively small number of parameters that have to be estimated (11 in place of 21 for the bivariate case). However we decide to not employ a multivariate GARCH model for datasets with observation collected at frequencies above 5 minutes. This also to consider the great impact of the microstructure noise that arises at such high sampling frequencies. The BEKK representation describes the conditional covariance dynamic using the following (2×2) matrix structure:

$$\boldsymbol{H_t} = \boldsymbol{C} \cdot \boldsymbol{C'} + \sum_{i=1}^{m} \boldsymbol{A_i}(\boldsymbol{\varepsilon_{t-i}}\boldsymbol{\varepsilon'}_{\boldsymbol{t-i}})\boldsymbol{A'_i} + \sum_{j=1}^{s} \boldsymbol{B_j}\boldsymbol{H_{t-j}}\boldsymbol{B'_j} \qquad (1)$$

where A_i, B_j and C are (2×2) coefficient matrices; C is an upper triangular matrix while A_i e B_j are symmetric and positive definite. This model specification automatically guarantees the positive definiteness of the conditional covariance matrix H_t and allows to dynamically captures the mutual interdependence between the volatility series. In particular, while the non-diagonal elements of matrix B measure the extent to which the conditional variance of one market is correlated with the lagged variance of the other market, the diagonal elements depict the effects on current squared volatilities caused from their own past. In case of a GARCH-BEKK(1,1) the general functional form expressed in (1) reduces to:

$$\boldsymbol{H_t} = \boldsymbol{C} \cdot \boldsymbol{C'} + \boldsymbol{A}(\boldsymbol{\varepsilon_{t-i}}\boldsymbol{\varepsilon'}_{\boldsymbol{t-i}})\boldsymbol{A'} + \boldsymbol{B}\boldsymbol{H_{t-j}}\boldsymbol{B'} \qquad (2)$$

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[10] The diagonal representation of the VECH model (see Bollerslev et al., 1988) requires a large number of parameters to be estimated (21 in the bivariate case).

with

$$A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}, \quad B = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \text{ and } C = \begin{bmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{bmatrix}.$$

2.3. Realized Measures: Volatility and Correlations

In recent time the volatility literature has steadily progressed toward the use of higher-frequency data and recent works has clarified the comparative desirability of alternative volatility estimators. The so-called *realized measures* are placed in this context. Andersen and Bollerslev (1998) show that, under the usual assumption that log asset prices evolve as a diffusion process, *realized volatility* and *correlation* computed from high-frequency intraday returns are effectively error-free[11] measures. Moreover, such estimators are easily constructed (respectively sum of intra-period high-frequency squared returns or cross products returns), they allow to limit the effect of possible market microstructure noise effects (Andersen et al., 2001, 2003) and they are recognized as being the closest estimate of the true latent integrated volatility (Andersen et al., 2005). The first quantity we computed is the *Realized Variance (RV)* measure, formally defined through the following formula:

$$\boldsymbol{RV_t^f = \sum_{n=1}^{N^f} r_{n,t}^2} \qquad (3)$$

where RV_t^f is the *Realized Variance* referred to the $(t-1, t)$ time interval, $r_{n,t}^2$ is the n^{th} squared logarithmic price variation observed at the considered frequency *f* and N^f is the total number of the observation that falls in each time interval (in our case a 5-minute time interval is adopted). We iterate this procedure for six sampling frequencies (*f = 1 sec, 3 sec, 5 sec, 10 sec, 15 sec, 30 sec*). Afterwards a *Realized Volatility* (*RVol*) measure is simply computed as the square root of the abovementioned *Realized Variance* and expressed in daily percentage points using the following formula:

$$\boldsymbol{RVol_t^f = 100 \cdot \sqrt{day^f \cdot RV_t^f}} \qquad (4)$$

[11] Estimated realized volatilities and correlations are "error-free" in the sense to result approximately not affected by measurement error (see Andersen and Bollerslev, 1998).

where the day^f coefficient indicates the number of daily observations at the sampling frequency *f*. Similar methodologies as previously described are subsequently used to compute the following *Realized Covariance (Rcov)* e *Realized Correlation (RCor)* measures:

$$\boldsymbol{RCov_t^f} = \sum_{n=1}^{N^f} \boldsymbol{r'_{n,t} \cdot r''_{n,t}} \qquad \boldsymbol{RCor_t^f} = \frac{\boldsymbol{RCov_t^f}}{\sqrt{\boldsymbol{RV{\prime}_t^f \cdot RVl''^f_t}}} \qquad (5)$$

where the $r'_{n,t}$ and $r''_{n,t}$ are the logarithmic price variations observed on two different assets. Afterwards a *kernel approach* is employed in order to smoothly estimate the probability density functions of the above mentioned quantities. In our case, for each considered sampling frequency of the considered *Realized Correlation* ($RCor_t^f$) and *Realized Volatility* ($RVol_t^f$) measures, the *kernel density estimator* are:

$$\boldsymbol{F_{RCor_t^f}(x)} = \frac{\mathbf{1}}{\boldsymbol{Th}} \cdot \sum_{t=1}^{T} \boldsymbol{k}\left(\frac{\boldsymbol{x - RCor_t^f}}{\boldsymbol{h}}\right), \quad \boldsymbol{F_{RVol_t^f}(x)} = \frac{\mathbf{1}}{\boldsymbol{Th}} \cdot \sum_{t=1}^{T} \boldsymbol{k}\left(\frac{\boldsymbol{x - RVol_t^f}}{\boldsymbol{h}}\right) \qquad (6)$$

where *T* is the length of the considered time series, *h* is the *bandwidth* (a parameter that controls the smoothness of the resulting probability density curve and it is usually chosen according to some rules, in order to produce reasonably smooth densities) and $k(\cdot)$ is the *Gaussian kernel function* defined with the following formula:

$$\boldsymbol{k(x)} = \frac{\mathbf{1}}{\sqrt{\mathbf{2}\boldsymbol{\pi}}} \boldsymbol{e}^{-\frac{1}{2}x^2} \qquad (7)$$

2.4. The Granger Causality Test

We perform the *volatility spillover* analysis in an attempt to identify potential transmission effects between the two considered markets, employing a sequence of *Granger Causality Tests* (Granger, 1969). Such econometric tool, largely adopted in literature, assumes a time series *X* to “cause” (in the sense of Granger) another series *Y*, if the former is useful in forecasting the latter within a given time lag. More rigorously, Granger causality concept is defined as follows:

$$\boldsymbol{X} \overset{\boldsymbol{G-cause}}{\boldsymbol{-}} \boldsymbol{Y} \Leftrightarrow \mathbb{E}(\boldsymbol{y_t}|\boldsymbol{y_{t-1}}, \boldsymbol{y_{t-2}}, \dots, \boldsymbol{x_{t-1}}, \boldsymbol{x_{t-2}}, \dots) \neq \mathbb{E}(\boldsymbol{y_t}|\boldsymbol{y_{t-1}}, \boldsymbol{y_{t-2}}, \dots) \qquad (8)$$

If a bivariate VAR model of order p is employed to describe y_t e x_t dynamics, the G-causality condition recalled in (8) may be tested relying on the following joint hypothesis:

$$\boldsymbol{H_0 : \beta_1 = \beta_2 = \cdots = \beta_p = 0} \qquad (9)$$

where the β_i coefficients capture the cross-interactions between y_t and the lagged values of x_t. If the null hypothesis holds, we can exclude that *X* Granger-cause *Y*. The inference on such parameters happens through a Test statistic that, under the null hypothesis, follows a *Fisher* distribution with p and $T - 2p - 1$ degrees of freedom (where p is the *order*, or *lag*, adopted in the VAR specification and *T* is the time series length). Significantly large values of the above mentioned *F*-Statistic may allow to reject the null hypothesis, reported in (9), detecting the presence of a causal relationship (in the sense of Granger) between the two series.

Finally, before conducting Granger causality tests we check across all the sampling frequencies if the considered time series are stationary. We adopt the *Augmented Dickey Fuller (ADF)* test in order to detect the presence of unit root. Resulted ADF statistics are reported in Table 3 and suggests that we can strongly reject the presence of a unit root in all considered time series, that means we can assume all series be stationary across all frequencies.

3. BTP futures: market developments and contribution to MTS liquidity

The implications in terms of liquidity for MTS market arising from the development of BTP futures were evaluated adopting an econometric analysis. The starting point is represented by a simple functional specification that relates the equities bid-ask spread to trading volumes and volatility (Frino et al., 2015). In particular, a functional relationship between the logarithm of the bid-ask spread on the generic ten-year BTP (dependent variable) and the logarithms of the traded volumes on the MTS and the volatility of the return of the ten-year BTP has been tested as part of a simple OLS scheme (calculated on a monthly floating window).

The results related to the functional specification, not presented in the text, show a direct relationship between increased volatility and the widening of the bid-ask spreads, where an increase in the traded volumes on the MTS favors spread tightening. However, the Durbin Watson[12] statistics calculated on this specification suggest the presence of a strong positive

[12] The Durbin-Watson is a statistical test used to detect the presence of residual autocorrelation in a regression analysis. The value of the statistic is always between 0 and 4; a value of 2 indicates presence of autocorrelation while small index values (high) show positive correlation (negative) between residues.

auto-correlation in the error terms, as also indicated by the residual correlogram[13]. In addition, a very low R^2 value shows little explanatory power, thus suggesting an extension to the mentioned specification.

In order to assess the contribution to the MTS liquidity related to the development of the futures market, the functional specification has therefore been enriched by the inclusion of other explanatory variables. In particular, the daily traded volume of the derivative was introduced, as a proxy of the BTP futures market size. In addition, the spread between the BTP ten year yield and the yield of Bund with similar maturity was added. It can be argued that an increase in risk premium required by investors to hold BTPs (as measured by the BTP-Bund spread) may also negatively reflect on their liquidity (Pelizzon et al., 2014). Finally, the functional specification has been extended with some lag terms of the bid-ask spread in an attempt to reduce the problem of auto-correlation of the error term. Results are reported in Table 4.

The analysis seems to support the idea that the increase in the size of BTP futures market may positively affect the liquidity of MTS Cash market. On the other hand, the widening in BTP-Bund spread (and the related increase in risk premium) may adversely affect the liquidity of the BTP. Furthermore, according to the Durbin Watson statistic no problems of auto-correlation among lags of the error term seem to emerge (see also the correlogram reported in Figure 1).

The value of R^2 shows a not negligible explanatory power of the proposed specification. In order to take into account potential problems of multi-collinearity arising from the strong correlation among the increase in MTS traded volumes and the increase in futures traded volumes, a two-steps regression procedure has been carried out. In the first step, the futures traded volume has been regressed against the MTS traded volume. The errors of the first step regressions have been used as regressor instead of the futures volumes in the functional form; results are reported in Table 5.

The analysis seems to confirm empirically the positive effect of the development of the BTP futures market on the liquidity of MTS Cash market in terms of tightening of bid-ask spread,

[13] The correlogram is a representation technique that depicts the value of the autocorrelation of a time series reported with different delays (x-axis). From an inferential point of view, the represented horizontal stripes allow to identify the confidence interval (95%) of acceptance of the hypothesis of correlation values equal to 0. Therefore, in a nutshell, the out of band autocorrelations are to be considered as "statistically significant. "

other being equal. Therefore, the development of the derivative market seems to have actually supported the liquidity of the secondary, cash market. In the following paragraphs an high frequency analysis is carried out in order to analyze more thoroughly the interconnections between the two markets in terms of correlation and propagation of volatility shocks.

4. Correlation analysis

The correlation analysis between BTP futures and CTD returns has been first of all carried out through the estimation of a bivariate GARCH model as described in Section 2.

The graphs outlined in Figure 2 show episodes of correlations breaks which are promptly reabsorbed. Analyzes based on GARCH estimates do not seem reliable for higher frequencies (Andersen, 2005). Therefore, specific analysis were adopted on the basis of descriptive statistics. In addition, for higher frequencies, in order to verify that the behavior of futures-CTD correlations does not represent a "mechanical" effect of the increased detection of frequencies[14], an analysis of the dynamics of the correlation of pairs of cash securities with the same maturity was also conducted.

Plots reported in Figure 3 show the correlations dynamics at different sampling frequency between the BTP futures and its relative CTD bond (*cash 1*). For each trading day, the correlation between log-return of pairs of above mentioned securities was calculated, allowing to carry out a cross-sectional analysis of the sample estimates. This procedure was re-iterated for each sampling frequency. Figures show that the average correlation between futures and CTD is close to one for lower frequencies, as well as the correlation between cash securities with similar characteristics.

Therefore, as the sampling frequency increases, a progressive reduction of the correlation for all pairs of titles analyzed is observed on average. However, this effect seems more emphasized for the futures-CTD couple that, at least in theory, should be the most similar pair of titles. In particular, at the 1 second frequency the average correlation between futures and CTD is lower (about 30%) than the correlation of the other couples of cash securities.

[14] Increasing the frequency of detection, even minimum time discrepancies between quoted prices of securities on different markets are more likely, thus showing a reduced correlation.

This phenomenon is more evident if we exclude from the data set the days when auctions of ten years BTP are carried out (June 30, July 13, July 30 and August 28; see Figure 4). At this regards, the price dynamics in the moments immediately before and after the auctions could reflect idiosyncratic behaviors due to changes in market makers inventories. Those adjustments may produce a greater impact on the cash market, thus affecting the correlation between pairs of cash securities.

However, computing daily correlations based on high frequency data may significantly suffer from outliers observations. Even in large samples, it can't be excluded that few observations may influence the overall correlation estimate if values are considerably divergent from others. In our case, correlations estimated in datasets with a sampling frequency below 10 seconds may potentially overweight atypical price dynamics observed in tight time intervals, for example if pretty instantaneous bid-ask widening shocks occurs. We thus decide to make use of realized measures mentioned in Section 2, as a straightforward way to properly cope with such technical drawbacks. In this regard, intraday realized correlations dynamics are captured at four distinct sampling frequencies and kernel density estimators are adopted in order to deal with outliers issues. Results are shown in Figure 5 and support what emerged from the previous box plots.

The partially divergent trends between futures and CTD prices arising at high frequencies may be explained by differences in some structural features of the MTS and futures markets that contribute to shape the price discovery processes across the two trading venues. First of all, the cash market is limited to market makers, while the futures market allows a wider range of interested parties to have access to the trading platforms. Second, the order-driven nature of the futures market makes it easier for all operators to enter, delete or modify their trading orders on a continuous basis. Moreover, futures contracts allow to implement a large deal of trading strategies (see Annex A). Finally, this operational flexibility of the futures market, available to all categories of investors, has encouraged the use of automated trading systems (*algo-trading*); some of these systems – known as High Frequency Trading or HFT – are characterized by high computational capacity and very advanced technologies and are able to carry out trades in extremely short times.

High-frequency traders initially developed in the US stock market about ten years ago, thanks to a favorable regulatory environment[15] and a market microstructure[16] that favored their developments. The futures markets in the US were immediately subject to the attention of HFTs. For example, the presence of HFTs on the S&P 500 futures market is significant (30-40%) as well as on other US traded asset class futures markets, such as oil or government securities. A recent study published by the Federal Reserve Bank of New York[17] shows that more than half of trading of US Treasuries are carried out by automated trading systems and a significant part of those trades is carried adopting high-frequency technologies. In Europe, numerous researches show a non-negligible presence of HFTs on several European equity markets, where HFTs seem to be responsible for a trading percentage between 20% and 40% of the total. Over the past two years, the increased use of electronic trading platforms and the increased fragmentation of the markets are slowly encouraging HFT colonization of other markets such as foreign exchange and fixed income.

Although official statistics about the presence of high-frequency traders in the European fixed income futures markets are not present, the order-driven nature of such markets and their growing liquidity are undeniable attraction factors for high-frequency traders. Therefore it is reasonable to assume a significant presence of these operators also in the BTP futures market. This could explain the peculiar dynamics of the futures price that, at high frequencies and for short time intervals, may partially deviate from the dynamics of the price of the underlying bond, with implications in terms of reduction of the correlation observed. In addition, negotiations on the BTP futures are realized on a platform technologically different and physically separate from the platform on which negotiations on BTP cash are carried out. Therefore, any hedging or arbitrage operation that involves both markets and that in turn exerts a pressure to prices realignment, necessarily it requires some technical implementation time. The realization of an arbitrage strategy involving securities traded on the same platform would undoubtedly be faster.

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[15] The decisive impulse to the development of high frequency was offered by Regulation National Market System (NMS Regulation) of 2005; European innovations contained in the US standard were later introduced by MiFID.

[16] One of the first stimulus to the birth of HTT was offered by the decision of the Securities and Exchange Commission that, in the early 90s, allowed the use of Electronic Communications Networks (ECN) as electronic trading systems alternatives to regulated markets.

[17] “Automated Trading in Treasury Markets”; TMPG Consultative paper, October 2015.

5. Volatility analysis

Studying interdependence in financial markets has increasingly attracted significant attention in recent times and the vastly growing literature in this topic provides strong evidence in this regard. Against this backdrop, we focus our analysis on financial markets volatility cross-interactions. Volatility is a key elements in financial markets analysis, ranging from asset allocation to risk management needs. Our analysis is aimed to detect to what extent futures market volatility might play a leading role *vis-a-vis* the cash market volatility and on its turn might affect BTP secondary market liquidity. The analysis leverages on several econometric tools outlined in Section 2. We first consider a bivariate GARCH specification; Figure 6 illustrates the estimated conditional volatilities dynamics of the BTP futures contracts and its relative *cheapest-to-deliver*.

The two series show similar intraday volatility patterns through the considered time period with frequent *spikes* episodes and, as the data frequency increases, more structural breaks occurs in the volatility patterns for both considered series. In order to deepen the analysis considering the higher sampling frequency dataset we move to the so called *realized measures*, which are recognized as a more accurate volatility measure with better forecasting capabilities in high-frequency environments.

As for the correlation analysis, probability density estimates are computed for time series volatilities as well, by employing the Kernel methodology outlined in Section 2. Results are showed in Figure 7 and confirms the greater volatility detected on BTP futures instruments compared with respect to all bonds in the deliverable basket. The higher volatility is partially explained by the optionality enclosed in the derivative contracts that exposed the *long* position to buy, at maturity, the underlying asset that has performed worse (*delivery option*); therefore, compared to related underlying asset, BTP futures prices pay a premium to face such risk exposure.

Now therefore we investigate potential transmission mechanisms between the *futures* and the *spot* market in order to mainly asses if the higher volatility recorded on the derivative contract may potentially propagate on the Italian Government Bond secondary market also affecting its liquidity conditions.

In order to investigate such spillover phenomena across the two markets, we leverage on the concept of Granger Causality test for determining whether one time series is useful in forecasting another. In a first step we focus on volatility transmission effects. For each trading day and for each considered sampling frequency we estimate a *lead-lag* VAR framework using absolute *log-price* variations of BTP futures and related CTD contract as proxies for their respective volatility dynamics[18]. Figure 8 reports Granger causality test statistics and a common box-plot representation is adopted in order to better represents all values obtained across different frequencies and trading days included in our sample period.

Results provide a strong statistical evidence for a causal relationship running from the future market to the spot market with a tendency to strengthening as the sampling frequency increases[19]. For the sake of completeness we also investigate the opposite causal effect (from *cash* to *future*) with much weaker results than vice versa.

Figure 8 highlights that for lower sampling frequency observations (15 to 5 minutes), Granger Causality test fails to be conclusive with a 99% confidence intervals (*dashed line*) on several trading days, implying a bidirectional transmission mechanisms between the two markets; on the other hand the F-statistics values above the threshold obtained for the ultra-high-frequency datasets support a strong unidirectional spillover effect only from the futures to the cash market.

Showed results seem to point out that to better understand causal relationship on such liquid markets, it requires to gather the much richer information enclosed in the higher sampling frequency datasets. In our case in order to properly assess a causal relationship between the two markets and identify unidirectional spillover we had to fall under the five minutes sampling frequency. Such empirical evidence may be strictly linked to the peculiar microstructure characteristics of the BTP futures market that we have highlighted in Section 4 and that potentially have non negligible implications for the MTS Cash market as well.

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[18] The number of lags is selected according the Bayesian information criteria (BIC).

[19] A recent work (Rittler, 2009), based on high-frequency data, is devoted to analyze the relationship of European Union Allowance *spot* and *futures* prices; the work reaches similar conclusions. The paper analyses both a price discovery process (Information Share - Hasbrouck 1995) and a volatility spillover analysis between the two markets (employing a Granger Causality test and a multivariate GARCH specification). Authors detect unidirectional volatility transmission from the futures to the spot market at highest frequencies.

A detailed analysis referred to the US Treasury market (conducted by U.S. Department of the Treasury, Federal Reserve System and Bank of New York, the U.S. Securities and Exchange Commission and the Commodity Futures and Trading Commission[20]) states that in normal condition, the link between cash and futures market positively contributes to an efficient prices formation process; however such relation between the two markets may, in same circumstances, constitute a channel for shocks transmission from one market to others. In the same report a cross-market analysis states that top ten proprietary traders activities usually begins on the futures market and subsequently shifts on the cash market in a five milliseconds time interval.

6. Spillovers effects on MTS liquidity conditions

As shown in Section 3, the development of the futures market seems to support the liquidity of the MTS market. However, propagation of volatility from the futures to the cash market could have a negative impact on the MTS liquidity (as measured by bid-ask spreads[21]). Market makers protect themselves from increased volatility by reducing the price at which they are willing to buy and increasing the price at which they are willing to sell, with a consequent increase in the bid-ask spread. Therefore, the increase in volatility on the cash market naturally leads to a deterioration in liquidity conditions[22]. In order to empirically test the relationship between volatility and bid-ask spreads, appropriate tests of Granger Causality were conducted for different frequencies and for each trading day.

Figure 9 shows the presence of a causal relationship between market volatility and bid-ask spreads quoted by market makers, especially for frequencies below 30 seconds. Moreover the trend of the F-statistic, above the limit threshold, with a maximum "local" value around ten seconds[23], suggests the possibility that the widening of the bid-ask spreads occurs for more

[20] "The US Treasury market on October 15, 2014"; Joint staff report, October 2014.
[21] Bid-ask spreads represents only one dimension of market liquidity. However in the purpose of our analysis it may be considered as the most relevant one. A widening in the bid-ask spreads represents higher transaction costs regardless of the orders size. This is not always true for other market liquidity measures such as depths and turnovers. Moreover the binding nature of the quoted proposal submitted on the MTS Cash platform makes bid-ask spreads detected on this market highly informative of its liquidity condition.
[22] Moreover, it is not inconceivable that market-makers directly infer market volatility from exchanged futures prices in order to adjust their proposal on the cash market, as the futures market, characterized by more trades than those recorded on a single cash security, can offer more frequent and granular information.

[23] For 10 and 5 seconds frequencies, Granger test is conclusive for 70% of analyzed trading days.

persistent volatility spikes, presumably in order to avoid the noise of volatility meddle with their proposals.

7. Conclusions

A liquid futures market contributes to the efficiency and proper functioning of the underlying cash market, favoring price discovery and offering market players the possibility to more easily hedge their positions. In addition, a future market characterized by an adequate soundness facilitates market makers activity; it promotes the compression of bid-ask spreads, and therefore tends to improve the underlying liquidity.

The futures and the underlying cash market are strongly intertwined. However, for higher frequency observations (seconds), price dynamics tend partially to diverge, including those between futures and CTD. This may be due to differences in micro-structure of the two markets and to different players active in each market. Given the order-driven nature of BTP futures market, it is reasonable to assume that the negotiation of this instrument may also be affected by the activity of high frequency traders (HFT) likewise what occurred in recent years on equity order-driven markets.

The analysis highlights that significant changes in volatility occurring on the futures market tend to spread to the cash market, thus affecting the liquidity of the latter (Bank of Italy, 2015): it is indeed fully rational for market makers to adapt their offers when the increase in volatility is deemed not negligible and not transitory. The cash market volatility dependence from the futures volatility should not be underestimated, however. It is also possible that, when market conditions are fragile and particularly sensitive to any negative news, the presence of HFT operators in the futures market, may amplify futures prices volatility thus magnifying the temporary liquidity drop in the cash market.

Annex A. Feasible strategies through futures

Futures contracts may be used to implement several trading strategies. In more details:

a) **Position Hedging:** futures are often used to minimize risk exposure on specific fixed income positions. This feature proved to be particularly useful for market makers, also in the light of more recent regulatory developments. According to a recent BIS study (BIS, 2014), many market makers have reduced their inventories of securities as a response to increased regulatory constraints, which potentially weakens their ability to absorb large sale and purchase orders. A futures market characterized by an high degree of liquidity allows market makers to effectively manage their book even without large inventories.

b) **Portfolio Hedging:** futures are an effective tool also to hedge entire bond portfolios (Moorad and Choudry, 2004). The adoption of BTP futures, along with German Bund futures, might improve the hedge effectiveness of diversified portfolios of fixed income securities in respect to the hedge effectiveness brought about with the use of Bund futures alone (Bessler et al., 2014). Such a usage of BTP futures has become even more common in the aftermaths of the European government debt crisis in 2010 – 2011 when, on one hand, bonds characterized by larger risk premiums, including BTPs, assumed price dynamics strongly similar, while, on the other hand, the correlation decreased against the Bund, and, to a lesser extent, the OAT. Therefore, the use of BTP futures increased as hedging instruments for positions not only in Italian government bonds.

c) **Arbitrage:** considerable discrepancies between the futures price and the price of the cheapest-to-deliver determine relative value[24] opportunities that can be seized by purchasing (or selling) the futures and simultaneously selling (or buying) the CTD (so called "basis trading"). This acts as a natural pressure and price discrepancies are rapidly reabsorbed. In this sense, the arbitrage activities, facilitated by the availability of a liquid futures market, contributes to the price discovery also on cash instruments.

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[24] Although many consider the basis trading an arbitrage opportunity, it is subject to a modest risk. For a detailed description of the basis trading (see Burghardt and Belton, 1994).

d) **Speculation:** futures contracts stimulate speculative traders activity, because, unlike what happens in cash markets, they can easily take also short positions. Although speculation is often linked to aggressive or opportunistic behaviors, the presence of an adequate number of speculators operating in both directions can help improve price discovery, thus increasing market efficiency.

In conclusion, the development of BTP futures market may represent, ceteris paribus, a factor supporting cash market liquidity, as it can result in a reduction of market making activity costs (position/portfolio hedging). Moreover, the possibility offered by the futures to quickly and efficiently implement (with limited use of cash) directional strategies ("speculation") or arbitrage operations contributes to improve price discovery.

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Table n.1

frequency	# Obs	BID - ASK 10Y (bp)		Spread BTP - BUND (bp)		BTP daily volatility (bp) *(diff yield, rolling 30 days)*		Daily turnover MTS (mln)		Daily turnover BTP futures (mln)	
		Mean	*Stand. Dev*	*Mean*	*Stand. Dev*	*Mean*	*Stand. Dev*	*Mean*	*Stand. Dev*	*Mean*	*Stand. Dev*
daily	*2328*	*1.5*	*1.13*	*167*	*123*	*6*	*4*	*4.000*	*2.180*	*3.155*	*3.571*

Table n.2

Prices (%, logarithmic return)

frequency	# Obs.	Future		BTP 5% marzo 2025 (ctd - cash1)		BTP 3.75% 9/2024 (cash2)		BTP 2,5% 12/2024 (cash3)	
		Mean	*Stand. Dev*	*Mean*	*Stand. Dev*	*Mean*	*Stand. Dev*	*Mean*	*Stand. Dev*
15 min	1472	0.00001478	0.06642218	0.00007954	0.06433042	- 0.00021828	0.06303222	- 0.00041157	0.06679181
10 min	2208	0.00000985	0.05560975	0.00005303	0.05429722	- 0.00014552	0.05311328	- 0.00027438	0.05784421
5 min	4416	0.00000493	0.03999072	0.00002651	0.03917962	- 0.00007276	0.03790682	- 0.00013719	0.04136402
1 min	22080	0.00000099	0.01894237	0.00000530	0.01926481	- 0.00001455	0.01880501	- 0.00002744	0.01892717
30 sec	44160	0.00000049	0.01351648	0.00000265	0.01371133	- 0.00000728	0.01291285	- 0.00001372	0.01313673
15 sec	88320	0.00000025	0.00963156	0.00000133	0.01056484	- 0.00000364	0.00891502	- 0.00000686	0.00919920
10 sec	132480	0.00000016	0.00782027	0.00000088	0.00863813	- 0.00000243	0.00724343	- 0.00000457	0.00781955
5 sec	264960	0.00000008	0.00550670	0.00000044	0.00636090	- 0.00000121	0.00549775	- 0.00000229	0.00555523
4 sec	331200	0.00000007	0.00492509	0.00000035	0.00592192	- 0.00000097	0.00503454	- 0.00000183	0.00493525
3 sec	441600	0.00000005	0.00428743	0.00000027	0.00524915	- 0.00000073	0.00436821	- 0.00000137	0.00430648
2 sec	662400	0.00000003	0.00348571	0.00000018	0.00437780	- 0.00000049	0.00358964	- 0.00000091	0.00355369
1 sec	1324800	0.00000002	0.00244672	0.00000009	0.00323978	- 0.00000024	0.00255557	- 0.00000046	0.00254182

Table n.3: Unitroot test for stationarity

(Augmented Dicky-Fuller)

frequency	*Future (abs. returns)*	*CTD (abs. returns)*	*spread bid-ask (abs. returns)*	*1% significance level*
15 min	-3.872	-3.541	-5.013	-4.197
10 min	-4.841	-5.202	-6.987	-3.968
5 min	-7.674	-7.964	-6.942	-3.665
1 min	-11.862	-10.635	-11.273	-3.472
30 sec	-13.326	-12.013	-15.086	-3.452
15 sec	-12.833	-13.634	-19.246	-3.444
10 sec	-14.981	-14.400	-22.170	-3.438
5 sec	-18.296	-20.236	-29.293	-3.434
4 sec	-20.429	-22.428	-32.253	-3.434
3 sec	-22.987	-24.876	-38.101	-3.434
2 sec	-28.699	-32.539	-44.557	-3.433
1 sec	-41.493	-49.481	-64.179	-3.433

Table shows for each sampling frequency the averaged ADF test statistics across all trading days. Values reported are in general beyond the 1% confidence level and permit to reject the hypothesis of a unit root presence, giving evidence of a stationarity series (the more negative the ADF statistics is, the stronger the rejection of the hypothesis that there is a unit root at some level of confidence).

Table n.4: BTP *futures* market development and contribution to MTS liquidity

OLS estimates, daily data from 2009/09/15 to 2015/08/21
Dependent Variable: l_BID_ASK_10Y
Heteroscedasticity-consistent standard errors

	Coefficient	*Std.error*	*t-statistic*	*p-value*	
Const	0.29804	0.162633	1.8326	0.06706	*
MTS_Volumes	-0.0543848	0.0244849	-2.2212	0.02649	**
BTP_Volatility	0.0163743	0.0256154	0.6392	0.52276	
Future_Volumes	-0.033391	0.0149557	-2.2327	0.02571	**
Spread_IT_DE	0.0200428	0.0120266	1.6665	0.09581	*
BID_ASK_10Y_(1)	0.501936	0.0658738	7.6197	<0.00001	***
BID_ASK_10Y_(2)	0.111692	0.0618559	1.8057	0.07116	*
BID_ASK_10Y_(3)	0.0692628	0.0632853	1.0945	0.27393	
BID_ASK_10Y_(4)	0.214281	0.0603932	3.5481	0.00040	***

R^2	0.881801	Adj R^2	0.881187
F(8, 1540)	1474.753	P-value(F)	0.000000
		Durbin-Watson	2.047764

Figure n.1: Correlogram

(auto-correlation and partial auto-correlation of the residuals)

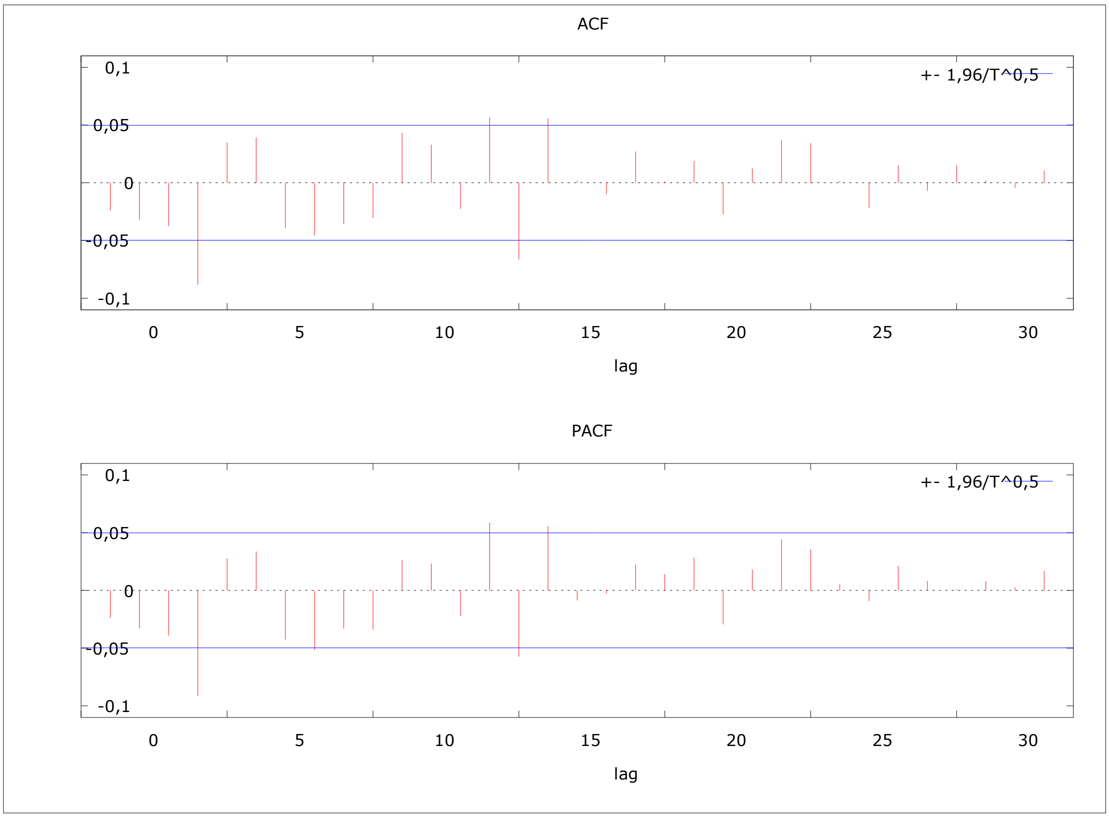


Table n.5: BTP *futures* market development and contribution to MTS liquidity

OLS estimates, daily data from 2009/09/15 to 2015/08/21

Dependent Variable: l_BID_ASK_10Y

Heteroscedasticity-consistent standard errors

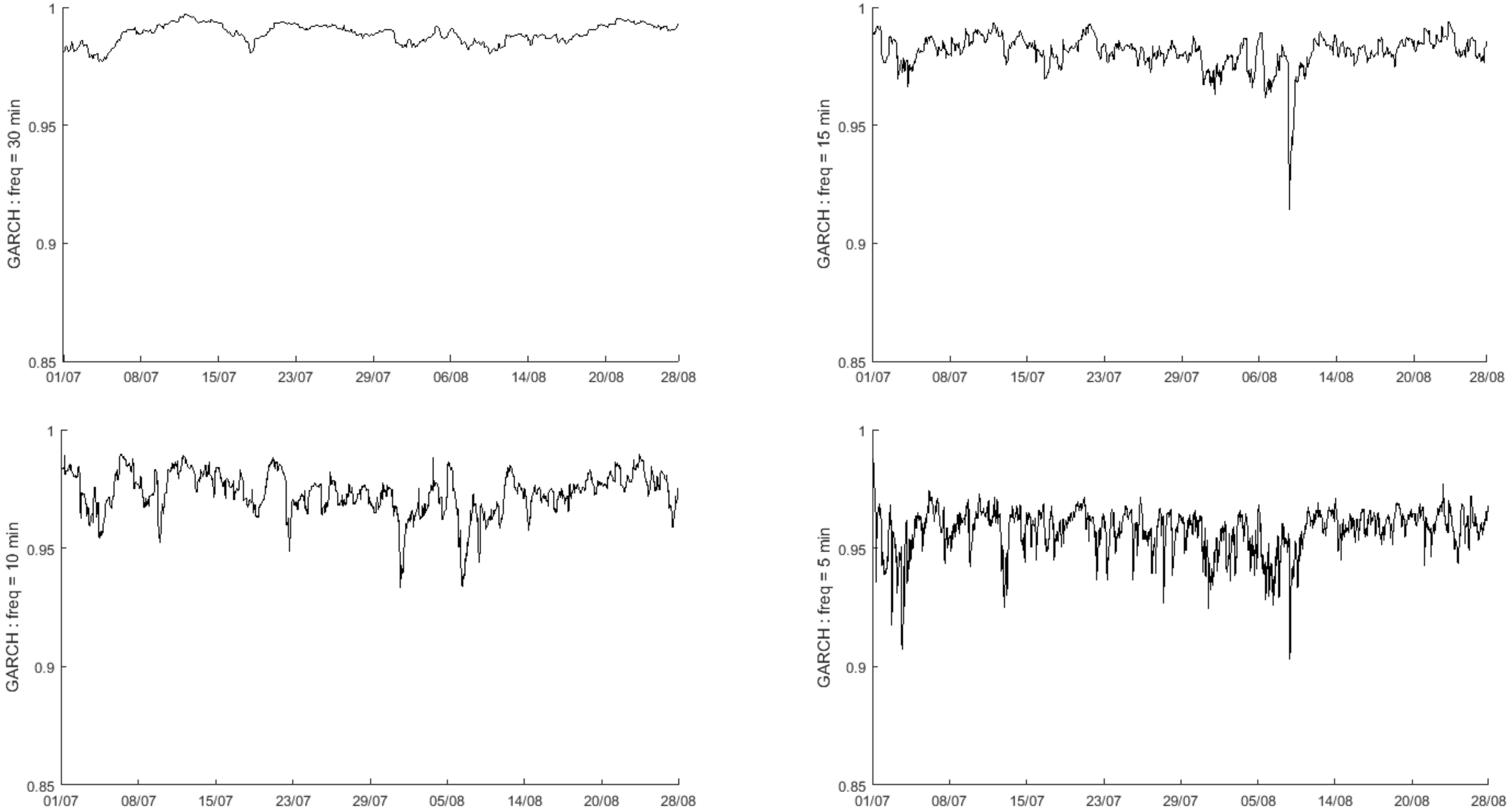
	Coefficient	*Std.error*	*t-statistic*	*p-value*	
Const	0.242809	0.164164	1.4791	0.13933	*
MTS_Volumes	-0.0790045	0.0273885	-2.8846	0.00397	***
BTP_Volatility	0.0365697	0.0265292	1.3785	0.16826	
Future_Volumes[25]	-0.0271826	0.0104881	-2.5917	0.00964	***
Spread_IT_DE	0.02255	0.00963293	2.3409	0.01936	**
BID_ASK_10Y_(1)	0.503941	0.0577338	8.7287	<0.00001	***
BID_ASK_10Y_(2)	0.112639	0.0826049	1.3636	0.17290	
BID_ASK_10Y_(3)	0.0689276	0.0513519	1.3423	0.17971	
BID_ASK_10Y_(4)	0.214525	0.0459099	4.6727	<0.00001	***

R^2	0.882038	Adj R^2	0.881428
F(8, 1540)	1967.603	P-value(F)	0.000000
		Durbin-Watson	2.047321

[25] The BTP futures traded volume has been first regressed against the MTS traded volume, in order to consider potential multi-collinearity problems. The residuals from the first regression are thus considered in the model specification instead of BTP futures volumes.

Figure n.2: Dynamic Conditional Correlations between BTP *future* and CTD

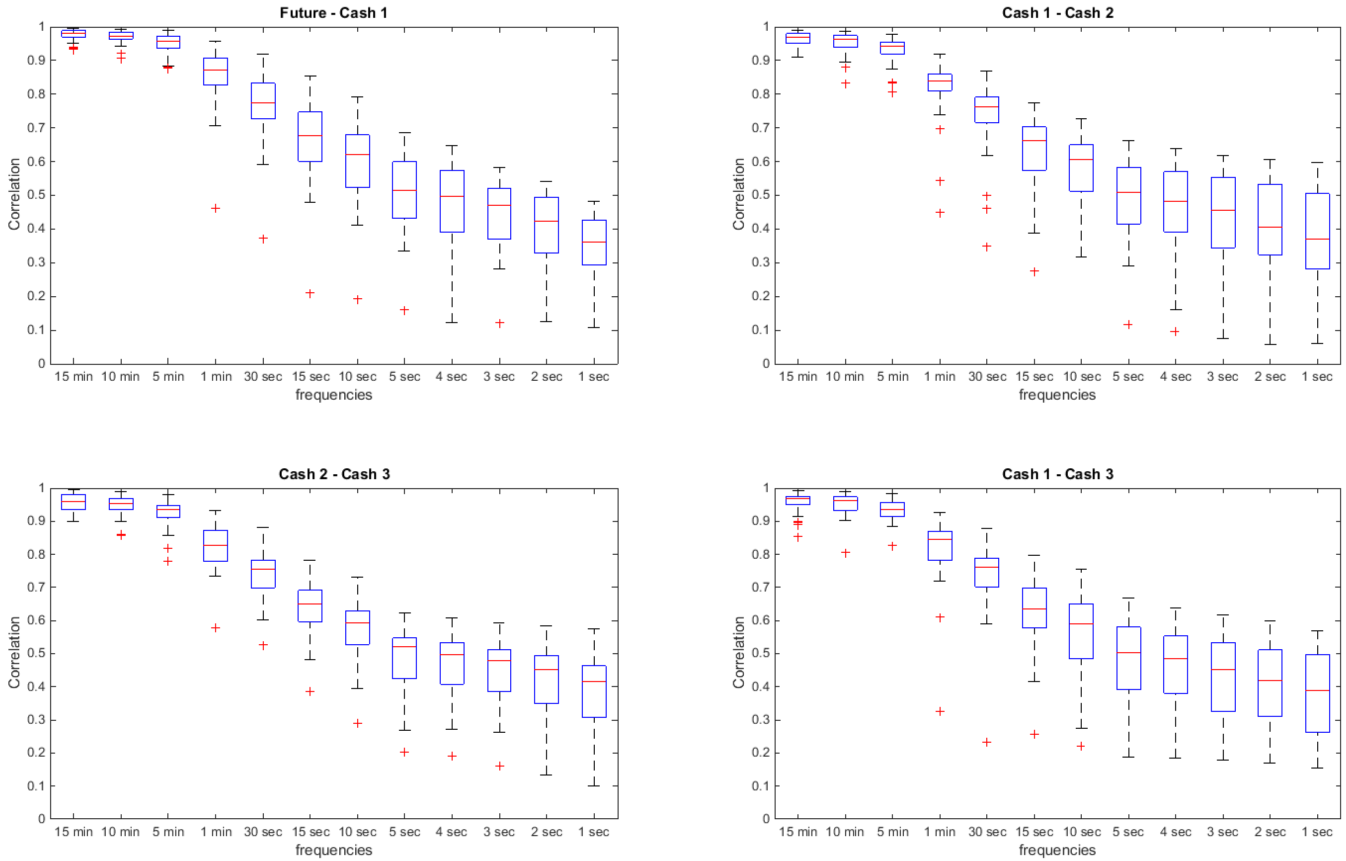
(multivariate GARCH-BEKK(1,1) estimates, different frequencies)



Figures show the dynamic correlations behavior between BTP *futures* and related *cheapest-to-deliver* bond estimated through a multivariate GARCH-BEKK(1,1) model. The procedure was iterated across 4 different sampling frequencies at 30, 15, 10 and 5 minutes.

Figure n.3: Correlation curves based on differetent sampling frequencies

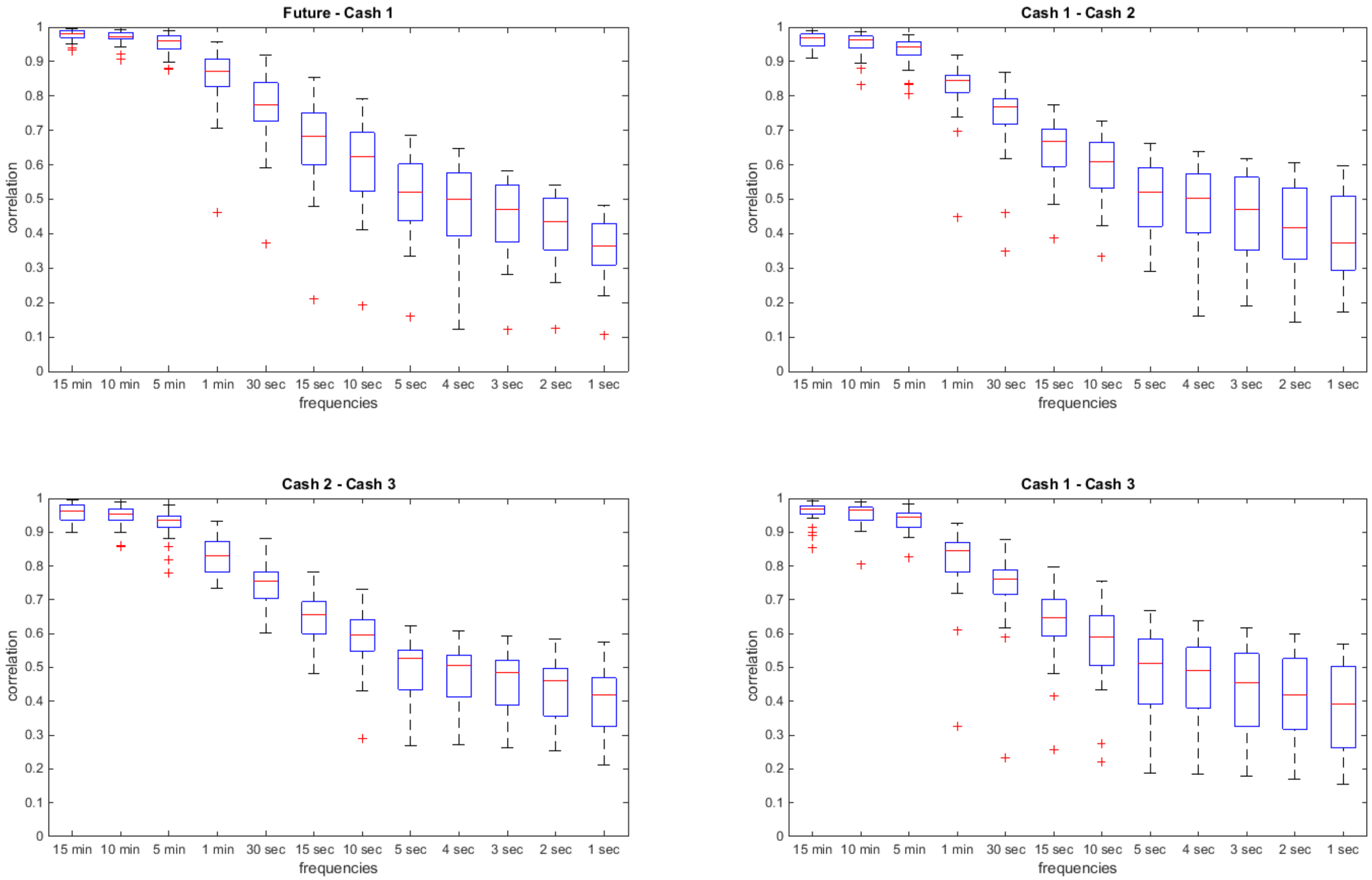
(Full sample)



Red lines represents the median value, the upper and lower boundaries of the box represent values corresponding to the 25th and 75th percentile, while the upper and lower dotted lines extend from minimum to maximum values, excluding the outliers. The outliers are highlighted by asterisks and they represent observations greater than 3 standard deviations.

Figure n.4 : Correlation curves based on differetent sampling frequencies

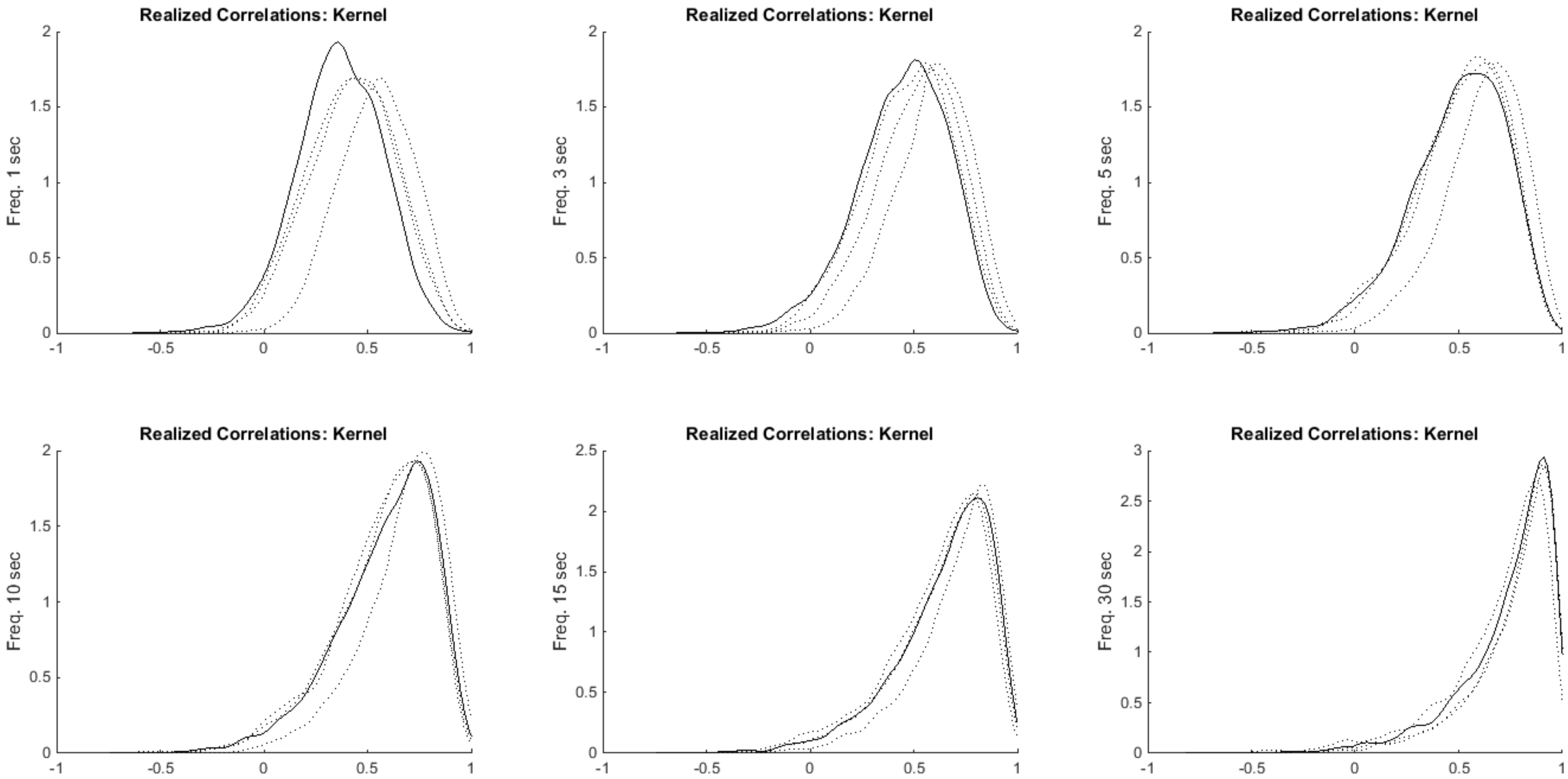
(Treasury auctions day excluded)



Red lines represents the median value, the upper and lower boundaries of the box represent values corresponding to the 25th and 75th percentile, while the upper and lower dotted lines extend from minimum to maximum values, excluding the outliers. The outliers are highlighted by asterisks and they represent observations greater than 3 standard deviations.

Figure n.5: Realized Correlations density function

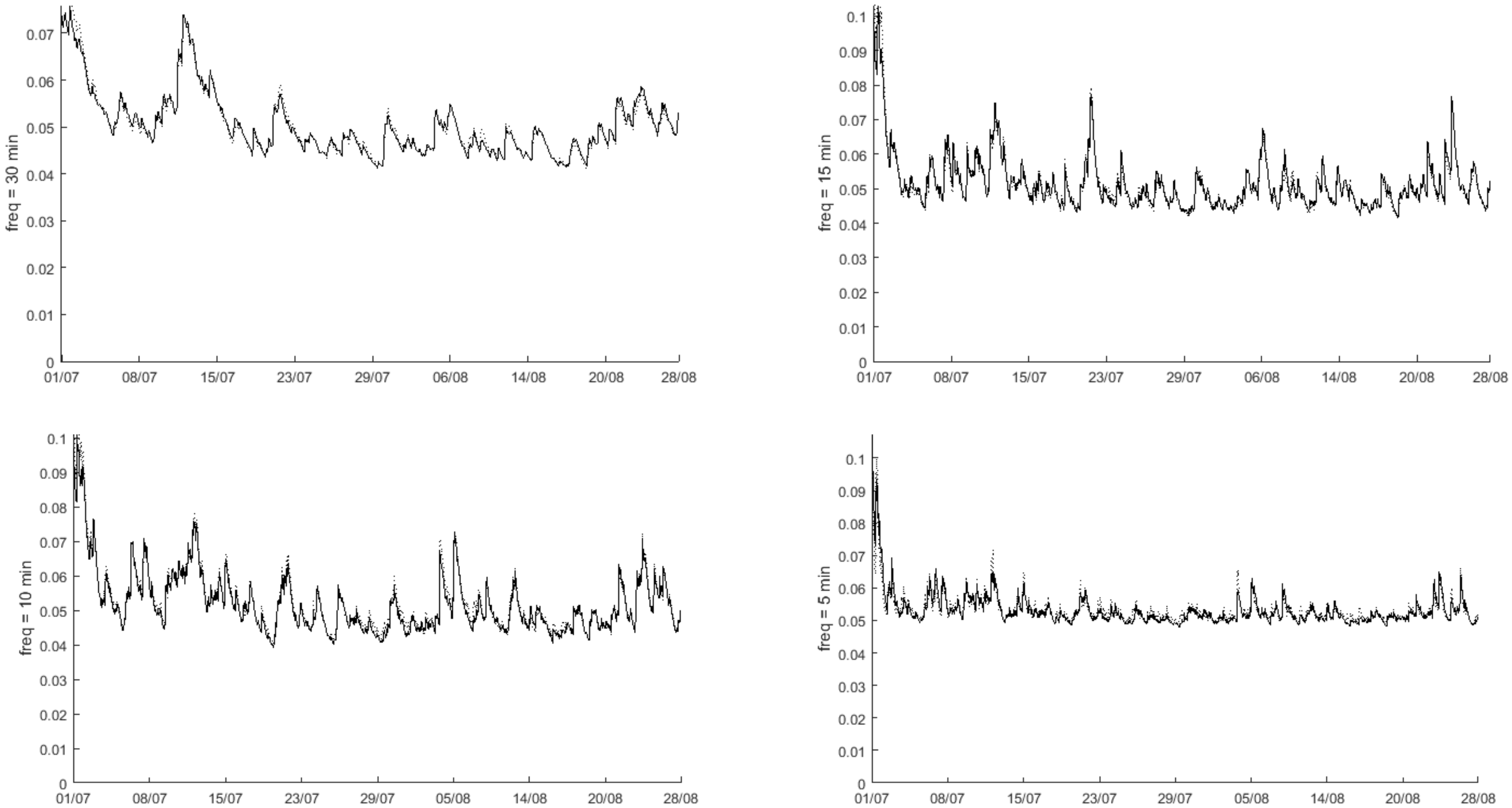
(Gaussian Kernel estimates, different frequencies)



Figures show probability density function estimates adopting a gaussian kernel methodology. Continous line is the correlation between BTP *futures* and the related *cheapest-to-deliver*, dashed lines are density correlations among all the cash securities included in the basket of the deliverable future contract during the period under review.

Figure n.6: Dynamic Volatility estimates between BTP *futures* and *cheapest-to-deliver*

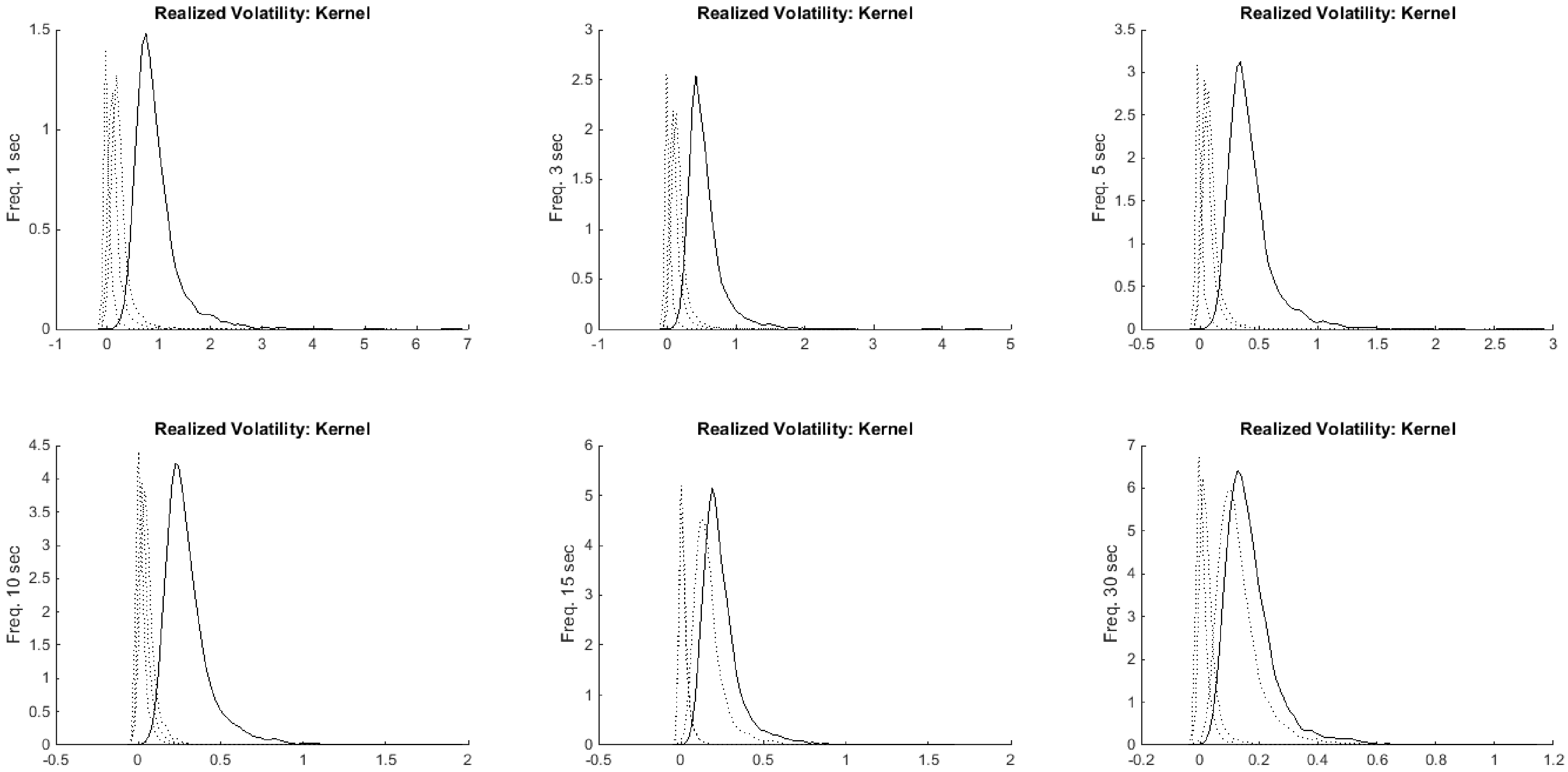
(Multivariate GARCH estimates, different frequencies)



Figures show the dynamic volatility behavior of the BTP *futures* and the related *cheapest-to-deliver* bond estimated through a multivariate GARCH-BEKK(1,1) model. The procedure was iterated across 4 different sampling frequencies at 30, 15, 10 and 5 minutes. Continous line is the BTP *futures* volatility, dashed line it's the *cheapest-to-deliver* bond volatility.

Figure n.7 : Realized Volatility density function

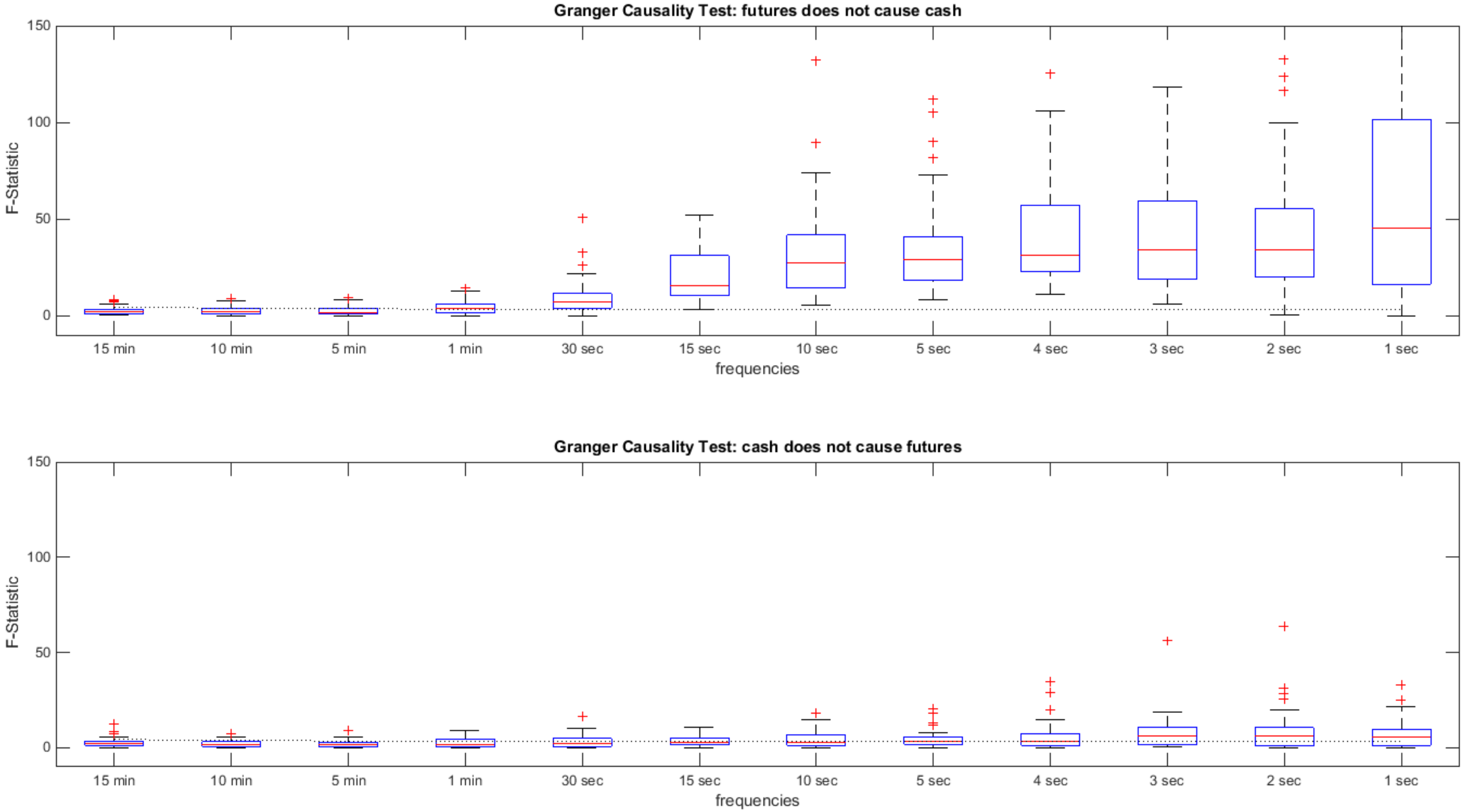
(Gaussian Kernel estimates, different frequencies)



Figures show volatility density function estimates adopting a gaussian kernel methodology. Continous line is the BTP *futures* volatility density, dashed lines are density volatilities of all the cash securities included in the basket of the deliverable future contract during the period under review.

Figure n.8: Volatility *Spillover*

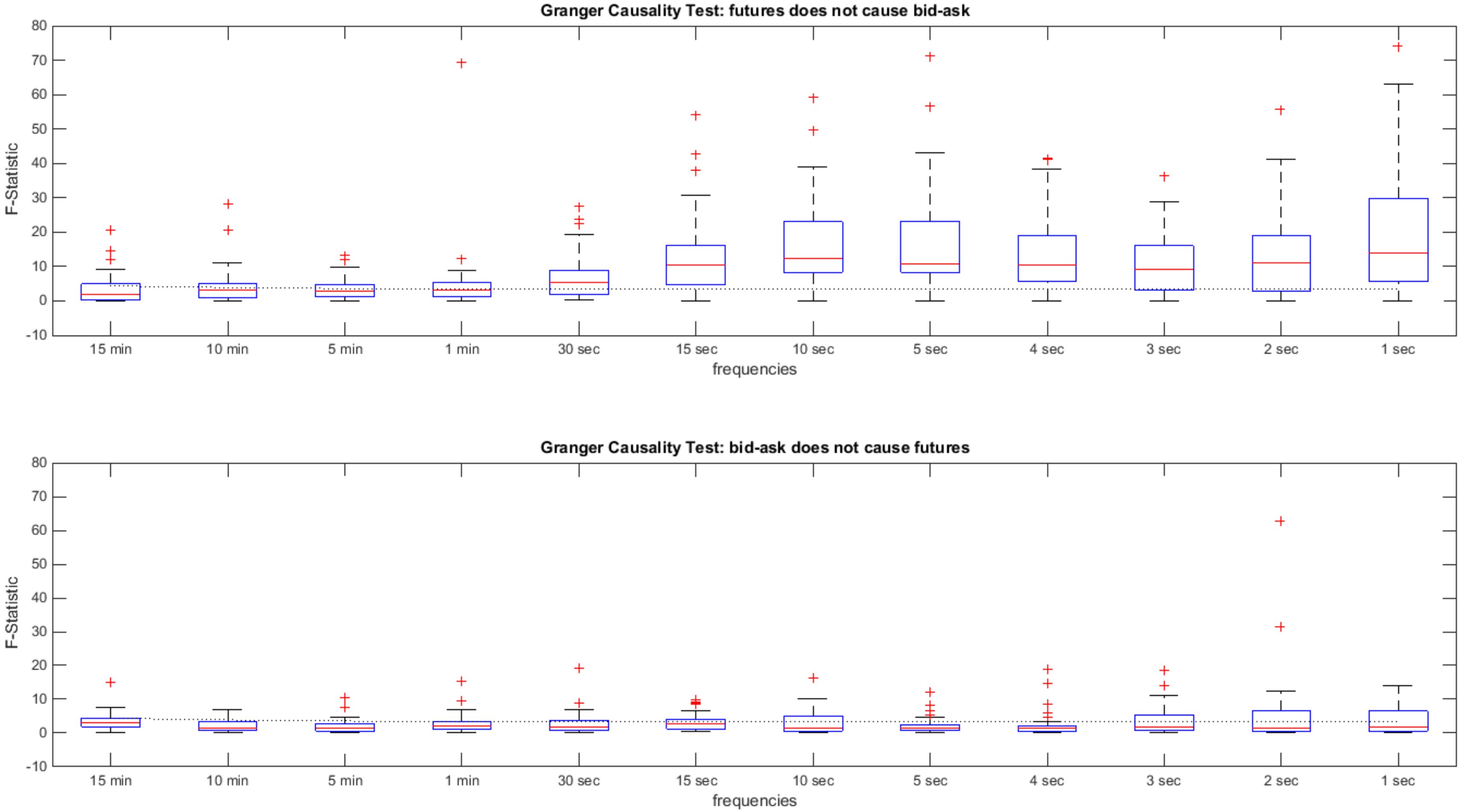
(Granger Causality Test, different frequencies)



Figures show for each sampliung frequency, Granger causality test statistics. A boxplot representation is choosen in order to represents F-statistic values obtained across all considered business days (cross-sectional dimension). Values observed above the threshold (99% confidence interval, dashed line) allow to reject the null hypothesis, detecting the presence of a causal relationship (in the sense of Granger) between the two series.

Figure n.9: Volatility *Spillover* on *Bid-Ask*

(Granger causality test, different frequencies)



Figures show for each sampliung frequency, Granger causality test statistics. A boxplot representation is choosen in order to represents F-statistic values obtained across all considered business days (cross-sectional dimension). Values observed above the threshold (99% confidence interval, dashed line) allow to reject the null hypothesis, detecting the presence of a causal relationship (in the sense of Granger) between the two series.

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