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CORRELATION RELATIONSHIPS**

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Breakeven inflation rates and their puzzling correlation relationships

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Résumé

Il est usuellement admis que les deux composantes des taux d'intérêt nominaux, selon l'approche proposée par Fisher – le taux réel et l'inflation –, évoluent de façon autonome, leurs déterminants n'étant pas les mêmes. Cependant, l'évaluation de ces deux composantes à partir d'instruments financiers récemment introduits sur les marchés ne fournit pas d'enseignements clairs. L'analyse des évolutions des taux nominaux et réels (indexés sur l'inflation) dans les grandes zones économiques amène à observer i) que l'écart entre ces deux taux (le point mort d'inflation) et les taux réels sont positivement corrélés entre les différents pays ; ii) mais que cette corrélation devient négative en cas de certaines distorsions importantes. La corrélation est proche de zéro pour chaque pays tant que ces distorsions demeurent nationales ; elle devient négative quand ces distorsions sont généralisées, comme à certains moments de la crise actuelle. La présente étude propose une approche internationale permettant de distinguer les composantes idiosyncratiques de ces corrélations de celles plus générales qui ont été affectées dans le contexte de la crise actuelle.

Mots-clés : Obligation indexées sur l'inflation ; point mort d'inflation ; hypothèse de Fisher

Codes classification JEL : E43, G15

Abstract

It is generally assumed that the two Fisher components of the interest rate -the real interest and the inflation- evolve independently over time, considering that they are driven by unrelated economical events. However, the market pricing of those components deduced from newly-available bond data does not provide conclusive evidence. While studying the price behaviour of inflation-linked (real) bonds beside nominal bonds in the major fixed-income markets, we observe that the real bond yields and the yield differentials, the breakeven inflation rates, have the propensity to be positively correlated between each other across the various countries, yet are pushed into a negative correlation relationship due to market-related price distortions. As long as those distortions are local, the net result is near-zero correlation within countries; when they become global, as in the heat of the current crisis, the correlations turn negative worldwide. In this paper insight is gained by taking an innovative worldwide study approach and thanks to revealing crisis period events.

Key words: inflation-linked bonds, breakeven inflation, Fisher hypothesis

JEL classification: E43, G15

1. Introduction

The yield of an inflation-linked bond, informally called the real bond yield (RBY), reflects the market pricing of the long-term real interest rate in the same manner as the nominal bond yields (NBY) ‘price’ the nominal interest rate. The relatively recent issuance of inflation-protected securities by governments around the world has made it possible, for the first time¹, to pair up the two bond types and observe the yield differentials, called the breakeven inflation rates (BEIR). The longstanding idea of decomposing interest rates into two components, introduced by Irving Fisher in his seminal book named *Theory of Interest* (1930), can eventually be tried now the new bond markets are maturing and becoming more liquid.

Fisher had hypothesized that the two components should be unrelated to one another: “... *the real interest rate is entirely determined by the real factors in an economy, i.e. the productivity of capital and the investors’ time preference, and should thus be unrelated to the inflation expectation.*” Many efforts have been undertaken to provide empirical evidence; see Cooray (2002) for a literature review. In Cetto and de Jong (2008), we had made a renewed attempt with tests on recent bond market data, observing that the Fisher hypothesis seems to hold country per country yet is definitely rejected in an international context. Tests were based on a historical correlation matrix measured between the two interest rate components, BEIR and RBY, across various countries, featuring near zeros (more exactly, unsystematically negative, nil or positive numbers) on the diagonal, i.e. within countries, and strictly positive numbers elsewhere, i.e. between countries.

By means of standard statistical analysis, by which worldwide common bond yield movements are separated from idiosyncratic movements within countries, we had succeeded in disentangling two effects in the correlation structure. The schema is given in Figure 1 below. The complete matrix, displayed in (a), turns out to be the net sum of a positive common global correlation (b) and a negative idiosyncratic country-specific correlation (c). The diagonal terms in (a) are the sum of a positive term (from matrix (b)) and a negative term (from matrix (c)), and can consequently be nil, negative or positive.

¹ The scale in which such bonds are being issued is new, not the concept. According to Shiller (2003) the first inflation indexed bonds were issued by the Commonwealth of Massachusetts in 1780 during the Revolutionary war to deal with severe wartime inflation.

Figure 1

Schematic decomposition of the correlation matrix between BEIR and RBY variation across countries

$$\begin{array}{c}
 \text{total correlation} \\
 \left[\begin{array}{cc} 0 & + \\ - & 0 \end{array} \right] \\
 \text{(a)}
 \end{array}
 =
 \begin{array}{c}
 \text{common correlation} \\
 \left[\begin{array}{cc} + & + \\ + & + \end{array} \right] \\
 \text{(b)}
 \end{array}
 +
 \begin{array}{c}
 \text{idiosyncratic correlation} \\
 \left[\begin{array}{cc} - & 0 \\ 0 & - \end{array} \right] \\
 \text{(c)}
 \end{array}$$

The finding is puzzling. The correlation structure, untypical for bonds and casting doubt on the Fisher hypothesis, pulls all analyses traditionally made in a national perspective into scrutiny.

In our previous article we had shown the correlation structure to be stable over time up to mid-2008. In this article we study what happened after, in the current financial crisis, up to mid-2010, during which bonds have been in great turmoil, as documented by many such as Campbell *et al.* (2009). Our main findings are the following. While the idiosyncratic correlation structure remained unchanged in the turmoil, the common correlation became negative, resulting in a negative correlation matrix overall with significantly negative coefficients on the diagonal. We explain this change by a worldwide lack of liquidity in the real bond markets affecting the prices, and we observe that, as soon as this simultaneous liquidity problem resolved in 2009, the bond prices settle back into the same regime as given in Figure 1. Our international study approach remains original in the literature to our knowledge, many other articles focusing on national indexed bond markets only. It proves essential in gaining insight in the effects behind the interest rate component movements.

Section 2 discusses the data issues, section 3 and 4 give an analysis of the bond correlations respectively before and since the crisis, and section 5 concludes.

2. Data issues

The data has been retrieved from Barclays Capital. Developed countries issuing inflation-linked bonds since at least a decade have been retained.² It covers the Inflation-Linked Gilts issued in the United Kingdom, the Treasury Inflation-Protected Securities (TIPS) in the United States, *les Obligations Assimilables du Trésor indexées sur l'inflation* (OATi) in

² Japan has not been retained for this reason.

the Euro Area, the Treasury Indexed Bonds in Australia, the Index-Linked Treasury Bonds in Sweden and the Real Return Bonds in Canada. Generic bond yields have been calculated by Barclays Capital per interval of maturity dates. The seven-to-ten-year term-to-maturity interval with a bond-duration close to 7.5 years has been selected for this study, since it is by and large the most liquid category. We refer to Barclays' *Global Inflation-Linked Products* edited by James (2010) for more details on their calculus.

The observation period, from mid-2002 to mid-2010 has been divided in three in order to separate out the period of great market turbulence in 2008-2009. There is a pre-crisis period, from July 2002 to September 2008, a turbulent period, from October 2008 to May 2009, and a post-turbulent period, from June 2009 to June 2010. In order to set the cut-off dates we have measured market turbulence by means of the standard deviation of the weekly variation in the breakeven inflation rates over four weeks and over all countries in the dataset. If this measure exceeds two times its historical average, the market is deemed turbulent.

3. The bond correlation structure before the financial crisis

The correlation matrix measured in Cette and de Jong (2008) between the major bond markets over a six-year period from 2002 to 2008 is reprinted in Table 1.

Table 1

Correlation matrix between breakeven inflation variation and real bond yield variation across countries

Period: July 2002 to September 2008 – Weekly data frequency.³

Data source: Barclays Capital. Correlation measures made by the authors.

| | | RBY | | | | | |
|------|---------------|----------------------------|-----------------------------|----------------------------|-----------------------------|---------------------------|---------------------|
| | | Australia | Canada | Euro Area | Great Britain | Sweden | United States |
| BEIR | Australia | 0.25 ^{***} | 0.16 ^{***} | 0.36 ^{***} | 0.30 ^{***} | 0.40 ^{***} | 0.31 ^{***} |
| | Canada | 0.34 ^{***} | -0.14 ^{***} | 0.38 ^{***} | 0.28 ^{***} | 0.29 ^{***} | 0.39 ^{***} |
| | Euro Area | 0.18 ^{***} | 0.04 | -0.11 ^{**} | 0.05 | 0.15 ^{**} | 0.11 ^{**} |
| | Great Britain | 0.15 ^{***} | 0.02 | 0.17 ^{***} | -0.26 ^{***} | 0.25 ^{***} | 0.17 ^{***} |
| | Sweden | 0.29 ^{***} | 0.16 ^{***} | 0.43 ^{***} | 0.34 ^{***} | 0.13 ^{**} | 0.35 ^{***} |
| | United States | 0.21 ^{***} | 0.02 | 0.10 [*] | 0.13 ^{***} | 0.15 ^{***} | -0.07 |

^{***} : significant at the 1% level (critical value at 0.13); ^{**} : significant at the 5% level (critical value at 0.11);

^{*} : significant at the 10% level (critical value at 0.09) - Using an asymptotic *T*-test with *T*=325.

A dual phenomenon can be observed. The correlations are nil, or more precisely they are unsystematically negative, nil or positive, as discussed in the introduction, within countries (on the diagonal), while in contrast they are strictly positive between countries (the cross terms). This is puzzling. In practical terms, it means that the yield variation of an

³ On a monthly data frequency results are very similar.

American TIPS, to take an example, is uncorrelated with the breakeven inflation movements in the US (bottom right number in the matrix). It indicates that the bond price is insensitive to inflation concerns, which is in effect the *raison d'être* of the security. Yet why would its yield correlate with breakeven movements registered in other countries (the numbers in the rightmost column)? The correlations do not strike with theory either. The Fisher hypothesis seems to hold within countries –in effect a joint test of zero correlation is not rejected even on a 10 % error level-, however it is rejected, on a 1 % significance level, across countries.

An explanation can be given on the basis of an elementary matrix decomposition analysis. The movements of the breakeven inflation and real bond yields are decomposed into a common- and an idiosyncratic component per country. The common component of each variable is extracted through a regression across countries with time-fixed effects as explanatory variables; the idiosyncratic component is for each variable the residual of this regression. Ignoring the (small) cross terms and ignoring that correlations don't exactly add, it results, as shown in the schema in Figure 1, that the total correlation, displayed in Table 1, turns out to be the net sum of two distinct effects⁴:

- (i) The common global component of the BEIRs tends to move in the same direction as the common global component of the RBYs, resulting in a positive common correlation matrix;
- (ii) The idiosyncratic country-specific component of the BEIRs tends to move against the idiosyncratic components of the RBYs within the same country, yet have no statistical relation with those of other countries, resulting in a diagonal negative correlation matrix.

We interpret the two effects separately. The negative idiosyncratic correlation can be directly associated with certain time-varying market distortions that are being mentioned in the literature; see Christensen *et al.* (2004) for a survey. As soon as the real bond price moves due to such country-specific market-related events, which are typically not mirrored in the nominal bond price, the breakeven rate mechanically moves in opposite direction. Those events appear to be sufficiently recurrent to provoke a systematic idiosyncratic negative correlation over time. Our observation complements the literature that analyses a price premium on real bonds relative to nominal bonds resulting from those market distortions.

Abrupt market liquidity problems are mentioned to be the main cause of the price distortions, for example by Craig (2003), Sack and Elsasser (2004), Shen (2006), D'Amico *et*

⁴ The detailed decomposition is available upon request from the authors.

al. (2009), Campbell *et al.*, (2009) as well as Gürkaynak *et al.* (2010). Gürkaynak *et al.* (2010) relate the liquidity premium, which is being observed in the inflation-linked bond prices compared to the nominal bond prices, to the particularly low trading volumes for inflation-linked bonds.⁵ They explain in a regression analysis the time-variability of the liquidity premium on TIPS directly by the variations in the TIPS trading volumes. These market-related events being usually country specific, explain the idiosyncratic negative correlation between the BEIR and RBY.

Others observe a risk premium rather, which varies depending on the aversion to inflation uncertainty among the market participants; see Hördahl and Tristani (2007) on Euro Area data, Emmons (2000), on US data, Evans (1998), on US and UK data, and Côté *et al.* (1996), on Canadian data. Ejsing *et al.* (2007) show that the seasonality in consumer prices over the year adds to the price discrepancy as well. Note that those price influences are also mainly idiosyncratic.

The positive correlation between the global BEIR and RBY is less commented in the literature, since it is not easily observable on a national level. In fact, market practitioners do recognise its existence indirectly when they mention the *beta effect* (see Pond, 2008). It is the observation that the RBY tends to move in the same direction as the NBY yet in smaller amplitude. Note that in that situation, the BEIR mechanically moves in the same direction as well, resulting in positive correlation. The market phenomenon is illustrated in Figure 2 on a global scale. The weekly global RBY variation is set out on the Y-axis against the global NBY variation in the same week on the X-axis. The dots cover the off-crisis weeks and the triangles the crisis-period weeks. Note the R-squared of the regression line through the off-crisis observations being significantly high.

Does this market observation match with usual macroeconomic theory? In theory the nominal and real interest rates should move together with the same amplitude after a shock that has no significant impact on inflation expectations (for example, at the first order, a technological shock). Or otherwise, the nominal interest rate should move alone after a pure inflation shock. Notice in Figure 2 that those events rarely occur in practice. The fact that most of the time the net result of the two scenarios is observed means that the two types of shock very often coincide or that somehow bond prices absorb the two types of shock simultaneously.

⁵ Gürkaynak *et al.* (2010) report that in the US, the TIPS market expressed as a share of total Treasury trading represented about 0.5% in 1999 and 2% in 2006.

Figure 2

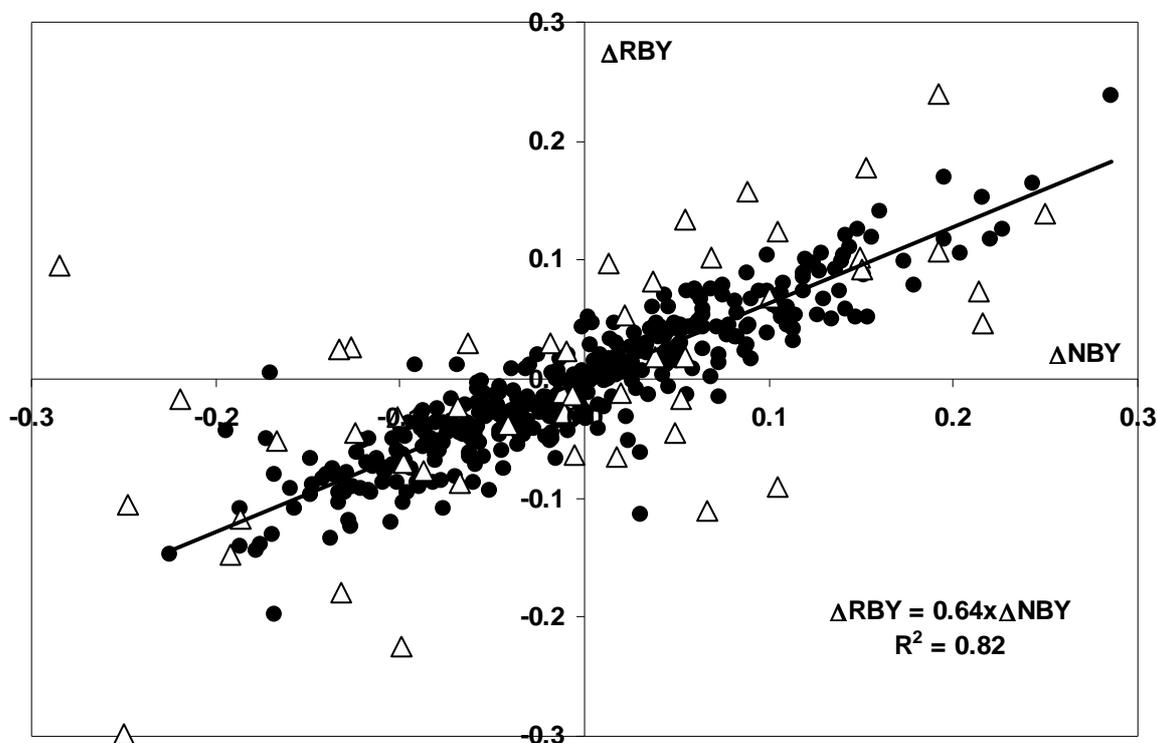
The beta effect between global nominal- and real bond yield movements

Period: July 2002 to June 2010

●: Weekly NBY and RBY variations registered from 07/2002 to 09/2008 and from 06/2009 to 06/2010

△: Weekly NBY and RBY variations registered from 10/2008 to 05/2009, in the heat of the crisis

Data source: Barclays Capital. Calculations made by the authors.



4. Bond market experience since the financial crisis

We investigate what happened during the current crisis period. The correlation matrix between breakeven inflation and real bonds measured between September 2008 and May 2009 is given in Table 2. Over this period, the correlations are (i) strongly negative within countries (on the diagonal), and (ii) weakly negative between countries (the cross terms). The test of zero correlation is integrally rejected on a 1% significance level. Despite the admittedly reduced reliability of the tests in non-stationary times, it may be concluded that the Fisher hypothesis does not hold, even within countries.

Table 2

Correlation matrix between breakeven inflation variation and real bond yield variation across countries

Period: October 2008 to May 2009 – Weekly data frequency.

Data source: Barclays Capital. Calculations made by the authors.

| | | RBY | | | | | |
|------|---------------|--------------|------------------|------------------|------------------|----------------|------------------|
| | | Australia | Canada | Euro Area | Great Britain | Sweden | United States |
| BEIR | Australia | -0.21 | -0.31* | -0.08 | -0.23 | -0.21 | -0.22 |
| | Canada | 0.12 | -0.62 *** | 0.19 | -0.26 | 0.23 | -0.34** |
| | Euro Area | 0.04 | -0.04 | -0.70 *** | -0.38** | 0.07 | 0.03 |
| | Great Britain | -0.11 | -0.40*** | -0.28* | -0.68 *** | 0.20 | -0.33** |
| | Sweden | 0.22 | -0.01 | 0.06 | 0.06 | -0.32 * | 0.06 |
| | United States | 0.26 | -0.38** | 0.13 | -0.12 | 0.18 | -0.59 *** |

*** : significant at the 1% level (critical value at 0.39); ** : significant at the 5% level (critical value at 0.33);

* : significant at the 10% level (critical value at 0.28) - Using an asymptotic T -test with $T=35$.

The same elementary matrix decomposition produces the schema as displayed in Figure 3.⁶ Note that the sole difference with the pre-crisis period lies in (b): the correlation between the common global BEIR and RBY movements turns negative. The sign change is informative. It is, to us, caused by the same issues of liquidity and risk attitude mentioned above. The worldwide market distortions have provoked a negative common correlation between the BEIR and the RBY, in the same way as they do on a national scale in normal times. In the heat of the crisis, the inflation-linked bond markets contracted in all countries simultaneously. Considering the relatively small trading volumes on these markets, the price shocks the inflation-linked bonds incurred provoked a negative correlation with the breakeven inflation rates in all countries. Any global price shock in the real bonds that is typically not registered in the nominal bond markets leads to a mechanic opposite movement in the global breakeven inflation.

Figure 3

Schematic decomposition of the correlation matrix in Table 2

$$\begin{array}{c}
 \text{total correlation} \\
 \left[\begin{array}{cc} - & - \\ - & - \end{array} \right] \\
 \text{(a)}
 \end{array}
 =
 \begin{array}{c}
 \text{common correlation} \\
 \left[\begin{array}{cc} - & - \\ - & - \end{array} \right] \\
 \text{(b)}
 \end{array}
 +
 \begin{array}{c}
 \text{idiosyncratic correlation} \\
 \left[\begin{array}{cc} - & 0 \\ 0 & - \end{array} \right] \\
 \text{(c)}
 \end{array}$$

This interpretation fits in with the finance literature reporting on the crisis events: there was a massive flight to liquidity. James (2010) wrote: “*the extreme deleveraging phase that engulfed almost all financial markets included the majority of off-benchmark investors in*

⁶ The complete decomposition is omitted but can be obtained from the authors upon request.

inflation-linked bonds being stopped out of their positions". The bankruptcy of Lehman Brothers added to the turmoil for it was the world leader on inflation-secured instruments (see Hu and Worah, 2009, or Bekaert and Wang, 2010). Simultaneously in the economic literature, the near-meltdown of the financial sector was seen as the start of an extended low-growth period, with lower inflation than expected before the crisis. The relevance of inflation issuance by inflation-linked bonds decreased, reducing its demand. The price fall of commodities -in particular petrol- was reinforcing this view.

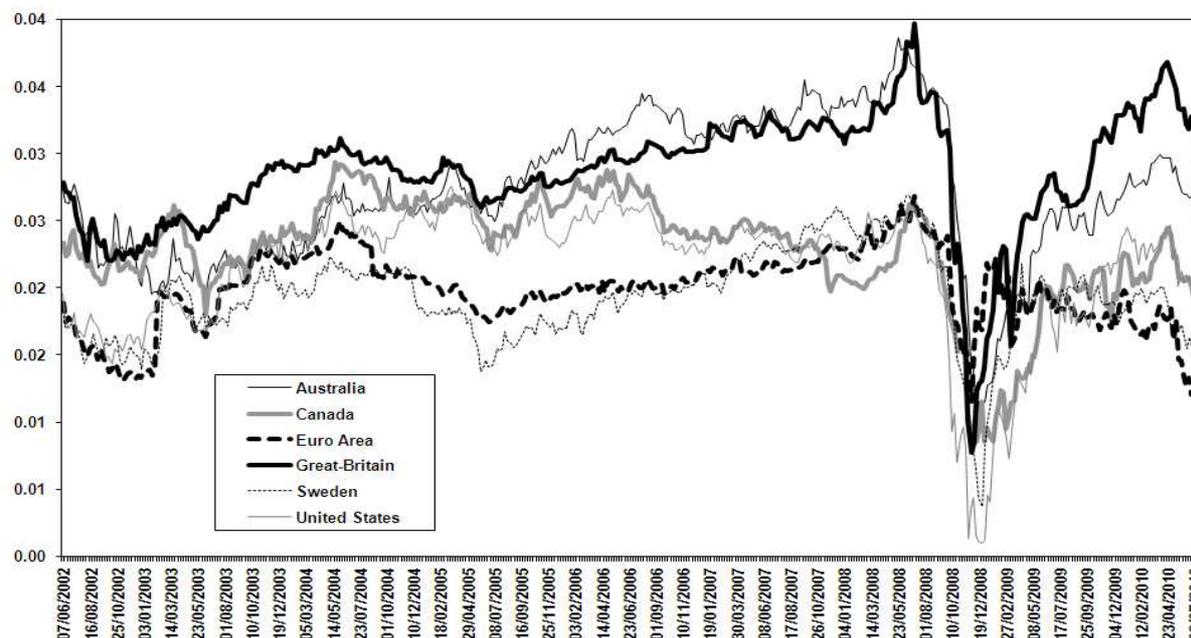
The flight to the mature nominal bond markets, which penalized TIPS demand and increased their risk premium in 2008, as show Gürkaynak, Sack and Wright (2010), was worldwide, its factors being themselves worldwide, as mentioned before. It is shown in Figure 4 that not only in the US, but in all developed world countries, the BEIR decreased dramatically from in the last quarter of 2008, to normalize after in the first half of 2009, back to pre-crisis levels. The abnormal BEIR levels in 2008 and 2009 stem from a decrease in the nominal rates as well as an increase in the real rates. These global co-movements, that are a good illustration of the generalized flight-to-liquidity behaviour, explain the common negative co-movements of the BEIR and the RBY, which explain on its turn why the common correlation matrix exhibits negative numbers during this short period.

Figure 4

The 10-year breakeven inflation rates in the developed world

Data source: Barclays Capital.

Period: July 2002 to June 2010.



From June 2009 when markets calmed down, the correlation matrix settled back into the same regime as before (see Table 3), and its decomposition matches with Figure 1. This shows, or gives strong indication, that the untypical correlation structure between BEIR and RBYs is nevertheless robust.

Table 3

Correlation matrix between breakeven inflation variation and real bond yield variation

Period: June 2009 to June 2010 – Weekly data frequency.

Data source: Barclays Capital. Calculations made by the authors.

| | | RBY | | | | | |
|------|---------------|---------------|------------------|--------------|-----------------|----------------|---------------|
| | | Australia | Canada | Euro Area | Great Britain | Sweden | United States |
| BEIR | Australia | 0.24 * | -0.06 | 0.37*** | 0.18 | 0.24** | 0.22* |
| | Canada | 0.42*** | -0.34 *** | 0.19 | 0.23* | 0.49*** | 0.19 |
| | Euro Area | 0.20* | -0.07 | -0.14 | 0.27** | 0.42*** | 0.15 |
| | Great Britain | 0.25* | -0.15 | 0.04 | -0.31 ** | 0.16 | 0.04 |
| | Sweden | 0.36*** | 0.08 | 0.44*** | 0.50*** | 0.24 ** | 0.17 |
| | United States | 0.40*** | 0.10 | 0.48*** | 0.42*** | 0.54*** | -0.02 |

***: significant at the 1% level (critical value at 0.31); **: significant at the 5% level (critical value at 0.26);

*: significant at the 10% level (critical value at 0.22) - Using an asymptotic *T*-test with *T*=56.

5. Conclusion

The events on the capital markets during the present crisis provide new insight in the price covariance structure of bonds. The two components of the nominal bond yield, the breakeven inflation and the real bond yield, have the propensity to be positively correlated, yet are pushed into a negative correlation relationship by certain market events. As long as those market distortions are local, the net result is near-zero correlation within countries; when they become global, as was the case in the heat of the crisis, the correlation between real bond yields and breakeven rates turns negative worldwide. Those empirical findings have been shown to be robust over the pre- and post-crisis period.

This untypical correlation behaviour has been left uncommented in the literature, the reason for that being that studies on inflation-linked bonds are traditionally made in a national context, while an international analysis is necessary to reveal the underlying effects. We consider the demonstration of the correlation relationships an important contribution to the finance literature; its understanding is essential in bond risk analysis, in particular in establishing the risk profile of fixed income portfolios.

The results are a contribution to the economic literature as well, the more that they are not in line with conventional theory of Fisher (1930) postulating zero correlation between the two interest rate components. The discrepancy between macroeconomic theory and financial practice has been indirectly reported by central bankers, e.g. in Bernanke's (2004) speech *What Policymakers Can Learn from Asset Prices*. The issuance of inflation-linked bonds had in part been motivated by the expectation that the observed breakeven inflation would in some way reflect the credibility granted to Central Banks regarding their control on inflation. Bernanke reckons the volatility of the breakeven inflation too high, to the extent that the market data remains as it stands of very limited use for policymaking purposes.

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