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## **Nominal and Inflation-Linked Government Bonds**

An assessment of arbitrage opportunities in UK Gilt Market

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**Nominal and Inflation-Linked Government Bonds: *An assessment of arbitrage opportunities in UK Gilt Market***

**Abstract:** This study is an assessment of the existence of deviations of the Law of One Price in the UK sovereign debt market. UK government issues two types of debt instruments: nominal gilts and inflation-linked (IL) gilts. Constructing a synthetic bond comprising the IL bonds and also inflation-swaps and gilt strips I was able to build a portfolio that pays to investor exactly the same cash-flow as nominal gilts, with the same maturity. I found that the weighted-average mispricing throughout the period of 2006-11 is only £0,155 per £100 notional. Though, if I restrain my analysis to the 2008-09 crisis period, this amount raises to £4,5 per £100 invested. The weighted-average mispricing can reach values of £21 per £100 notional or, if measured in yield terms, 235 basis points. I have also found evidence that available liquidity on the market and increases on index-linked gilts supply do play a significant role on monthly changes of mispricing in the UK market. I concluded that, although the global mispricing is not significant on UK gilt market, every pair of bonds in the sample presented huge and significant arbitrage opportunities in downturn periods.

**Keywords:** Gilts, Inflation-Linked Gilts, Mispricing, Supply, Liquidity

## 1. Introduction

The basics of the Law of One price defend that if two instruments pay an investor the same, they should be equally priced. On the sovereign debt market the theory should also hold. As the present study suggests, that doesn't happen in the UK gilt market. It was found that index-linked gilts, on average, are undervalued in relation to the nominal gilts. The mispricing<sup>1</sup> is not always constant through time, often changing its sign. Still, at the crisis period it reaches a huge positive magnitude. During that period, the mispricing of a single index-linked gilt in relation to its nominal counterpart can reach values above £28 per £100 notional. On average, the index-linked gilts reach a mispricing maximum of 21% of the notional invested.

The methodology used on the present study is mainly based on two instruments issued by the governments on their sovereign debt balances: nominal and inflation-linked government bonds<sup>2</sup> (ILB). An investor who buys an inflation-linked bond can, by entering in an inflation swap agreement, turn his variable cash-flows into fixed ones. Additionally, through the usage of strips, the investor is able to build a synthetic bond that pays exactly equal cash-flows to the ones paid by nominal bonds with same maturity. The final price of both instruments will allow an assessment of whether or not there is mispricing (and with which sign).

Based mainly on **Fleckenstein, Longstaff and Lustig (2012)**, the present study is of utmost importance since it aims at providing an insight on the mispricing in other markets than in the American one. By doing so, I try to test if the American bond prices relationship holds in markets outside America (namely in the UK) or if the TIPS mispricing is an isolated case when studying ILBs. It also goes in line with the literature

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<sup>1</sup> Throughout this study, the term mispricing will stand for an undervaluation of the IL bonds in relation to the nominal counterparts. A negative mispricing stands for the opposite relationship.

<sup>2</sup> The latest would be referred throughout this paper as ILB

by trying to study, in a simplistic way, what might be the factors causing mispricing in UK market and compare them with the results for the American case.

In order to perform the aforementioned strategy, data for UK gilt market was taken from January 2006 until the end of 2011. Although the average mispricing is positive, presenting a value of £0,155 per £100 invested (this value goes up on the 2008-09 period for 4,5% of the notional) or 6,84 basis points, two of the five pairs selected had a negative mispricing. The first does not include the crisis years, a period that turned out to be the most relevant factor on the analysis of the remaining pairs. The second one, though, was also the one presenting the higher mispricing occurrence. All of the pairs considered presented negative mispricing clustering periods throughout the sample.

Since all bond pairs presented great mispricing levels on the crisis period, a further analysis led to a comparison between the changes on mispricing with the returns of the stock market. In fact, as it was predictable, the higher levels of mispricing were verified on periods of weaker performance of the market.

Such times are characterized by lower investing capacity of the investors. As such, the study tried to test if the mispricing levels are caused either by shortages of capital available or by changes on bonds supply. Both factors turned out to be relevant, being the returns on the stock market, the investing capacity of global hedge funds and the supply of IL gilts significant variables for the monthly change of mispricing. The results are aligned with previous similar studies for the American market. Still, relation between mispricing and bonds supply is quite different. On the gilt market, supply of nominal instruments is not significant (in contrary with what happens in the American market) and issuing ILBs creates the opposite effect on mispricing of the American TIPS supply.

The rest of this paper is organized as follows. **Section 2** aims at providing a brief literature review of the related studies. Besides giving a brief description of the main differences between nominal and ILBs, **section 3** provides a description of UK markets for each of the fixed-income instruments. **Section 4** describes the arbitrage strategy built in order to perform the study as well as the data used. **Section 5** scrutinises the size of mispricing as well as further issues on this matter. Concluding remarks are present on **section 6**.

## **2. Literature Review**

This study is consequent to some recent literature on the Asset Pricing Puzzle resulting from the mispricing between the two aforementioned types of Government debt instruments. Namely **Fleckenstein, Longstaff and Lustig (2012)** studied the relationship between TIPS and Treasury bonds and concluded that there was, consistently, a great mispricing between the two types of securities. Their evidence suggests that the nominal markets are usually overpriced when comparing with the TIPS market.

Other important studies on this subject include an even more recent study by **Fleckenstein (2012)**, who performs an analysis for several other countries. The evidence on G7 countries' markets points to the same conclusions previously mentioned for US data and so, challenging the Asset Pricing Theory and the Law of one Price.

Both studies are not focused solely on measuring the mispricing on the bonds market. The authors go further in the matter, analysing which factors can be on the roots and on the persistence of the mispricing as well as its financial and economic implications. Yet, they focus their studies mostly on the scope of the Slow-moving Capital theory. The authors go in line with other studies as **Mitchell, Pedersen and**

**Todd Pulvino (2007)** and state that arbitrage opportunities may arise and persist in time due to some frictions, as liquidity shortages. Although basing the present study on these papers, I have tried to hold off my analysis from the Slow-moving Capital theory, as further considerations would have to be made on that matter.

### **3. UK fixed-income Markets**

This section aims at providing some insights about the fixed-income instruments and respective markets relevant for the building of the proposed arbitrage strategy. A summary of each instrument features can be found on **Appendix A, table 1**.

The first three instruments are traded on the UK Gilt Market, responsibility of the UK Debt Management Office (DMO). The main responsibility of this entity is the issuance of the sovereign debt instruments, as conventional gilts and index-linked gilts (at the end of March 2012, the latest accounted for around 22,8% of the total gilt portfolio<sup>3</sup>).

#### *UK Conventional Gilts*

Nominal Gilts constitute the largest part of UK Government bonds portfolio. This instrument defines an obligation between the Government and the debt-holder: the former receives the bond price, whilst the second receives several fixed interest payments with a specific frequency within a year<sup>4</sup>. At maturity, the debt holder receives the last coupon and also the face value of the instrument.

#### *UK Index-Linked Gilts*

Nowadays, inflation-linked government bonds have been gaining major importance in Europe, as their outstanding volume has been increasing since the beginning of the last decade. This trend is observable both in Euro Area countries (with relatively recent

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<sup>3</sup> DMO - *UK Government Securities: a Guide to 'Gilts' – Tenth Edition 2012*

<sup>4</sup> Both the fixed coupon rate and the frequency of payments are defined at the issuance date.

issuances from the French, Italian and German governments), which increased ten times the outstanding volume since 2002<sup>5</sup>, and also in non-Euro Area countries as UK and Sweden. In **Appendix A, figure 1**, one might find a ranking of the main issuers of inflation-linked debt in the World as well as their respective issued notional amount.

Focusing on the UK's case, British Government started to issue ILBs in 1981, being one of the first issuers of such kind of debt instruments between developed countries. The government acted in response to a great decrease in real value of nominal debt caused by the rising inflation at the 70ies. In such way, debt was endowed with an anti-inflationary measure that could protect its value. Moreover, those instruments would overcome the reducing demand for sovereign instruments on inflationary periods.

Inflation-linked gilts are also characterized by a coupon rate. However, each payment – which is made twice a year in all the existent UK government ILBs – is adjusted for inflation. This is, coupons and the principal payment are adjusted for the RPI index (General Index of Retail Prices), in order to account for the change in inflation since the issuance of the bond. This adjustment is made by an indexation factor which, further, it will be called  $I_t$ . It is calculated by doing the ratio between reference RPI at payment date and the reference RPI at issuing date.

DMO's portfolio is constituted by two different index-linked gilts. They differ on the price calculation, in result of different indexation lags. The reference RPI to be used in each indexation factor depends on the lagging of these bonds.

Bonds issued prior to 2005 have an 8-month lag, while all bonds issued after that date have a 3-month lag<sup>6</sup>. Besides the difference on the computation of the indexation factor, they also differ on the price calculation and quotation. The 8-month lag bonds

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<sup>5</sup> **Danmarks Nationalbank (2011)**

<sup>6</sup> Which means that reference RPI used on indexation factor for a specific date is the 8-month and 3-month prior quoted value

are quoted on nominal terms, this is, their price is adjusted for the inflation verified since the issue of the bond. This price is obtained by multiplying the “real price”<sup>7</sup> by the indexation ratio. These bonds prices are often quoted above £200 since the RPI had risen by more than 200% since 1983 (when the government started issuing inflation-linked bonds)<sup>8</sup>. The bonds using a lagging mechanism of 3-months (also called *Canadian Style*), are quoted in real terms (as it happens with the nominal gilts). There are also differences to take into account on the cash-flow and accrued interest calculation<sup>9</sup>.

In contrary with what happens with US TIPS, inflation-linked gilts do not have a deflation floor. This means that if there is a deflationary effect from the issuance to the maturity, the principal value can go below the settled par value.

### *UK Gilt Strips*

The process of stripping a bond consists in separating each cash-flow paid by the gilt into individual zero-coupon bonds. This means that each Strip will only pay to its holder one cash-flow on its maturity. In example, a one year maturity bond paying a semi-annual coupon of 2% would be strippable into 3 Strips: two paying 1 on each semester, and other one paying 100 on the maturity. In UK the process of stripping issued bonds was started in 1997, with the introduction of an official Strip facility.

### *Inflation Swaps*

The most common inflation swaps are the zero-coupon (ZC) inflation swaps. This kind of securities is considered to be the standard inflation derivative<sup>10</sup>. A ZC inflation swap is an agreement between two parties: a buyer and a seller. They are used as

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<sup>7</sup> The term “real price” means that the price is quoted for 100 units of principal. It works as a percentage of the principal.

<sup>8</sup> **Brynjolfsson (2002)**

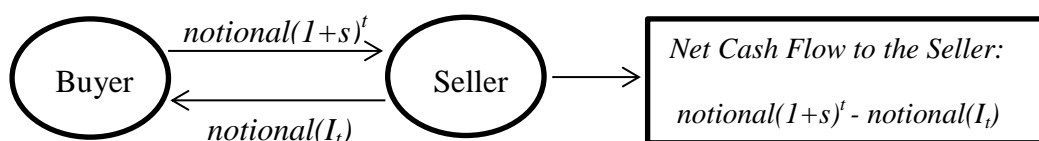
<sup>9</sup> Price, cash-flow and accrued interest calculations for both type of bonds are explained on DMO’s handbook *Formulae for Calculating Gilt Prices from Yields*

<sup>10</sup> **Kerkhof (2005)**



protection instruments against inflation risk. This kind of security only pays one cash-flow at its maturity date. Whilst the buyer pays to the seller a fixed rate,  $s$ , this one pays inflation indexed cash-flows (in UK case, the value of the RPI from the issuance to the maturity date – again  $I_t$ ) to the former. The fixed rate,  $s$ , reflects the inflation expectations during the lifetime of the agreement. The cash-flow transaction is depicted on **figure 2**.

**Figure 2: Zero-Coupon Inflation Swap Mechanics**



The quotation of the ZC inflation swaps is made through the stated fixed rate. There are quotations ranging the 1-year to 50-years maturity. As the inflation-linked bonds, these rates do also have a lagging mechanism. The UK’s inflation swaps have a 2 months lag (and so they report to the two-months prior RPI). This may play an important role on defining the arbitrage strategy as it will be further explained on the next section.

#### 4. How to measure the Mispricing?

##### *Strategy*

Measuring a hypothetical mispricing between inflation-linked and nominal bonds, implies that an arbitrage strategy is built<sup>11</sup>. An investor pursuing this kind of strategy starts by taking a position on a nominal bond. This instrument pays in a semi-annual frequency a coupon  $c$  (considering a par value of 100).

Similarly, a position on an ILB should be made. Such investment should be made on an ILB maturing on the same date as the nominal bond, in order to compare

<sup>11</sup> Both strategy and methodology followed the steps taken by **Fleckenstein, Longstaff and Lustig (2012)**

cash-flows. The former pays a semi-annual coupon  $b$ . As explained in the previous section, each coupon payment will be adjusted for inflation by a factor  $I_t$ , and so, the cash-flow of each semester before maturity will be  $bI_t$  (at maturity,  $(100+b)I_t$ ).

In order to turn each variable cash-flow into a fixed one, the investor has to enter in ZC Inflation Swap agreements – paying a fixed inflation swap rate of  $s$ . The maturity of each agreement should match the ones of the ILB coupon payments as well as the notional value should equal the fixed component of the ILB’s coupon,  $b$ . In a particular date,  $t$ , the cash-flow provided by the swap agreement will be  $b(I+s)^t - bI_t$ . By taking this position on the swaps for each of the ILB payments, all the cash-flows to the investor will be non-variable<sup>12</sup>.

Finally, to eliminate the differential between the cash-flows available of the two instruments, the investor will have to take a small position on the Strips market. That position is equal to the difference between each nominal and inflation-linked cash-flow. As it can be seen on **table 2**, and following the steps described above, at a particular date  $t$  (that can be generalized for all the payments of the securities), the final cash-flows present a perfect match.

**Table 2: The strategy cash-flows at year t**

Instrument		Cash Flow
2.1	<b>Nominal Bond</b>	$c$
2.2	<b>Inflation Indexed Bond</b>	$bI_t$
2.3	<b>Inflation Swap</b>	$b(I+s)^t - bI_t$
2.4 (2.2+2.3)	$\Sigma$	$bI_t + b(I+s)^t - bI_t = b(I+s)^t$
2.5 (2.1-2.4)	<b>Strip</b>	$c - b(I+s)^t$
2.4+2.5	$\Sigma$	$b(I+s)^t + c - b(I+s)^t = c$

<sup>12</sup> The sum of ILB cash flows and Inflation swaps considering a general case, date  $t$ , will be:  $bI_t + b(I+s)^t - bI_t = b(I+s)^t$

The mispricing, then, can be measured by comparing the nominal bond price with the price of all positions taken in the synthetic bond. In case of non-violation of the Law of One Price equation 1 must hold.

$$(1) \text{ Gilt Price} = \text{IL Gilt Price} + (\sum \text{ Strips Cash-Flows}_i) \times \text{Price of Strip}_i^{13}$$

### *Data and Methodology*

In order to perform the aforementioned strategy, I have gathered daily prices for UK conventional, index-linked gilts and Strips from January 3<sup>rd</sup>, 2006 to December 30<sup>th</sup>, 2011 (all the prices are adjusted for accrued interest). For the inflation swaps, daily data was also taken but from July 1<sup>st</sup>, 2005 to the end of 2011. Although the data for all securities is available on the Bloomberg terminal, Strips prices were taken from DMO's website.

The first step was to select all the possible matching pairs of bonds. The securities' maturity gap must be the lower possible. There are any pairs with equal maturities so, defining a two-month criterion for maturity differences, five pairs of bonds were selected. Their main features are summarised on **table 3**.

**Table 3: Selected pairs of conventional and index-linked bonds**

<b>Gilt</b>	<b>Coupon</b>	<b>Index-Linked</b>	<b>Coupon</b>	<b>Indexation Lag</b>	<b>Maturity Difference</b>
07-09-2016	4%	26-07-2016	2,5%	8-month	41
07-03-2020	4,75%	16-04-2020	2,5%	8-month	39
07-12-2027	4,25%	22-11-2027	1,25%	3-month	15
07-12-2042	4,5%	22-11-2042	0,625%	3-month	15
07-12-2055	4,25%	22-11-2055	1,25%	3-month	15

In order to start building the strategy, monthly fixed rates for the Inflation Swaps were needed. From Bloomberg I had access to daily closing prices of inflation swaps with maturities of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15, 20, 25, 30, 40 and 50 years.

<sup>13</sup> Inflation swaps do not have a settlement price as previously explained.

The monthly fixed rates can be obtained from the set of annual rates using an interpolation method. In order to get a smooth curve the method chosen was the cubic interpolation. The higher the interpolation degree is, the smoother the curve<sup>14</sup>. However, having monthly rates, seasonality on inflation should be taken off the series.

Therefore, following the literature<sup>15</sup>, in order to estimate seasonality effects, a dummy variable model should be built. I have taken monthly data for the RPI index since January 1980 until December 2011. Given those numbers, logarithms of moving-base index numbers were calculated in order to capture the changes in the RPI. The last step was to use an Ordinary Least Squares regression of the logs on monthly dummies,  $m_i$  ( $m_1$ =January,  $m_2$  = February, (...),  $m_{12}$ =December ).

$$(2) \log(\text{RPI}_t/\text{RPI}_{t-1}) = \sum_1^{12} \delta_i m_i + \varepsilon_i, \text{ where}$$

$$(3) m_i = \begin{cases} 1, & \text{month } i \\ 0, & \text{otherwise} \end{cases}$$

A first normalization was calculated in order to get each month corrected seasonal effect. After calculating the regression coefficients, one should subtract the average of all the coefficients to each one of them<sup>16</sup>.

$$(4) \delta'_i = \delta_i - \bar{\delta}$$

Then, the seasonal adjustment factors,  $m_i$ , are obtained by scaling the corrected coefficients, turning the product of all factors equal to 1. The rationale here is that this will guarantee that full year swaps are not influenced by seasonal patterns.

In order to take the seasonal effects from the interpolated rates, one should find the forward rates,  $f$ , corresponding to each estimated month. **Equation 5** describes the formula used for the computation.

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<sup>14</sup> Wanningen (2007)

<sup>15</sup> Fleckenstein, Longstaff and Lustig (2012)

<sup>16</sup> Belgrade (2004) found evidence that inflation seasonality follows an additive model.

$$(5) f_{a-b} = \frac{as_a - bs_b}{a-b} \quad 17$$

The monthly inflation swap rates adjusted for seasonality are obtained by multiplying all the forward rates for the seasonal adjustment factors and converting them again into spot rates.

After calculating the monthly inflation swap rates, I was able to start building the strategy explained on the previous subsection. However some adjustments should be made. The first has to do with the fact that 8-months index-linked gilts are quoted in nominal terms. In order to compute the mispricing, and because all the other prices are on real terms, the nominal price should be divided by the respective indexation ratio in order to get the real price.

$$(6) \text{Nominal Price} = \text{Real Price} \times \frac{\text{Reference RPI at settlement date}}{\text{Reference RPI at issue date}} \quad 18$$

The second adjustment is made when entering on inflation swap agreements. Here and as aforementioned, the differences on the lagging should be taken into account. As the UK's inflation swaps have a two-month lag, the rate used on a specific date of the strategy must not be the one quoted on that day. For 8-months and 3-months index-linked gilts, the rate to apply on the strategy should be the one quoted exactly on the preceding sixth and first month respectively. This step is crucial in order to overcome the differential on the lagging between the two instruments.

Finally, cash-flows should be adjusted for the maturity mismatch. The inflation indexed synthetic bond should equal the maturity of both conventional gilts and strips. For that purpose, I have calculated the yield to maturity of the synthetic bond

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<sup>17</sup> **Cassino and Pepper (2011)** state that that formula can be applied when calculating forward rates for zero-cupon inflation swaps.

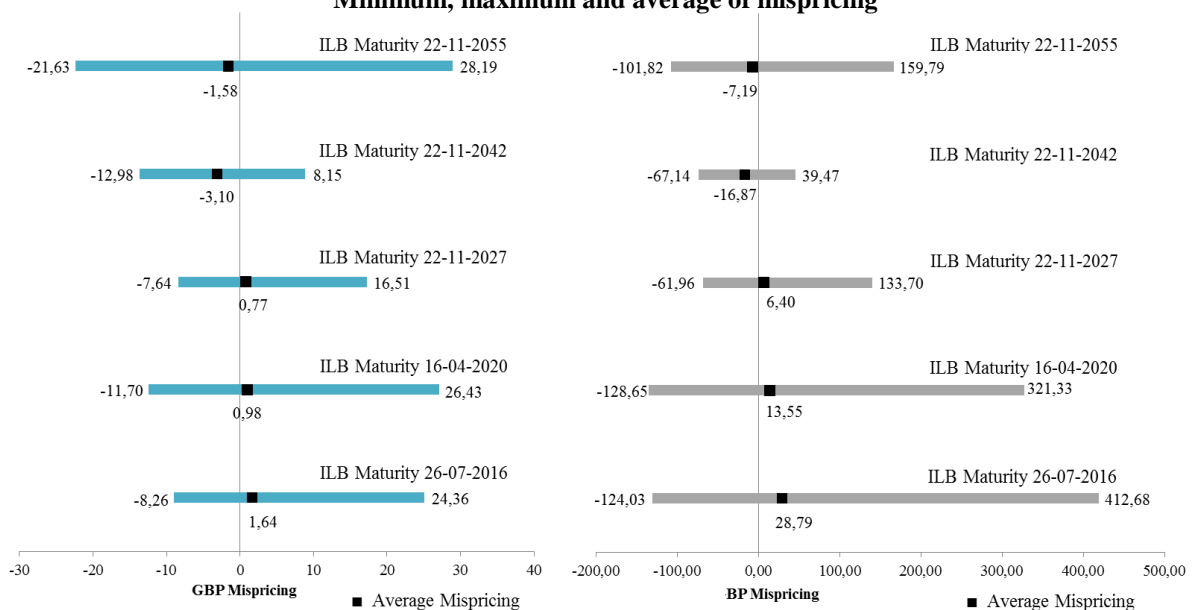
<sup>18</sup> The reference RPI for each date is the eighth-month prior RPI

comprising ILB and inflation swap agreements' positions. This allowed me to calculate the price of a new synthetic bond exactly matching the nominal gilt maturity<sup>19</sup>. The remainder of the strategy is simply follow the steps described on the previous subsection

### 5. Is there any arbitrage opportunity on Gilts Market?

The main results from applying the arbitrage strategy on the Gilt market can be observable on **Figure 3**. The left-hand side graph depicts the magnitude of the mispricing in British Pounds. Each bar is identified by the inflation-linked bond of the pair. Besides the amplitude of the mispricing, observable by the range between the minimum and the maximum mispricing per £100, the average mispricing is plotted with the black marker. The right hand-side also shows the mispricing but measured as the difference on the yield to maturity of the gilt and the synthetic bond (in basis points). On **Appendix B, table 4** summarizes the statistics for the five pairs, including the number of observations and also the standard deviation and the coefficient of variation.

**Figure 3 - Mispricing in British Pounds by £100 notional (left-hand side) and in Basis Points (right-hand side) – Minimum, maximum and average of mispricing**



<sup>19</sup> The price computation took into account the accrued interest calculation differences for the two types of IL Bonds

The results described on **figure 3** and on **table 4, appendix B**, are not completely clear in what concerns the existence of mispricing in the UK sovereign debt market. Three of the five pairs do show an average mispricing of the index-linked securities. The other two have, on average, a negative mispricing. Yet, all the pairs reached a significant mispricing value at some point of the sample period<sup>20</sup>. The longer maturity pair, although presenting a negative mispricing average of £1,58 per £100 notional, present the higher maximum value between all pairs included (28% of notional).

The results can be compared with the ones reached by **Fleckenstein, Longstaff and Lustig (2012)** for the United States<sup>21</sup>. By doing so, one might conclude that evidence on US markets for mispricing is much more conclusive than in the UK market. In all 29 pairs included on their study, the authors report a positive mispricing of the inflation-indexed bonds in relation to the nominal ones. Moreover, only ten do present cases of overpricing of the Treasury nominal bonds over all sample period. On average, the mispricing on US market is constantly positive, fact that does not occur in any of the UK pairs that present times of negative mispricing clustering, as it can be seen on **Appendix C, figure 4**.

Comparing also the five pairs included in the sample, one might not conclude that the mispricing level varies either with maturity or with the lagging mechanism. Even though longer maturities and 3-month index-linked gilts are the ones presenting lower mispricing levels, the 2055 maturity pair, as aforementioned, is the one that presents a higher mispricing occurrence.

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<sup>20</sup> Issues on this matter will be discussed in detail further in this study

<sup>21</sup> The differences on the sample period of the study mentioned are not relevant for this comparison

Following the literature<sup>22</sup>, in order to measure the occurrence or not of mispricing in the gilt market, for each trading day, I have computed a weighted average of all the pairs that were available on that date. The daily mispricing is weighted by each inflation-linked gilt notional amount (in total) issued. The average mispricing of all securities is only £0,155 per £100 notional. However, analysing the respective statistics, the mispricing reaches a level of around £21 per £100 notional (at the end of 2008), which is a huge value when comparing with the maximum mispricing verified on US and computed on the study previously mentioned (9,6% of the notional).

Moreover, a deeper analysis throughout the sample leads to the conclusion that the 2008-2009 crisis had a great impact on the gilt market mispricing. The mispricing values were plotted on the graphs presented in **appendix C, figure 4**. The ten graphs on the top depict the mispricing in all five bond pairs (in British pounds and in basis points), while the two in the bottom shows the weighted average mispricing throughout the sample period.

As suggested on all graphs, in the period of the crisis, after September 2008 and until middle of 2009, the mispricing magnitude is huge. Comparing with the remaining sample period, where the amplitude of mispricing is very unstable – varying from periods with negative mispricing to others with a positive one –, the behaviour of the series in that period stands out. In fact, restraining the sample period to the period from September 2008 until December 2009, the weighted-average mispricing jumps to over £4,5 per £100 notional.

The (non)existence of a deflation floor for the index-linked bonds does play a role on the mispricing. In case of inflation-linked gilts, as already mentioned, they do not

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<sup>22</sup> Fleckenstein, Longstaff and Lustig (2012)



have a deflation floor. In other words, at the maturity, if a deflation is verified the principal value of the bond is adjusted downwards. If IL gilts were endowed of such feature, the mispricing amplitude would be smaller. As a remark, transaction costs even though not considered in this study, would not have a great impact on gilts mispricing (mainly in the crisis period)<sup>23</sup>.

The observable impact of downturns on mispricing turns out to be one plausible explanation for the lower values of mispricing verified on the pair maturing on 2042. The index-linked gilt was only issued on July 2009 and so the most relevant period for the other pairs' mispricing had to be excluded from the analysis.

So, it is now interesting to investigate how the mispricing behaved with the stock market returns. In order to do so, changes on monthly mispricing measured in basis points were calculated for the weighted-average mispricing series. On **Appendix D, figure 5**, those fluctuations were plotted against the returns on the London Stock Exchange Index (FTSE 100).

Although not completely clear, the graph shows a negative relation between the two variables, confirmed by a correlation coefficient of -0,23. Such relationship is much more obvious on the crisis period than in other periods in which both variables move alongside with each other. It is so plausible to argue, that such relation can appear due to other factors than the performance of the stock market itself.

#### *Further issues on Gilt Market Mispricing*

Following the literature, some factors to analyse the mispricing in the Gilt market were considered. **Kilponen, Laakkonen and Vilmunen (2012)**, study the impact of Central Bank policies on the sovereign debt yields. In order to do so, the authors

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<sup>23</sup> an estimation of such costs was performed by **Fleckenstein, Longstaff and Lustig (2012)** for US markets

considered some variables that might influence bond yields. Some of those factors were considered also as potential drivers for the mispricing on the US markets by **Fleckenstein, Longstaff and Lustig (2012)**.

In order to complement the previous analysis of the influence of stock markets performance<sup>24</sup> on mispricing in the Gilt market, a market risk perception measure was considered. The referred authors include on their sample a global uncertainty feeling, which is often measured by the implied volatility index for S&P500 (*VIX*). Furthermore, as argued by **Nagel (2011)** and **Fleckenstein (2012)**, implied volatility is also a liquidity provision proxy. Periods of downturns are also periods when risk perception is higher and liquidity is restrained. This might influence the occurrence of mispricing.

On **Appendix D**, it is plotted on **figure 6** the monthly variation in basis points of the weighted-average mispricing against monthly data for *VIX*. Additionally, as values of *VIX* of 20% might indicate less worrying times on the market, while an index over 30% signals high uncertainty<sup>25</sup>, a green and a red dotted line were plotted on the graph for those values respectively. As it might be expectable, the mispricing variation peaks coincide with the times when implied volatility is higher. Periods of high perception of risk (observable by the occurrences above the plotted lines) are the ones where the series denote a more similar behaviour. Indeed, the global market perception of risk, and the mispricing on Gilt markets, present a correlation of 0,28. The evidence seems to confirm that high turbulence times have impact on the mispricing.

In order to conclude this analysis a regression was estimated in order to try to test which factors are responsible for the mispricing. This regression was based on the

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<sup>24</sup> **Mitchell, Pedersen and Pulvino (2007)**

<sup>25</sup> **Wei (2012)**

literature referred above and sticks to two main drivers for mispricing: the liquidity available for investors and the supply of bonds.

Complementarily, **Brunnermeier and Pedersen (2009)** discuss market liquidity in the scope of its co-movement with the market and its relation with volatility. As such, the two already analysed variables, stock returns and the returns on the VIX index, were considered as measures of liquidity. Basing on **Fleckenstein, Longstaff and Lustig (2012)**, the authors also include on their model the Global Hedge Fund Index as a proxy for the liquidity available for investors, globally. As the authors argue, the investing capacity of hedge funds does seem to influence asset pricing. This index is available on the Bloomberg terminal with the ticker *HFRXGL*, and the monthly return of the index was considered as explanatory variable.

The supply factor was considered following the same literature. The authors concluded that for the US market, both supply of treasury and TIPS influence negatively the mispricing. Thus it is interesting to test whether or not such relationship verifies on the UK market. For this purpose, month-to-month changes on supply of either nominal or index-linked bonds were considered. Both series were built based on issue data taken from the DMO's website.

The dependent variable considered was the monthly change on basis points mispricing (the weighted-average series for all sample pairs). The aforementioned variables are identified, respectively, by the following names: *FTSE*; *VIX*; *HF*; *Supply\_nominal* and *Supply\_IL*. The first three variables are in percentage, whilst the latest two are on million £. The model considered is described by **equation 7**.

$$(7) \text{ Mispricing(chg)} = c + \alpha_1 FTSE + \alpha_2 HF + \alpha_3 VIX + \alpha_4 \text{Supply\_nominal} + \alpha_5 \text{Supply\_IL}$$

The output of the regression is presented on **table 5, appendix D** and it allows us to take some interesting conclusions. The first factor considered, available liquidity, do present significant results. Both performance of the stock market and the variation on the hedge-funds capital are statistically significant for a 99% confidence level. A negative coefficient on both variables was achieved. In what concerns the performance of the market, this result is aligned with the previous analysis. A decrease on stock returns leads to an augmenting of the mispricing. The evidence that in periods of troubled waters the arbitrage opportunities on the gilt market arise is so confirmed. A shortening of hedge funds investing capacity should also cause an increasing mispricing. Such statement is confirmed by the negative sign of the regressed variable. The returns of implied volatility index, though, are not significant for any reasonable confidence level.

The results for bonds supply are interesting, since they deviate from the ones presented for the US case, studied on the papers previously referred. On the UK market the supply of nominal bonds doesn't seem to be significant. Such variable would only be significant for confidence levels of around 85% (before the usual corrections for heteroskedasticity, the variable was significant). Yet, it presents a negative sign which comes in hand with the results presented by the authors for the US case. On contrary, the supply of inflation-linked gilts is significant for a 2,5% level. Though, its sign is the opposite of the US similar variable. The model provides evidence that an increase of the amount of ILB available has a positive impact on mispricing and so, the composition of the Government debt structure influences the mispricing. An increase of the amount of IL gilts issued widens the mispricing, which means that it drives down their prices in relation with the nominal gilts.

The model, having global significance, confirms that both supply of bonds and liquidity available on the market do influence the mispricing on the market. Such results are, in general, aligned with the three studies mentioned on this section of the study.

## **6. Conclusion**

This study provides an assessment to arbitrage opportunities in the UK sovereign debt market. The theory predicts that if two assets generate the same cash-flows to an investor, they should be equally priced. However, in various markets this principle is not verified and, as proven, the Gilt Market is one of them. The present work project estimates that, on average, the inflation-linked bonds are undervalued by a value of £0,155 per 100£ notional in relation to their nominal counterparts.

Although the presented value is not as high as the one reached by related literature for the US case, one should not rely solely on this value. The magnitude of mispricing on the gilt market is much more significant in the 2008-09 crisis. Indeed, the weighted average mispricing on those years was £4,5 per £100 notional and had as maximum mispricing a value of 21% of the notional. These occurrences are very significant and above the ones estimated for the US. Still, it is shown that, on the UK, mispricing often changes the sign of its values. Negative mispricing is, generally, clustered on time.

Finally, these findings lead the mispricing analysis to the scope of market performance. As expected, in times of high turbulence of the markets the mispricing increases. Also, it is on those times that there is a shortening of liquidity provision for investors. As such, evidence was found that this factor do play a role on the changes of mispricing. The returns on the market and the investing capacity of global hedge funds have a significant influence on the mispricing. Additionally, the increase on the supply of index-linked gilts also impacts positively the mispricing.

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## Appendix A

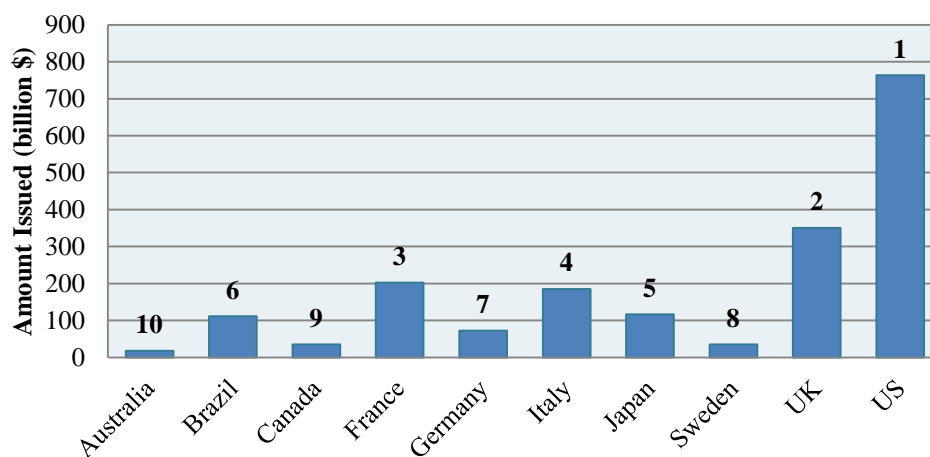
**Table 1 – Summarized features of the british fixed-income instruments considered**

<b>Instrument</b>	<b>Indexation Lag</b>	<b>Index</b>	<b>Issuer</b>	<b>Quotation</b>	<b>Other features</b>
<b>Gilts</b>	na	na	DMO	Real Clean Price	-
<b>IL Gilts</b>	3 months	RPI	DMO	Real Clean Price	No deflation floor
	8 months	RPI	DMO	Nominal Clean Price	No deflation floor
<b>Strips</b>	na	na	DMO (official Strip facility)	Real Clean Price	Coupon Strips and Principal Strips
<b>Inflation Swaps</b>	2 months	RPI	na	Annualized rate (fixed leg of the agreement)	-

*na – not applicable*

**Figure 1 - Main Issuers of Index-Linked Government Bonds in the World (ranked) and Amount Issued (Billion \$)**

*Source: UK Standard Life Investments and Bloomberg (values for January 2013)*



## Appendix B

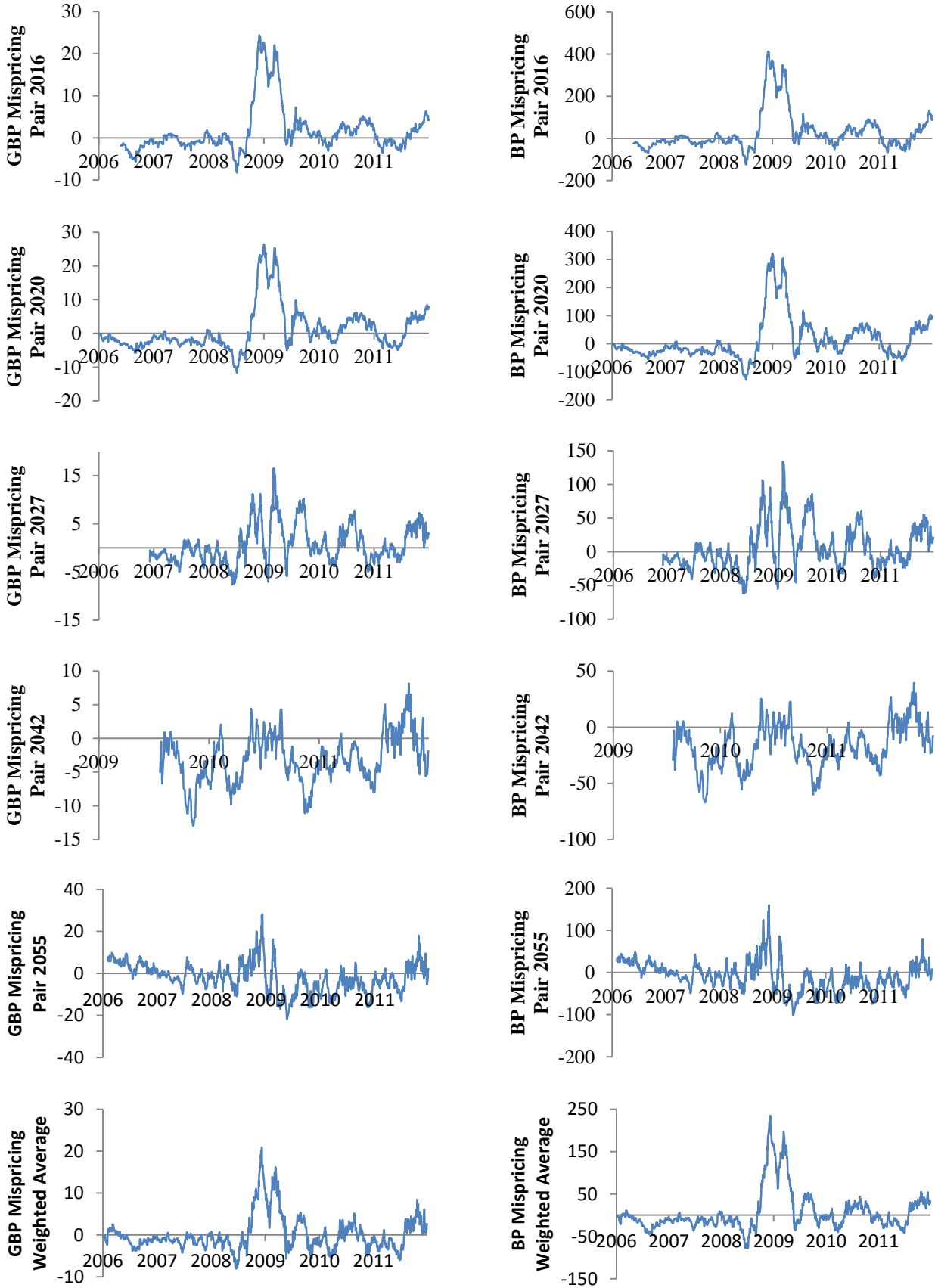
**Table 4 – Mispricing summarized statistics:** Considered pairs and respective observations. The middle panel summarizes the main statistics (average, standard deviation, coefficient of variation, maximum and minimum) in terms of Great Britain Pounds. The right panel provides the same statistics, now for the mispricing measured in basis points.

Pair	Gilt	Index-Linked Gilt	Trading Days	GBP					YTM				
				Avrg	Std. Dev.	CV	Max	Min	Avrg	Std. Dev.	CV	Max	Min
1	07-09-2016	26-07-2016	1461	1,64	5,68	3,46	24,36	-8,26	28,79	92,25	3,20	412,68	-124,03
2	07-03-2020	16-04-2020	1564	0,98	6,46	6,60	26,43	-11,70	13,55	76,55	5,65	321,33	-128,65
3	07-12-2027	22-11-2027	1324	0,77	3,90	5,06	16,51	-7,64	6,40	32,01	5,00	133,70	-61,96
4	07-12-2042	22-11-2042	637	-3,10	3,66	1,18	8,15	-12,98	-16,87	19,43	1,15	39,47	-67,14
5	07-12-2055	22-11-2055	1507	-1,58	6,67	4,21	28,19	-21,63	-7,19	32,53	4,52	159,79	-101,82



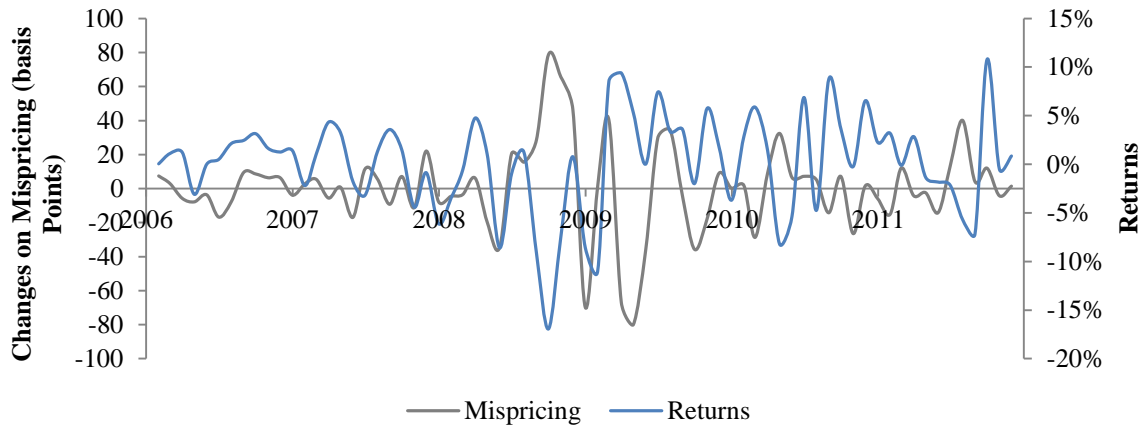
## Appendix C

Figure 4 – Pairs and Weighted Average Mispricing in GBP and Basis Point through time

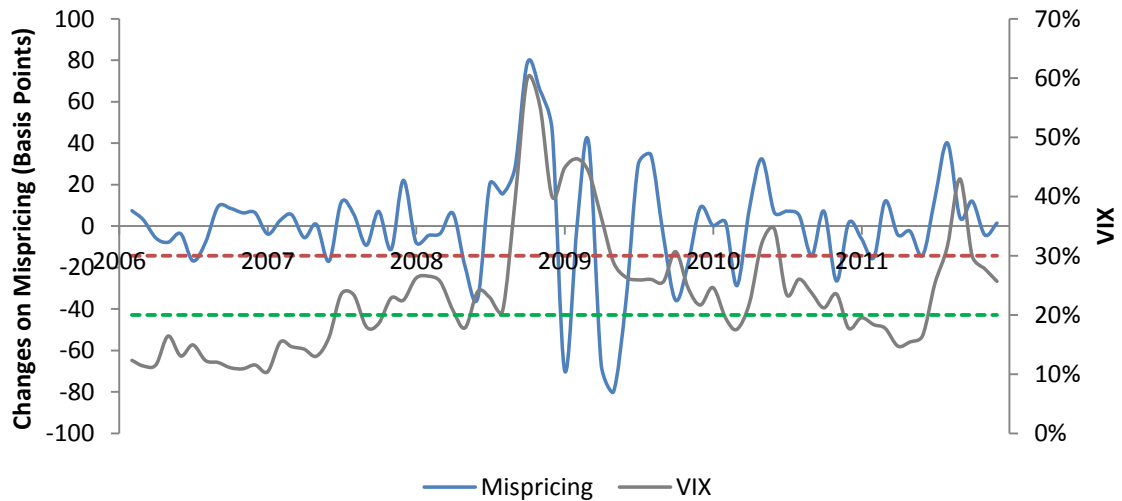


## Appendix D

**Figure 5 – Changes on mispricing (BP) against returns of the market (FTSE100)**



**Figure 6 – Changes on mispricing against VIX level: Below the green dotted line markets are not very volatile while above the red dotted line, markets face high turbulence**



**Table 5 – Regression output:** Regression of month-to-month changes on mispricing (BP) on FTSE returns, Hedge Funds investing capacity (asset balances), VIX, and supply of Nominal gilts and IL gilts

Dependent Variable	Month-to-month changes on basis points mispricing		
Independent Variables	Coefficient	t-Statistic	P-value
<i>C</i>	0,777	0,17	0,87
<i>FTSE</i>	-1,986	-3,194	0,002
<i>HF</i>	-5,406	-2,88	0,005
<i>VIX</i>	-5,759	-0,467	0,64
<i>Supply_nominal</i>	-0,0008	-1,438	0,155
<i>Supply_IL</i>	0,003	2,308	0,024
<i>R<sup>2</sup></i>	0,42		
<i>F-stat (prob)</i>	0		