REPLICATING THE BARCLAYS CAPITAL EURO TREASURY INDEX

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The recent volatility in European sovereign spreads has added a new dimension to euro government bond investing. Until 2008, it was possible to accurately track the Euro Treasury Index with concentrated portfolios of bonds, futures, or swaps assembled to neutralise rates exposures. This is no longer the case as replicating exposure to sovereign spreads has become critically important.

We review and compare different approaches to replicating the Barclays Capital Euro Treasury Index. Instruments considered in portfolio construction include cash bonds, German and Italian government bond futures, interest rate swaps, iTraxx SovX Western Europe, and sovereign CDS.

A series of carefully diversified bond portfolios holding between 19 and 22 positions exhibits a tracking error volatility of 5bp/month over the past five years, lower than any combination of synthetic liquid instruments.

In contrast, portfolios of government bond futures exhibit significant tracking error volatility of 35bp/month and higher, depending on the strategy. Futures replication benefits from investing in the Italian 10y BTP contract.

Combinations of futures and interest rate swaps allow for a better representation of the index interest rate risk. This reduces tracking error volatility further, to 30bp/month over the past five years.

Including iTraxx SovX Western Europe or single-name sovereign CDS helps reduce the index spread exposure. Corresponding tracking portfolios exhibit tracking error volatilities of 28bp and 19bp/month respectively. The relative advantage of CDS-based hedging is more visible in recent months.

This analysis complements our work on Replicating Bond Index Baskets (RBI™) designed for synthetic tracking of diversified bond indices.

Introduction[1]

The Barclays Capital Euro Treasury Index is widely used for benchmarking euro-denominated bond portfolios. It invests in euro-denominated fixed coupon nominal bonds from investment-grade rated euro sovereigns and represents a significant share of the Euro Aggregate (55.2%), Global Treasury (26.6%) and Global Aggregate (13.9%) bond indices. As of the beginning of December 2010, it held 293 bonds from 15 issuers and its market value was €4trn. The index is market capitalisation-weighted and is rebalanced every calendar month-end according to published index inclusion rules.

[1] The authors would like to thank Jay Hyman for his comments and suggestions as well as Dominik Winnicki for his help on this project.

We examine various strategies for replicating the Euro Treasury Index, focusing on concentrated portfolios of relatively liquid securities: cash bonds or liquid derivatives such as futures; interest rate swaps; and sovereign credit default swaps. These replicating portfolios can be used in a variety of situations, including, as part of a portable alpha strategy:

- to fill out an existing portfolio;
- for tactical asset allocation;
- to implement asset allocation transitions;
- for management of cash inflows and outflows.

Portable alpha strategies rely on the effective separation and recombination of alpha and beta strategies. Typically, a source of alpha is managed independently from the benchmark index and is combined with a beta replication strategy. The alpha source generally requires some funding even when investing in synthetic instruments. Beta management provides the returns of the desired bond index.

Diversified bond indices, such as the Global Aggregate Bond Index, for example, hold a significant allocation to EMU sovereign debt. For non-European investors unfamiliar with the sovereign debt developments in Europe, investing in this market may seem a daunting task. They may want to allocate their risk budget to active strategies in more familiar markets and neutralise the benchmark exposure to EMU sovereign debt.

Alternatively, a manager with the appropriate skill-set may want to actively manage a euro government bond portfolio for outperformance relative to the index, but may be uncomfortable with the performance prospects of the asset class as a whole. Reducing benchmark exposure through a synthetic short-beta strategy would allow that manager to retain the ability to generate outperformance from individual bond positioning.

Managers of diversified portfolios may want to change exposure to the euro treasury portion of their mandate according to tactical views. By buying and selling replicating portfolios of liquid instruments as an overlay to an existing portfolio allocation, asset allocation shifts can be implemented more quickly and efficiently than by buying or selling a large number of individual bond positions.

Portfolio managers facing cash inflows or outflows may consider liquid replication to ensure that their portfolios are fully invested according to benchmark guidelines at all times. This is particularly desirable when carry and roll-down returns are high, as is the case when yield curves are steep. Indeed, these are the conditions when the opportunity cost of holding cash, in the expectation of investor or transition-related cash flows, is high.

Conventional replication techniques of the Euro Treasury Index have typically relied on the assumption that the Euro government bond market is homogeneous. This implied that yields of bonds issued by peripheral countries, such as Greece, Portugal, Ireland, Italy, and Spain, are closely aligned with yields of the core euro issuers.

Since 2009, however, the spreads of EMU peripheral countries have increased substantially and become volatile. Large realised tracking errors of conventional replicating portfolios have underscored the need for revisiting the replication methodology. At the same time, new liquid instruments have gained acceptance – such as Italian government bond futures and sovereign CDS contracts – opening the door to new replication strategies.

In this article we review replication strategies for the Barclays Capital Euro Treasury Index. Section 1 discusses recent changes in the risk profile of the Euro Treasury Index. Section 2 presents the main choices in forming a replication strategy. The following sections provide empirical results for replication strategies related to different sets of instruments. Section 3 describes cash bond replication. Section 4 presents replication with German and Italian bond futures. Section 5 combines futures with interest rates swaps for a better matching of yield curve exposure. Section 6 explains the benefits of hedging the spread risk of the index with sovereign CDS or iTraxx SovX Western Europe. Section 7 discusses practical issues related to managing a replicating portfolio. Section 8 concludes with a comparison of different replication strategies and a summary table with main empirical results. Three Appendices provide a snapshot of the cash bond replication portfolio, a brief exposition of our approach to empirical durations, and a summary of the construction technique used for each considered derivatives replication strategy.

1. Sources of risk in the Euro Treasury Index

The Barclays Capital Euro Treasury Index includes government bonds issued by members of the European Monetary Union (EMU). Figure 1 profiles the composition of the Euro Treasury Index by country as of 30 November 2010. Italy, Germany, and France constitute the largest share of the index (68.5%). The average spread of the index over the German treasury curve is 113bp, with several issuers trading at spreads typical for corporate bonds.

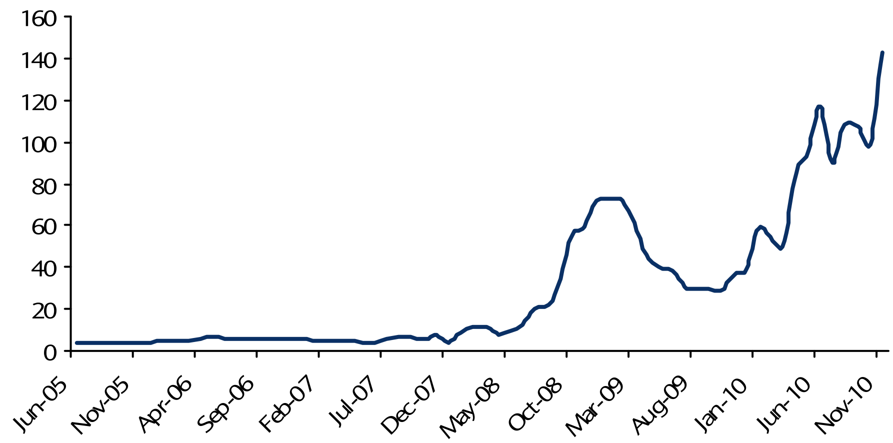
Figure 1: Market structure of the Barclays Capital Euro Treasury Index (30 Nov 2010)

Issuer	Market value, %	OAD, yr	OAS, bp
Italy	23.8	6.54	199
Germany	22.6	6.33	0
France	22.0	6.95	34
Spain	9.1	6.11	290
Belgium	6.1	6.04	118
Netherlands	5.8	6.42	17
Austria	4.1	6.71	46
Portugal	2.1	5.71	407
Ireland	1.8	5.45	601
Finland	1.4	5.56	19
Slovakia	0.5	5.14	136
Slovenia	0.3	5.79	141
Cyprus	0.2	3.18	249
Luxembourg	0.1	5.45	40
Malta	0.0	4.62	133
Total	**100**	**6.45**	**113**

Source: Barclays Capital

In most of the first decade of the euro market, sovereign spreads of peripheral countries were relatively low and stable, as shown in Figure 2. As a result, interest rates accounted for the largest contribution to the index volatility. In early 2009, however, sovereign spreads of peripheral countries increased and became an important factor driving index returns.

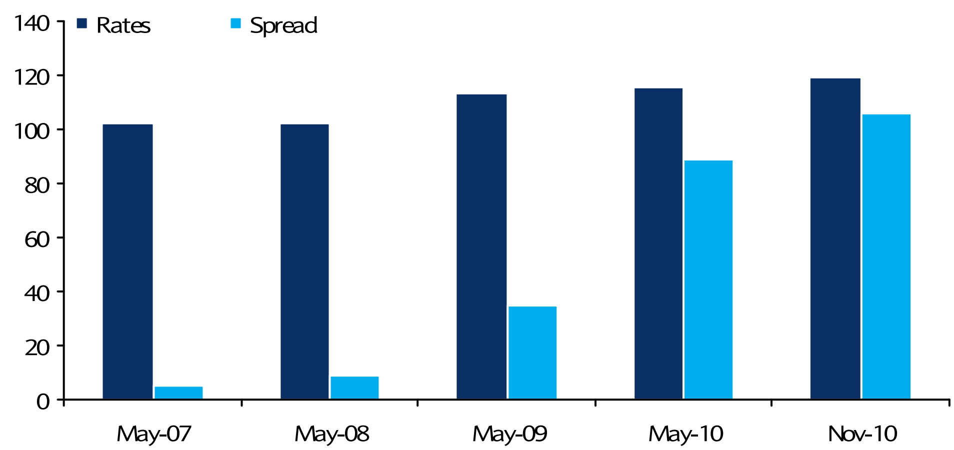
Figure 2: Average spread of the Euro Treasury Index over Germany (bp)



Source: Barclays Capital

Figure 3 shows the isolated return volatilities of the Barclays Euro Treasury Index attributed to rates and spreads.[2] While in May 2007 the isolated return volatility attributed to spreads was dwarfed by that attributed to rates, the two became comparable in 2010.

Figure 3: Isolated return volatility of the Euro Treasury Index (bp/month)



Source: Barclays Capital

Prior to the surge in sovereign spreads, most replication methodologies for the Barclays Capital Euro Treasury Index focused on hedging interest rate risk with a portfolio of liquid government bonds (cash replication) or interest rate swaps and German government bond futures (synthetic replication). Replicating strategies investing in swaps or in combinations of futures and swaps have been published as baskets called Replicating Bond Index (RBI®) Baskets.[3] Their tracking errors significantly increased as euro sovereign spreads became more volatile. This also provides the motivation for re-visiting replication techniques for the Barclays Capital Euro Treasury Index.

[2] See Ben Dor et al., "Managing European Sovereign Spread Risk", August 2010 for a description of the modelling framework underlying this risk attribution. In this paper, we highlight the linear relationship between spread level and spread volatility that exists for EMU sovereigns, as in other credit markets, and explain the suitability of Duration Times Spread (DTS) as a measure of spread risk in this market.
[3] See Dynkin et al, "Replicating Bond Index (RBI℠) Baskets: A Synthetic Beta for Fixed Income," August 2006, and Desclée et al, "Replicating Bond Index Baskets (RBI®s): Performance, Risk, and Alternative RBI Baskets", October 2009

2. Forming a replication strategy

Three broad categories of instruments may be used to replicate bond indices:

- Cash bonds
- Total return index swaps
- Liquid derivatives

Replication with cash bonds is appropriate for investors who are prepared to maintain, through periodic rebalancing, a diversified portfolio of cash bonds designed to track the index. Many cash bond replicating portfolios follow a stratified sampling approach where the index is divided into cells and representative bonds are selected within each cell. Such a strategy is typically followed by investors who expect a stable allocation to the asset class. It is possible to assemble cash portfolios that are relatively concentrated and hold relatively liquid bonds with a view to finding a balance between tracking error, liquidity and practicality. In section 3 below, we present an example of cash bond replication and discuss tracking error results.

Investors who want unfunded exposure to the index, but are unwilling to manage the replicating portfolio themselves, can choose total return index swaps. In this case, the investor receives the exact published returns of the index in exchange for a stream of Euribor-based payments. The total return swap market is well developed for government bond indices, so that the terms of the swap can be reasonably flexible. The TRS approach is most appropriate for investors with a high degree of aversion to tracking error risk and with relatively long (six months or longer) time horizons.

Many investors favour replication with liquid derivatives. In this case, they keep full control of all positions in their portfolio and effectively trade tracking error risk for direct oversight, high liquidity, low rebalancing costs, and reduced counterparty risk. Such flexibility in unfunded replication is particularly valuable in the context of tactical re-allocation, for example. Sections 4, 5 and 6 detail different approaches to liquid replication depending on different investment universes. They range from futures-only to a combination of futures, interest rate swaps and credit default swaps.

Tracking errors of Euro Treasury Index replicating portfolios can be roughly attributed to three main risk dimensions: Interest rates; sovereign spreads; and the basis between cash and synthetic instruments. How accurately a replicating portfolio can neutralise different sources of risk depends on the choice of instruments, as outlined in Figure 4.

Figure 4: Instrument choices and potential for tracking error reduction

Portfolio implementation	Rates	Spread	Basis
DE bond futures	✓✓	✗	✗
DE and IT bond futures	✓✓	✓	✗
Swaps	✓✓✓	✗	✗
DE, IT bond futures and swaps	✓✓✓	✓	✗
DE, IT bond futures, swaps, and sovereign CDS	✓✓✓	✓✓	✗
EMU Government bonds	✓✓✓	✓✓✓	✓✓✓

Source: Barclays Capital

Conventional replicating baskets of rates derivatives, such as German bond futures and swaps, do not hedge spread risk. This problem can be partially alleviated by adding Italian bond futures whose spreads are closely related to the ones of other EMU sovereigns. Adding credit default swaps can further improve spread risk hedging but still leaves the replicating portfolio exposed to the cash-synthetic basis risk. Finally, cash bond portfolios can be constructed to eliminate all major sources of the systematic tracking error.

In our analysis we build replicating portfolios using the *exposure matching* approach, which attempts to match portfolio exposures with the ones of the index. Relevant exposures include key rate durations for interest rate risk, market value weights and duration contributions for relevant issuer sectors. The number of positions in the portfolio is a function of the number of exposures the portfolio matches. Although extremely simple, this approach recognises the multi-dimensional nature of the underlying bond index which bundles together rates and spread risks. When relying on analytical exposures, there are no dependencies on historically calibrated risk parameters. Exposure-matching can be used in a linear optimisation where one maximises a linear objective function, such as liquidity, subject to a set of constraints.

Two alternative approaches that we do not use in our analysis, are *stratified sampling*, typically used in highly diversified cash bond portfolios, and *tracking error variance minimisation*. In the stratified sampling approach, the underlying index is divided into maturity- and country-specific buckets. Then, a few liquid bonds are selected from each bucket to match market value and duration contributions. The approach is simple and transparent and is often employed for relatively large and stable portfolios with many positions. Minimum-variance optimisation relies on a risk model and an optimisation tool that minimises ex-ante tracking error volatility. The quality of the resulting portfolios rests on the specifications of the underlying risk model and on historically observed correlations and volatilities of risk factors. The approach tends to produce highly diversified portfolios with many small size positions.

3. Replicating the Euro Treasury Index with cash bond portfolios

In this section, we explain how to construct a relatively concentrated and liquid portfolio of cash bonds by matching index exposures across two broad risk dimensions: rates and spread.

To neutralise spread exposure, we divide the Euro Treasury Index into 10 country groups (see Figure 5) and, for each country group, match the market value weight and the duration contribution of the index. As regards rates exposure, we require that the 2y, 5y, 10y, 20y, and 30-year key rate durations of the entire portfolio match the ones of the index.

Figure 5: Country groups for cash replication of the Euro Treasury Index (30 Nov 2010)

Countries	Group	Market weight (%)	Duration contribution (yr)
Austria, Finland, Luxembourg	1	5.6	0.36
France	2	22.0	1.53
Germany	3	22.6	1.43
Spain	4	5.8	0.38
Italy, Slovakia, Slovenia, Malta, Cyprus	5	24.8	1.60
Spain	6	9.1	0.56
Portugal	7	2.1	0.12
Ireland	8	1.8	0.10
Greece	9		
Belgium	10	6.1	0.37
Total		**100**	**6.45**

Source: Barclays Capital

We filter out of the investment universe half of all bonds with the lowest amount outstanding within each country group to ensure that all portfolio bonds be relatively liquid. Smaller countries with less liquid debt are represented by larger countries within the same country group. For example, securities issued by Slovenia, Slovakia, Malta, and Cyprus, would be represented by Italian bonds in the replicating portfolio. In order to further favour liquidity and obtain a unique, objectively determined portfolio allocation, we use a linear programme, solved by the simplex method, where portfolio liquidity is maximised subject to the exposure matching constraints detailed above.

In this context, liquidity is defined by a bond-level *liquidity metric* (LM) which is a function of amount outstanding[4] and distance to par:

$$\text{Liquidity metric} = 2/3\ /\text{LN(AmtOut)} + 1/3 \times |100 - \text{price}|/100 \qquad (1)$$

A lower liquidity metric means higher liquidity. Bonds with higher amount outstanding will have a lower LM value, while bonds trading significantly away from par will have a higher LM value.[5] The tracking portfolio is constructed by minimising the portfolio weighted average liquidity metric subject to the investment constraints described above, which ensure matching the interest rate and spread duration exposures of the index.

Finally, we ensure that all positions be easily tradable by avoiding very small positions. For this, we set the minimum allocation to any single bond at 0.5% of the portfolio market value and redistribute the weights of very small positions to the entire portfolio.[6] Figure 6 compares the summary statistics of the tracking portfolio to the Euro Treasury Index as of 30 November 2010.

Figure 6: Comparison of the bond replicating portfolio with the Euro Treasury Index (30 November 2010)

Statistics	Tracking portfolio	Euro Treasury Index	Difference
Number of positions	22	293	-271
Price	99.2	104.4	-5.2
Coupon, %	3.0	4.1	-1.1
Yield to Maturity, %	3.08	3.09	-0.02
Spread over Germany, bp	115	113	2.0
Option Adjusted Duration	6.43	6.45	-0.02
Option Adjusted Convexity	0.79	0.80	-0.02
Key Rate Duration 6m	0.07	0.07	0.00
Key Rate Duration 2yr	0.65	0.64	0.01
Key Rate Duration 5yr	1.47	1.49	-0.01
Key Rate Duration 10yr	1.98	1.96	0.02
Key Rate Duration 20yr	1.33	1.34	-0.01
Key Rate Duration 30yr	0.94	0.95	-0.01

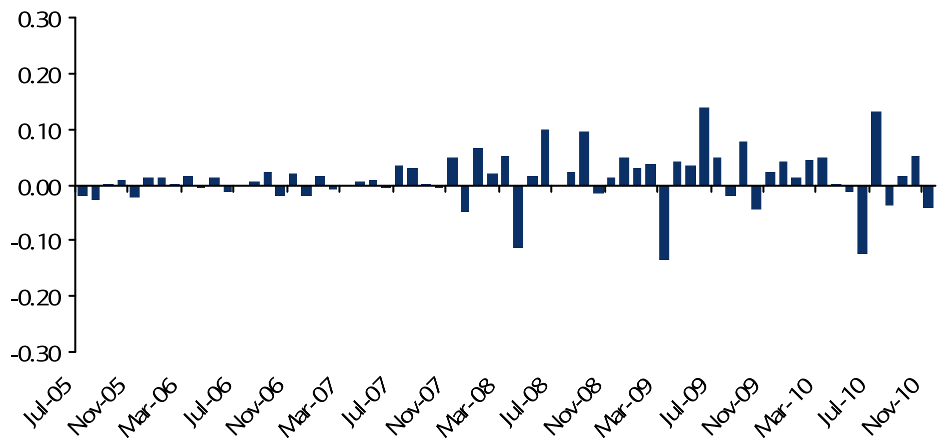
Source: Barclays Capital

[4] We use amounts outstanding in 1000s Euros.
[5] The formulation of this liquidity metric is arbitrary. Barclays Capital has recently started to publish objectively calculated Liquidity Cost Scores (LCS™) for a broad universe of index bonds, starting with US and Pan-European credit indices. We intend to expand LCS coverage to European government bonds soon. See S. Dastidar and B. Phelps, October 2009, *Introducing LCS – Liquidity Cost Scores for US Credit Bonds*, and S. Dastidar, A. Edelstein and B. Phelps, September 2010, *Liquidity Cost Scores (LCS™) for Pan-European Credit Bonds,* Barclays Capital
[6] This rounding step, which we have implemented after optimisation, can result in small deviations from the targeted rates and spread exposures.

The portfolio and the index have very similar yields to maturity, spreads over German government bonds, and key rate duration profiles. The list of bonds in the tracking portfolio as of month-end November 2010 is given in Appendix 1.

For back-testing purposes, we create 64 historical tracking portfolios (starting from June 2005) using the same technique. Figure 7 shows the realised tracking errors and summary statistics.

Figure 7: Monthly tracking errors (%) of cash bond replicating portfolios



	Jul 05 -Nov 10	Jul 05 – Jun 07	Jul 07 – Nov 10	Oct 09 – Nov 10
Average TE (bp/m)	1.1	0.0	1.8	0.8
TE Volatility (bp/m)	4.7	1.4	5.8	6.0
Worst Monthly |TE| (bp)	13.7	2.7	13.7	13.2

Source: Barclays Capital

Over the past 65 months, the replicating portfolio tracked the Euro Treasury Index with an average tracking error (TE) of 1.1bp/month and a tracking error volatility (TEV) of 4.7bp/month. The average number of bonds in the replicating portfolio was 21.

Our cash bond portfolio tracked very accurately up to July 2007: tracking error volatility was 1.4bp/m versus 6.0bp/m for the most recent months. The higher tracking error and TEV observed recently resulted from divergences in performances between highly liquid and less liquid index bonds and from portfolio concentration resulting in incomplete representation of some sources of risk such as, for example, changes in slope and shape of various sovereign spread curves.

4. Replication with Government bond futures

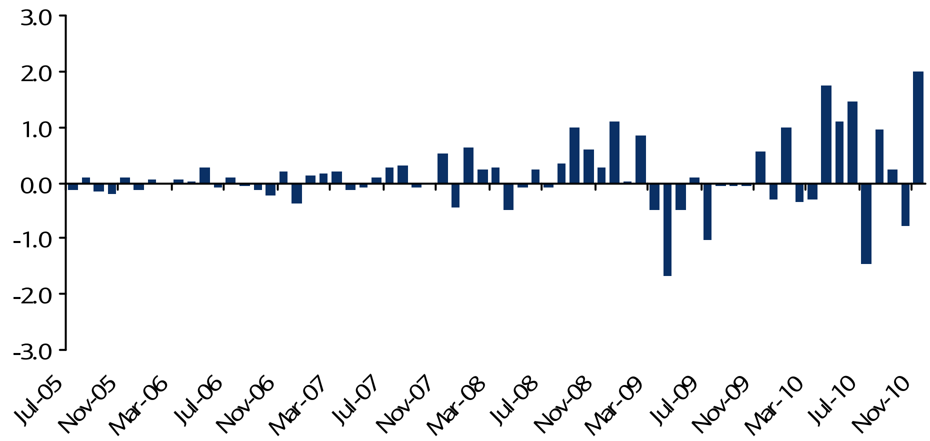
In this section we consider synthetic replication with a basket of government bond futures. We start by assembling a portfolio of the three most liquid German government bond future contracts: Schatz (2y), Bobl (5y), and Bund (10y).[7] These are weighted to match the index duration exposure. Specifically, the portfolio matches 2y, 5y, and 10y key rate durations of the index, with any longer key rate duration contributions being allocated to the 10y vertex. This may leave out significant yield curve reshaping risk, particularly for maturities longer

[7] There is also Buxl future contract launched in September 2005 with maturities of underlying issues lying between 24 and 35 years. The Buxl future, however, has a significantly lower liquidity than Schatz, Bobl, or Bund and is therefore not considered in our analysis.

than 10 years, as well as sovereign spread risk. Futures positions are adjusted every month-end to ensure exact exposure matching and the contracts are rolled every quarter, at the last month-end prior to expiry.

Figure 8 shows the historical tracking errors of the replicating basket in the period from June 2005 to November 2010. Replicating the Euro Treasury Index with three government bond futures was fairly efficient until mid 2008, as rate risk dominated the index risk profile.

Figure 8: Monthly tracking errors of a German futures basket matching the analytical key rate durations of the Euro Treasury Index



	Jul 05 - Nov 10	Jul 05 – Jun07	Jul 07 – Nov 10	Oct 09 – Nov 10
Average TE (bp/m)	11.1	-1.0	18.2	41.1
TE volatility (bp/m)	62.0	15.6	76.6	100.9
Worst monthly |TE| (bp)	199.3	36.6	199.3	199.3

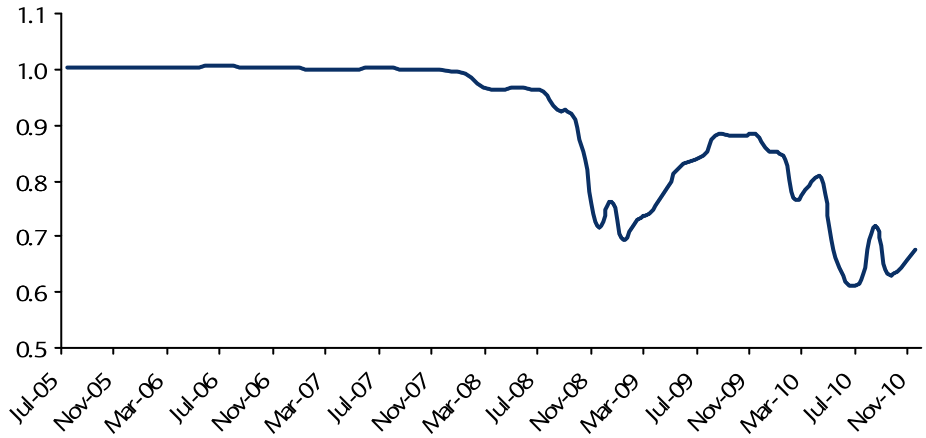
Note: For the purpose of all historical simulations we assume that synthetic portfolios are funded at one-month Euribor. Source: Barclays Capital

The situation changed drastically in 2008 when sovereign spreads of peripheral EMU countries widened and became volatile. Consequently, the tracking error volatility of the replicating futures basket increased from 15.6bp/month in the period between July 2005 and June 2007 to 76.6bp/month in the period between July 2007 and November 2010.

Higher index spreads often imply that the empirical sensitivities of the index to changes in rates become lower than analytically calculated durations. This is because changes in spreads and changes in German bond yields are generally negatively correlated. The relationship between empirical and analytical sensitivities to rates can be estimated[8] and reported as the ratio between empirical and analytical index durations. This is called the empirical hedge ratio and is the proportion of the analytical duration that one should aim to hedge in order to neutralise interest rate risk on a short horizon. Figure 9 reports 36-month rolling window hedge ratios of the Barclays Capital Euro Treasury Index. As sovereign spreads widen, the index hedge ratio decreases from 100% to around 70%, reflecting the fact that changes in German bond yields and sovereign spreads tend to offset each other.

[8] Details on the estimation methodology are provided in Appendix 2. For more research on empirical durations, see Ambastha, M., et al., "Empirical Duration of Corporate Bonds and Credit Market Segmentation", Barclays Capital, 25 January 2010, and Ben Dor, A., et al., "Managing European Sovereign Spread Risk", Barclays Capital, 12 August 2010.

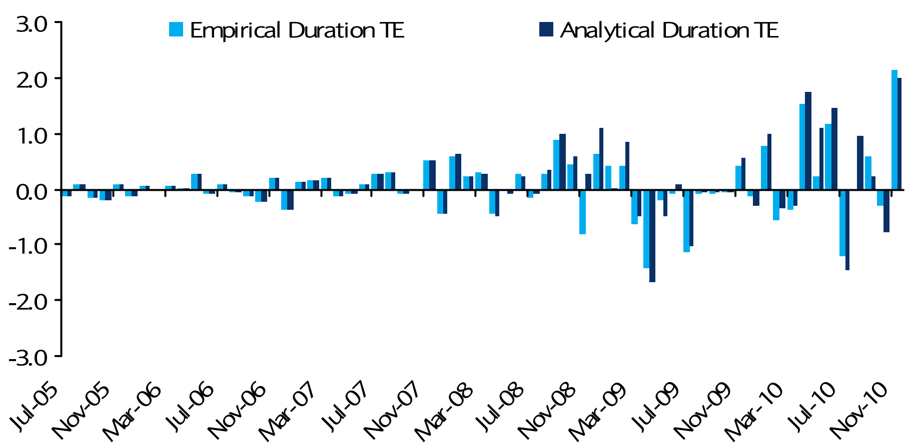
Figure 9: Hedge ratio of the Euro Treasury Index wrt the German government curve



Note: Hedge ratios are calculated in the period from July 2005 to November 2010 using a 36-month rolling window
Source: Barclays Capital

Relatively low recent hedge ratios indicate that a replicating portfolio matching the index analytical duration may be over-hedged. Therefore, we consider an alternative construction method where the replicating portfolio matches empirical key rate durations. Figure 10 provides resulting tracking errors and statistics.

Figure 10: Monthly tracking errors of the German futures basket matching empirical key rate durations of the Euro Treasury Index



	Jul 05 - Nov 10	Jul 05 – Jun 07	Jul 07 – Nov 10	Oct 09 – Nov 10
Average TE (bp/m)	5.9	-1.1	10.1	30.1
TE volatility (bp/m)	55.2	15.6	68.5	88.8
Worst monthly |TE| (bp)	215.1	37.0	215.1	215.1

Note: For the purpose of all historical simulations we assume that portfolios are funded at one-month Euribor.
Source: Barclays Capital

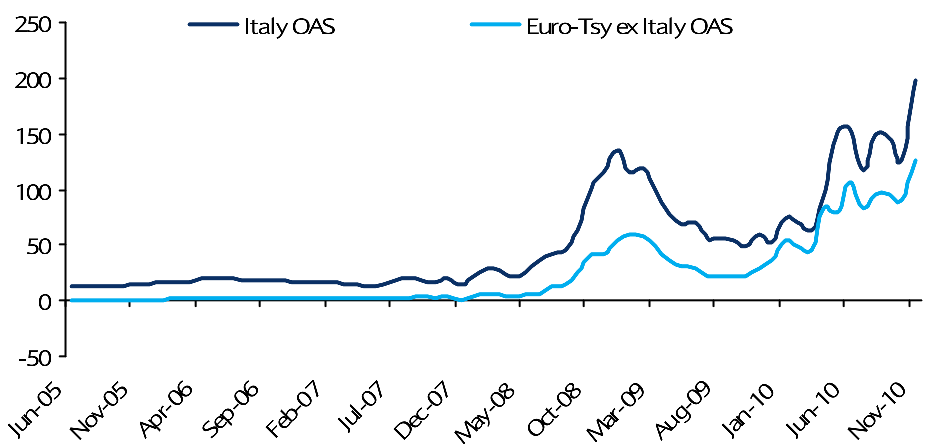
The reduction in tracking error volatility in the period between July 2005 and November 2010 is about 11% (55.2bp/month versus 62.0bp/month as reported in Figure 8). Empirical duration matching had no impact in the early period of our analysis, when spreads where low and the hedge ratio was close to 1, but resulted in lower tracking error volatility in the second period.

Empirical duration matching is appropriate for hedging risk on a short horizon, consistent with the calculation horizon of the empirical hedge ratio itself. On a longer horizon, the returns of the empirical duration-matched portfolio may deviate from index returns as the portfolio carry (yield carry and roll-down) may be less than that of the index.

Adding Italian BTP futures to the replicating portfolio

Italy is the largest issuer in the index and contributes significantly to its spread risk. In addition, the spread changes of many index participants, including Italy, are positively correlated with each other. Figure 11 illustrates the relationship between the spreads of the Euro Treasury Index ex Italy and of the Italian index. Therefore, a duration-hedged overlay of Italian government bond futures should help reduce tracking error volatility. Italian government bond futures (Euro-BTPs) were introduced in September 2009 and provide exposure to the 10y sector of the Italian government bond market. We recognise that Italian futures are less liquid than German ones, and therefore those investors who are very sensitive to transaction costs, including potential market impact, may want to use this strategy to only a limited extent.

Figure 11: Spread of the Euro treasury ex Italy and of the Italian treasury Index

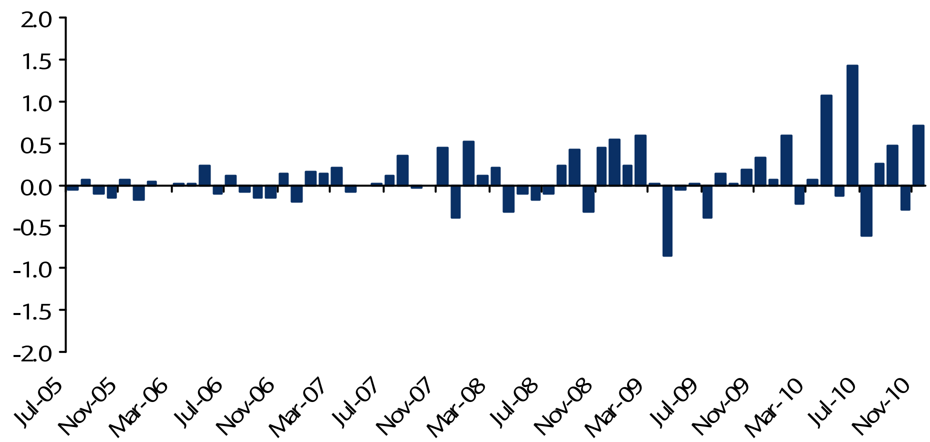


Source: Barclays Capital

We combine the three German futures with the Italian one to match two types of exposures: key rate duration contributions for rates risk and the duration contribution of the higher spread countries of the index, namely Italy, Spain, Portugal, Ireland, and Greece, until this last market was downgraded below investment-grade and exited the index. The BTP futures position is scaled so that its spread duration contribution corresponds to that of the high spread countries in the index and the three German futures complement it to ensure key rate duration matching. Now that some spread exposure is included in the basket, we use analytical sensitivities to determine position sizes.

Figure 12 shows summary results of a historical tracking error simulation of a portfolio investing in German and Italian futures.[9] This replicating portfolio compares favourably with portfolios restricted to German bond futures based on analytical or empirical duration (Figures 8 and 10). Nevertheless, all three futures-based replications considered in this section deliver much larger tracking errors than the diversified cash bond portfolio described in the section on cash bond replication.

Figure 12: Monthly tracking errors of a replicating basket of German and Italian government bond futures



	Jul 05 – Nov 10	Jul 05 – Jun07	Jul 07 – Nov 10	Oct 09 – Nov 10
Average TE (bp/m)	8.1	-0.7	13.2	27.5
TE volatility (bp/m)	35.2	12.3	42.7	54.5
Worst monthly |TE| (bp)	142.4	22.1	142.4	142.4

Note: For the purpose of all historical simulations we assume that portfolios are funded at one-month Euribor.
Source: Barclays Capital

5. Combining Government bond futures with interest rate swaps

A more complete strategy is available to investors who are able to use interest rate swaps in addition to government bond futures. As mentioned in the previous section, the futures-only strategy is based on highly liquid 2y, 5y, and 10y contracts only, and therefore, ignores the risk of yield curve reshaping in maturities longer than 10 years. With a combination of swaps and futures, it is possible to precisely match key rate duration exposures for a broader set of tenors, namely 6m, 2y, 5y, 10y, 20y and 30y. For short and intermediate tenors, the mix of futures and swaps can also be designed to proxy the index allocation to major spread issuers as changes in swap spreads can partially capture sovereign spread risk. Several futures and swap combinations are possible:

- Swap-only
- German futures + swaps
- German and Italian futures + swaps

[9] Before the launch of the BTP contract in September 2009, our backtest uses an approximation for the returns on Italian futures. We used the official conversion factor rules for the contract (see documentation on *www.eurexchange.com*) to determine which Italian government bond would have been the cheapest-to-deliver (CTD) at a given time, and then used the return of this bond.

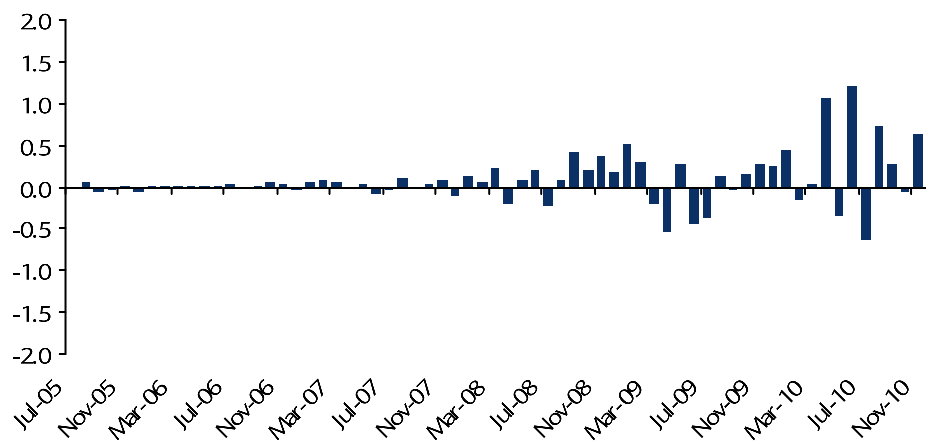
Tracking error results are shown in Figure 13 and repeated in Figure 19 of the conclusion, which summarises all empirical results.

The swap-only basket invests in six swaps to neutralise the index exposure to six key rate durations. The risk of this strategy is of course that sovereign spreads to swap become volatile, as has been the case recently.

In the second alternative (German futures and swaps) long maturity interest rate swaps and German bond futures represent the yield curve exposure of EMU core countries (Germany, France and the Netherlands). The exposure of other countries is hedged with six interest rate swaps. The futures portion of the portfolio should be able to capture "flight-to-quality" effects within the Euro Treasury Index, while interest rate swaps partially hedge changes in index sovereign spread.[10]

As expected, adding Italian futures to swaps and German futures helps reduce tracking errors significantly in the volatile second half of our empirical analysis. In this strategy, the yield curve exposure of the BTP future is offset with a portfolio of swaps[11] recognising the BTP futures contribution as a spread strategy that helps mitigate index overall spread risk.

Figure 13: Monthly tracking errors with swaps, German and Italian bond futures



Swap-only	Jul 05 – Nov 10	Jul 05 – Jun07	Jul 07 – Nov 10	Oct 09 – Nov 10
Average TE (bp/m)	9.4	-3.7	17.1	34.5
TE volatility (bp/m)	55.4	5.9	68.8	84.9
Worst monthly |TE| (bp)	173.7	14.9	173.7	164.6
Swaps, DE Futures	**Jul 05 – Nov 10**	**Jul 05 – Jun07**	**Jul 07 – Nov 10**	**Oct 09 – Nov 10**
Average TE (bp/m)	9.9	-2.1	16.9	38.1
TE volatility (bp/m)	55.3	4.9	68.9	91.0
Worst monthly |TE| (bp)	180.1	11.6	180.1	180.1
Swaps, DE and IT Futures	**Jul 05 – Nov 10**	**Jul 05 – Jun07**	**Jul 07 – Nov 10**	**Oct 09 – Nov 10**
Average TE (bp/m)	8.1	0.7	12.5	27.7
TE volatility (bp/m)	30.3	4.3	37.5	51.3
Worst monthly |TE| (bp)	121.2	9.2	121.2	121.2

Note: For the purpose of all historical simulations we assume that portfolios are funded at one-month Euribor.
Source: Barclays Capital

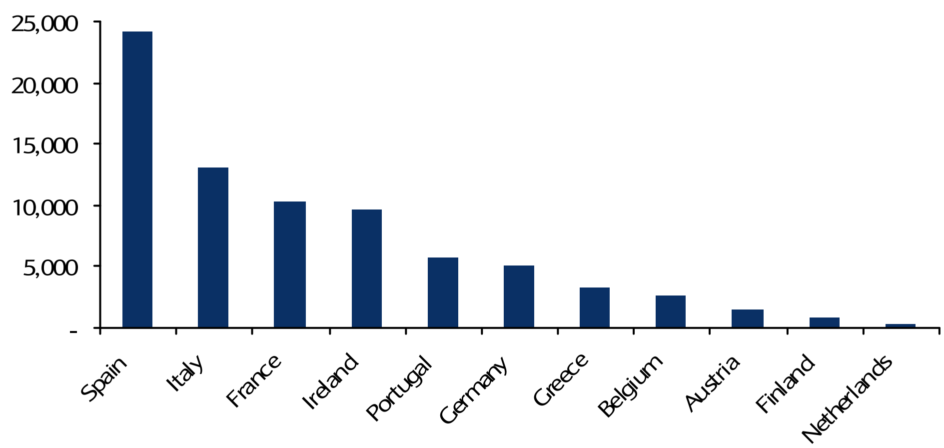
[10] As discussed in the previous section on futures-only portfolios, investors contemplating a short-horizon hedging strategy based on rates-related instruments may want to consider empirical exposures as opposed to analytical ones.
[11] Alternatively, it is possible to use Bund futures to hedge the duration of the BTP future.

Compared to the futures-only portfolio of DE and IT futures (results shown in Figure 12), including swaps was clearly a superior strategy in the period prior to the credit crunch. Indeed, from July 2005 to June 2007, tracking error volatility was reduced from 12.3 to 4.3bp/month by adding long-dated swaps and thereby matching the index exposure for long-dated maturities. However, reducing curve reshaping risk was, however, only modestly useful in more recent years. For the period starting in July 2007 swaps helped reduce TEV from 42.7 to 37.5 bp/month: a small improvement in tracking performance in both absolute and relative terms.

6. Synthetic replication with swaps, futures and sovereign CDS

The widespread acceptance of sovereign credit default swaps (CDS) and CDS indices makes them suitable candidates for hedging the spread risk of the Euro Treasury Index.[12] Indeed, the liquidity of sovereign CDS can now be considered as sufficient for many market participants. Figure 14 shows trading volumes of EMU sovereign CDS in November 2010, with monthly trading volumes in excess of $4bn for many significant issuers.

Figure 14: Monthly trading volumes of EMU sovereign CDS, $ millions (November 2010)



Note: Trading volumes are calculated from weekly data during November 2010.
Source: DTCC

We consider two CDS-based replication strategies: investing in a selection of single-name CDS to match the exposures of selected index issuers, or maintaining a position in the on-the-run iTraxx SovX Western Europe index which is an equally-weighted basket of 16 European sovereign CDS.[13] While the first strategy is expected to be more accurate, investing in iTraxx SovX has the advantage of keeping a more concentrated, easier-to-manage portfolio and benefits from superior liquidity. On the other hand, the allocation of iTraxx SovX Western Europe does not match the bond index exposure and includes a number of non-EMU countries that are not represented in the Euro Treasury Index. In both cases, interest rate risk is hedged with a basket of swaps and bond futures. In both cases

[12] For details on sovereign CDS (indices) see Willemann, S., et al., “Sovereign CDS Index Primer”, Barclays Capital Credit Research, 28 Aug 2009.
[13] The current on-the-run series (Series 4) of iTraxx SovX Western Europe includes Germany, France, Greece, Ireland, Belgium, Denmark, Norway, Spain, Sweden, Netherlands, Portugal, Austria, Finland, Italy, and the UK.

also, we prefer using the BTP futures to neutralise the spread exposure of Italy, and therefore do not require CDS hedging for that country.[14]

Figure 15 below shows that the higher the spread of an issuer, the higher the correlation between cash bonds and CDS. This calls for prioritising single-name CDS to high-spread markets. For lower-spread markets like France, Netherlands, Austria, Belgium, and Finland, the correlations between CDS and bond spreads over the German government curve (OAS) are generally higher than correlations between CDS spreads and spreads over swaps (L-OAS). This indicates that a significant part of these countries' spread performance is captured by swap spreads. Figure 16 plots the five-year swap spread together with the average index OAS of selected low-spread countries. For recent months, we see a positive relationship between country spreads and swap spreads. The spreads over Germany (OAS) of Italy, Spain, Greece, Ireland, and Portugal, on the other hand, are significantly higher and more volatile, with strong issuer-specific effects, and therefore exhibit only a loose relationship with swap spreads. This argues for using futures in combination with CDS for high-spread countries and swaps for low-spread countries.

We therefore expand our replication strategy and use sovereign CDS for high-spread countries with liquid CDS: Spain, Greece, Ireland, and Portugal.[15] CDS weights for each country are set to match the respective spread duration contributions.

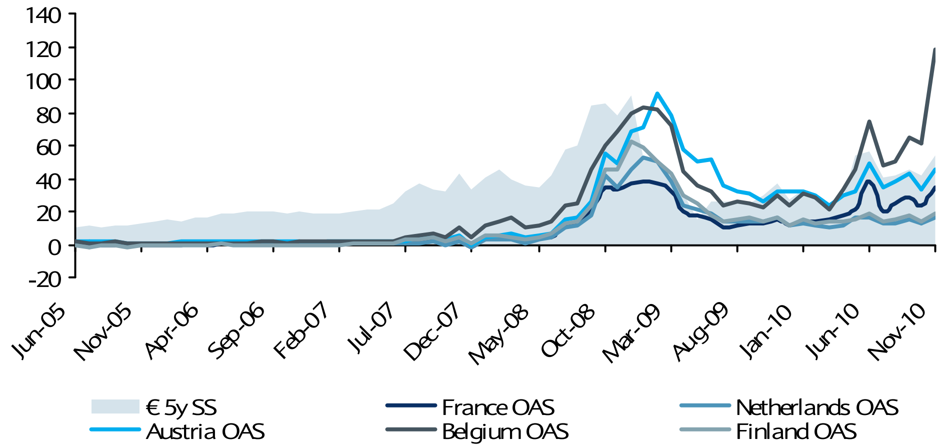
Figure 15: Correlations between changes in sovereign CDS spreads and changes in bond spreads of EMU sovereigns

Country	LOAS, bp	OAS, bp	CDS spread, bp	Correlation CDS/ L-OAS	Correlation CDS/ OAS
Italy	155	199	269	88%	84%
Spain	244	290	365	93%	91%
Greece	907	958	986	93%	94%
Ireland	555	601	618	71%	73%
Portugal	360	407	552	81%	84%
Germany	-47	0	56	-9%	-16%
France	-10	34	105	39%	71%
Netherlands	-29	17	62	43%	73%
Austria	3	46	94	66%	75%
Belgium	71	118	203	75%	82%
Finland	-30	19	35	18%	49%

Note: Correlations are calculated from monthly changes in spreads in the period from January 2006 to November 2010 while spreads are as of month-end November 2010.
Source: Barclays Capital

[14] iTraxx SovX Western Europe is used as the macro hedge for higher spread countries excluding Italy. Allocation to iTraxx SovX in the replicating portfolio is reduced to exclude duration contribution of Italy already hedged with BTP futures.
[15] And Greece prior to July 2010

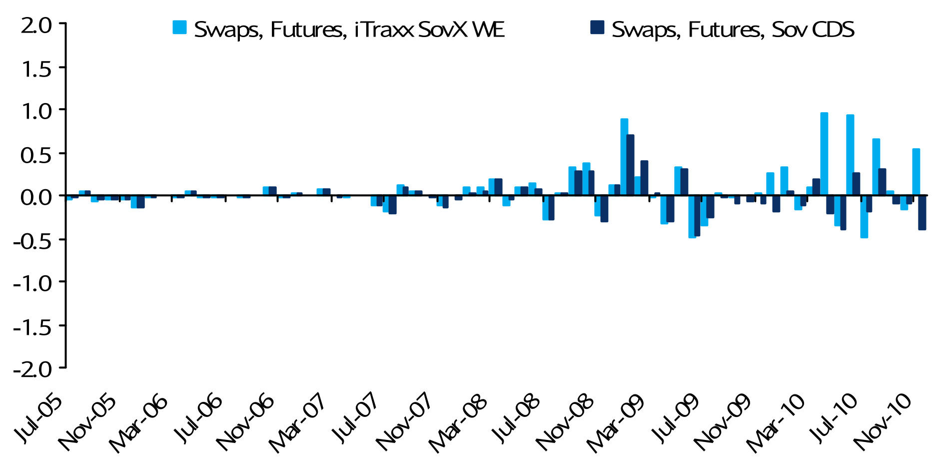
Figure 16: Country spreads over German government curve and 5y Euro swap spread



Source: Barclays Capital

In both single-name CDS-based and iTraxx SovX-based strategies, credit derivatives are combined with a rates hedging strategy that invests in interest rate swaps and German bond futures. The rates exposures of Germany itself and those of higher-spread countries (Italy, Spain, Portugal, Ireland, Greece, Spain) are neutralised with a blend of German futures and swaps (for long maturities); swaps are used to hedge rates in all other markets.

Figure 17: Replicating the Euro Treasury Index with iTraxx SovX and single-name CDS



With iTraxx SovX WE	Jul 05 – Nov 10	Jul 05 – Jun07	Jul 07 – Nov 10	Oct 09 – Nov 10
Average TE (bp/m)	5.0	-1.4	8.7	18.9
TE volatility (bp/m)	27.8	5.0	34.4	44.5
Worst monthly TE (bp)	95.3	13.8	95.3	95.3
With single-name CDS	**Jul 05 – Nov 10**	**Jul 05 – Jun07**	**Jul 07 – Nov 10**	**Oct 09 – Nov 10**
Average TE (bp/m)	-1.3	-1.3	-1.3	-7.5
TE volatility (bp/m)	19.1	5.1	23.8	21.6
Worst monthly TE (bp)	70.3	13.7	70.3	40.2

Source: Barclays Capital

As shown in Figure 17, using sovereign CDS products helps achieve tracking errors that are substantially lower than for any other synthetic strategy investing in futures and swaps. In particular, the single-name CDS tracking error volatility is nearly half that of the replicating portfolios of futures and swaps shown in the previous section. Nevertheless, recent months' tracking errors are significant, as this strategy remains exposed to CDS-cash basis; TEV remains substantially higher than that of the cash bond portfolio shown in section 3.

7. Practical considerations

The choice of one replicating strategy over another depends on many considerations, starting with institutional constraints and portfolio guidelines that may, a priori, limit the range of possibilities.

For investors looking to maintain their own replication strategy, a clear trade-off can be established between tracking error risk and the cost and complexity of the replicating portfolio.

Bond portfolios involve many (at least 20) positions and require some periodic rebalancing. Although our bond tracking simulation was based on successive independent portfolios in order to avoid path dependence, we estimate that maintaining such a portfolio structure over time would require a turnover of the order of 50% per year.

Simple futures portfolios provide the most liquid proxies. They require rolling positions quarterly into on-the-run contracts, in addition to relatively small monthly adjustments that keep duration aligned with the index. Portfolios based on empirical duration hedging may typically require larger month-end rebalancing as empirical hedge ratios change as a function of the spread level of the bond index.

Interest rate swaps assume monthly duration extension. In our simulations, we assume that swap positions are rolled into new benchmark tenors every month-end in order to normalise portfolio structure over time. In practice, only marginal duration extensions are required at month-ends to maintain duration neutrality.

To ensure high liquidity and on-the-run status, CDS positions should be rolled every quarter and iTraxx SovX every six months. This is in addition to possible monthly adjustments, which are generally very small.

Figure 18 displays estimated transaction costs, consistent with the portfolio structures detailed in previous sections. These estimates are split into two parts: the cost of entering and exiting the tracking portfolio in a round-trip transaction, and the cost of maintaining exposure over time. These costs are estimated from example portfolios calculated for November 2010. Indicative bid-ask quotes are taken from screens on 29 November 2010.

Figure 18: Estimated costs of transacting replicating portfolios

	Entry-exit cost (bp)	Rebalancing costs (bp/yr)
DE futures (analytical durations)	0.9	3.7
DE futures (empirical durations)	0.4	1.7
DE and IT futures	1.5	8.0
Swaps	4.5	0.6
DE futures and swaps	2.5	1.7
DE, IT futures and swaps	2.9	5.0
DE, IT futures, swaps, and iTraxx SovX	4.5	4.7
DE, IT futures, swaps, and sov CDS	14.8	10.5
EMU Gov bonds (cash)	28.2	14.1

Note: Estimates based on published bid-ask quotes as of 29 Nov 2010.
Source: Bloomberg, Barclays Capital

8. Conclusion

In this article we reviewed various strategies to replicate the Barclays Capital Euro Treasury Index. A summary of replication results is provided in Figure 19.

The lowest tracking error volatility is produced by cash bond portfolios that match both interest rate and major issuer exposures. Cash replication with Euro government bonds, however, requires full funding. The portfolio allocation is spread over a number of positions and requires periodic rebalancing, and may not be as liquid as portfolios invested in liquid instruments.

Synthetic tracking portfolios, on the other hand, are more likely to retain liquidity during stress scenarios and do not consume cash. As a result, they might be better candidates for tactical overlays (for example, to manage fund cash inflows and outflows). However, the tracking error volatility of synthetic replicating portfolios is much higher than for cash bond portfolios and particularly so in the more recent three years of our empirical analysis.

Our study indicates that the best replication results in synthetic replication can be achieved with portfolios that combine government bond futures, interest rate swaps, and sovereign CDS of high-spread issuers.

For investors who are constrained in the choice of financial instruments we also consider futures-only solutions. In this case, tracking error volatility is high as futures baskets cannot fully neutralise the rates and spread exposures of the Euro Treasury Index.

Figure 19: Summary of tracking error results

Jul 05 – Nov 10	Avg TE, bp/m	TEV, bp/m	Worst |TE|, bp
DE Fut (analytical KRDs)	11.1	62.0	199.3
DE Fut (empirical KRDs)	5.9	55.2	215.1
DE and IT Fut	8.1	35.2	142.4
Swaps	9.4	55.4	173.7
DE Fut and swaps	9.9	55.3	180.1
DE, IT Fut and swaps	8.1	30.3	121.2
DE, IT Fut, swaps, and iTraxx SovX	5.0	27.8	95.3
DE, IT futures, swaps, and Sov CDS	-1.3	19.1	70.3
EMU Gov bonds (cash)	1.1	4.7	13.7
Jul 05 – Jun 07	**Avg TE, bp/m**	**TEV, bp/m**	**Worst |TE|, bp**
DE Fut (analytical KRDs)	-1.0	15.6	36.6
DE Fut (empirical KRDs)	-1.1	15.6	37.0
DE and IT Fut	-0.7	12.3	22.1
Swaps	-3.7	5.9	14.9
DE Fut and swaps	-2.1	4.9	11.6
DE, IT Fut and swaps	0.7	4.3	9.2
DE, IT Fut, swaps, and iTraxx SovX	-1.4	5.0	13.8
DE, IT futures, swaps, and Sov CDS	-1.3	5.1	13.7
EMU Gov bonds (cash)	0.0	1.4	2.7
Jul 07 – Nov 10	**Avg TE, bp/m**	**TEV, bp/m**	**Worst |TE|, bp**
DE Fut (analytical KRDs)	18.2	76.6	199.3
DE Fut (empirical KRDs)	10.1	68.5	215.1
DE and IT Fut	13.2	42.7	142.4
Swaps	17.1	68.8	173.7
DE Fut and swaps	16.9	68.9	180.1
DE, IT Fut and swaps	12.5	37.5	121.2
DE, IT Fut, swaps, and iTraxx SovX	8.7	34.4	95.3
DE, IT futures, swaps, and Sov CDS	-1.3	23.8	70.3
EMU Gov bonds (cash)	1.8	5.8	13.7
Oct 09 – Nov 10	**Avg TE, bp/m**	**TEV, bp/m**	**Worst |TE|, bp**
DE Fut (analytical KRDs)	41.1	100.9	199.3
DE Fut (empirical KRDs)	30.1	88.8	215.1
DE and IT Fut	27.5	54.5	142.4
Swaps	34.5	84.9	164.6
DE Fut and swaps	38.1	91.0	180.1
DE, IT Fut and swaps	27.7	51.3	121.2
DE, IT Fut, swaps, and iTraxx SovX	18.9	44.5	95.3
DE, IT Fut, swaps, and Sov CDS	-7.5	21.6	40.2
EMU Gov bonds (cash)	0.8	6.0	13.2

Source: Barclays Capital

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Appendix 1 – Constituents of the cash bond replicating portfolio

Figure 20 provides the composition of the cash bond replicating portfolio discussed in section 3 as of month-end November 2010. The portfolio consists of 22 bonds.

Figure 20: Constituents of the cash bond replicating portfolio as of 30 November 2010

#	Identifier	Ticker	Cpn	Maturity date	Country	Mkt value [%]	Amount outstanding (€000's)
1	AT0000A001X2	RAGB	3.5	15/09/2021	Austria	2.8419237	12,910,820
2	AT0000A0CL73	RAGB	3.4	20/10/2014	Austria	2.7065308	11,140,871
3	BE0000307166	BGB	3.25	28/09/2016	Belgium	5.1631485	12,175,000
4	BE0000318270	BGB	3.75	28/09/2020	Belgium	1.0231427	17,574,000
5	DE0001135416	DBR	2.25	04/09/2020	Germany	14.561568	16,000,000
6	DE0001137305	BKO	0.5	15/06/2012	Germany	8.2198594	19,000,000
7	ES00000120L4	SPGB	3.9	31/10/2012	Spain	5.3436456	14,967,000
8	ES0000012411	SPGB	5.75	30/07/2032	Spain	3.6894417	14,122,170
9	FR0010371401	FRTR	4	25/10/2038	France	3.9769461	23,889,000
10	FR0118462128	BTNS	2	12/07/2015	France	18.241749	21,151,000
11	IE00B3KWYS29	IRISH	4	15/01/2014	Ireland	1.0649182	11,857,240
12	IE00B4TV0D44	IRISH	5.4	13/03/2025	Ireland	0.7079002	8,283,610
13	IT0001278511	BTPS	5.25	01/11/2029	Italy	2.3092846	27,385,380
14	IT0003535157	BTPS	5	01/08/2034	Italy	5.7741021	21,381,834
15	IT0004019581	BTPS	3.75	01/08/2016	Italy	3.790418	26,738,234
16	IT0004505076	BTPS	3.5	01/06/2014	Italy	8.7088565	19,421,810
17	IT0004508971	BTPS	2.5	01/07/2012	Italy	3.926434	17,274,576
18	NL0000102234	NETHER	4	15/01/2037	Netherlands	1.4845884	12,043,427
19	NL0009331461	NETHER	1.75	15/01/2013	Netherlands	3.7787276	15,043,000
20	NL0009348242	NETHER	3.5	15/07/2020	Netherlands	0.5252641	15,069,615
21	PTOTEGOE0009	PGB	5.45	23/09/2013	Portugal	0.6940222	8,737,917
22	PTOTEMOE0027	PGB	4.75	14/06/2019	Portugal	1.4675287	7,665,000

Source: Barclays Capital

The portfolio includes bonds with large outstanding amounts issued by the nine largest index participants – Austria, Belgium, France, Germany, Ireland, Italy, Netherlands, Portugal, and Spain. The construction approach matches the market value and spread duration contribution of each country group within the index, as well as five key rate duration contributions at the index level. The construction methodology can be easily modified to accommodate different levels of granularity in the index risk profile – rates, spreads, spread slopes, etc.

Appendix 2 – Empirical duration calculation

We define the empirical duration of a sovereign bond as its empirical price sensitivity to changes in the German government rate (the benchmark curve for euro treasuries). Empirical duration typically differs from an analytically-calculated bond duration because changes in spreads and changes in rates are (negatively) correlated. A bond's empirical duration can be obtained by "regressing" bond returns on changes in the German par rate:

$$R = Const - ED \times \Delta Rate + \varepsilon \,, \tag{1}$$

where ED is the empirical duration of the bond. Estimating empirical duration using this regression is impractical because individual bond returns are not stationary and contain a large idiosyncratic element.

Therefore, we use bond return attribution to systematic factors to estimate empirical duration. Bond returns can be decomposed into rate and spread components as follows:

$$R \approx Carry - AD \times \Delta Rate - AD \times \frac{\Delta Spread}{Spread} \times Spread \,, \tag{2}$$

where AD is the analytical duration of the bond. Comparison of equations (1) and (2) reveals that empirical duration should depend on the correlation between changes in government yields and sovereign spreads. In particular, the expression for empirical bond duration becomes:

$$ED = AD + Spread \times AD \times \frac{\operatorname{cov}\left(\Delta Spread / Spread \,, \Delta Rate\right)}{\operatorname{var}\left(\Delta Rate\right)} \,. \tag{3}$$

In practice, the covariance between an issuing country's percentage spread changes and changes in the German par rate is used to calculate empirical bond durations. The hedge ratio is defined as the ratio of empirical and analytical durations of the bond. The expression for the hedge ratio follows from equation (3):

$$HedgeRatio = 1 + Spread \times \frac{\operatorname{cov}\left(\Delta Spread / Spread \,, \Delta Rate\right)}{\operatorname{var}\left(\Delta Rate\right)} \,. \tag{4}$$

Appendix 3 – Description of replicating portfolios[16]

DE Fut **(analytical KRDs)** is a portfolio of three German bond futures (Schatz, Bobl, and Bund) assembled to match 2y, 5y and 10y *analytical* key rate durations of the Barclays Capital Euro Treasury Index.

DE Fut (empirical KRD's) is a portfolio of three German bond futures (Schatz, Bobl, and Bund) assembled to match 2y, 5y and 10y *empirical* key rate durations of the Barclays Capital Euro Treasury Index.

DE and IT Fut is a portfolio of three German bond futures (Schatz, Bobl, and Bund), assembled to match 2y, 5y and 10y *analytical* key rate durations of the Barclays Capital Euro Treasury Index, and a duration-hedged overlay of Italian 10y BTP futures matching the spread duration contribution of high spread EMU countries (Italy, Spain, Ireland, Portugal, Greece). The duration exposure of the BTP future is hedged with the Bund future.

Swaps: Is a portfolio of six interest rate swaps assembled to match the 6m, 2y, 5y,10y, 20y, and 30y key rate durations of the Barclays Capital Euro Treasury Index.

DE Fut and swaps is a portfolio of six swaps and three German bond futures assembled to match the rate exposures of the Barclays Capital Euro Treasury index. Key rate duration contributions of the core EMU countries (Germany, France, and Netherlands) are matched with a combination of the three German government bond futures and two long maturity interest rate swaps (20y and 30y). Key rate duration contributions of the remaining countries in the index are matched with swaps.

DE, IT Fut and swaps is a portfolio of six interest rate swaps, three German bond futures, and the Italian BTP (10y) futures assembled to match the rate and, to some extent, the spread exposures of the Barclays Capital Euro Treasury Index. The key rate duration contributions of the core EMU countries (Germany, France and Netherlands) are matched with a combination of the three German government bond futures and two long maturity interest rate swaps (20y and 30y). The key rate duration contributions of the remaining countries are matched with six interest rate swaps: 6m, 2y, 5y, 10y, 20y, and 30y. The spread duration contribution of high-spread countries (Italy, Spain, Portugal, Ireland and Greece) is matched with a duration-hedged overlay of Italian BTP futures. Finally, the swap positions are adjusted to hedge out the key rate duration exposures of the BTP futures.

DE, IT Fut, swaps, and iTraxx SovX is a portfolio of six interest rate swaps, three German bond futures, the Italian BTP (10y) futures, and the iTraxx SovX Western Europe index designed to match the rate and spread exposures of the Barclays Capital Euro Treasury Index. The key rate duration contributions of Germany, Italy, Spain, Portugal, Ireland, and Greece are matched with a combination of the three German government bond futures and two long maturity swaps. The key rate duration contributions of the remaining countries are matched with six interest rate swaps: 6m, 2y, 5y, 10y, 20y, and 30y. The spread duration contribution of Italy is matched with a duration-hedged overlay of Italian BTP futures, with its key rate duration exposures hedged with interest rate swaps. The spread duration contributions of Spain, Portugal, Ireland, and Greece are matched with the iTraxx SovX Western Europe index.

[16] Throughout this section we use portfolio abbreviations consistent with those of Figure 19.

DE, IT Fut, swaps, and sov CDS is a portfolio of six interest rate swaps, three German bond futures, the Italian BTP (10y) futures, and sovereign credit default swaps (CDS) designed to match the rate and spread exposures of the Barclays Capital Euro Treasury Index. The key rate duration contributions of Germany, Italy, Spain, Portugal, Ireland, and Greece are matched with a combination of the three German government bond futures and two long maturity swaps. The key rate duration contributions of the remaining countries are matched with six interest rate swaps: 6m, 2y, 5y, 10y, 20y, and 30y. The spread duration contribution of Italy is matched with an overlay of Italian BTP futures. KRD-hedged with swaps. The duration exposure of BTP futures is hedged with up to six interest rate swaps. The spread duration contributions of Spain, Portugal, Ireland, and Greece are matched with the respective sovereign CDS contracts.

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