Chapter 6: The Portfolio Simulation Tool

Introduction

The DMO has developed a new model referred to as the Portfolio Simulation Tool (PST). This model facilitates an analysis of the impact that gilt and Treasury bill annual issuance decisions have on the characteristics of the Government's outstanding debt portfolio. In the past, a simpler form of simulation modelling referred to as stock flow dynamics used to be presented each year in the Debt and Reserves Management Report (DRMR) produced by HM Treasury with the intention of conveying the impact that different issuance strategies and levels of financing can have on the composition of the Government's debt portfolio. However, the PST offers a much more sophisticated approach that is intended to allow more in-depth analysis, since it provides a much greater capacity to define possible issuance scenarios, it captures the DMO's operational rules more precisely and has the ability to produce a much larger range of portfolio statistics.

Although the UK Government does not have a duration target or other form of target for its debt portfolio HM Treasury and the DMO consider that it is important to understand the implications for the portfolio of issuance decisions going forward, particularly in the context of large projected financing requirements over the next few years. This is the rationale for developing the PST. The purpose of this chapter is to describe the key features of this model and to provide some illustrative results from it.

How the Portfolio Simulation Tool works

The PST takes the existing Government debt portfolio of gilts and Treasury bills as its starting point. For each year in the future that is being simulated, an estimate has to be supplied to the model for the Central Government Net Cash Requirement (CGNCR). The PST then computes the total gilt redemption payments for each year and adds this to the CGNCR figure to get an estimate for each year's gross financing requirement. For each year of the simulation, details need to be supplied to the model for the split of issuance between different instruments (conventional gilts, index-linked gilts and Treasury bills) and between different maturity bands. In addition, the model needs to be provided with the benchmark maturities to be targeted for issuance within each maturity band, as well as the maximum and minimum permissible size of auctions for each type of instrument. The default maximum and minimum auction sizes in the PST are in line with the DMO's operational rules. That is, conventional gilt auctions have a minimum size of £1.5 billion (cash) and a maximum size of £6.0 billion (cash), whilst index-linked gilt auctions have a minimum size of £0.5 billion (cash) and a maximum size of £2.0 billion (cash).

Once the PST, has computed the gross financing requirement for each year it creates a set of auctions for each instrument type and for each maturity band such that the total cash raised from these auctions equates to the gross financing requirement. In line with the practice followed by the DMO in its actual operations, the PST schedules gilt auctions to occur on Tuesdays, Wednesdays or Thursdays. As an alternative to using the auction schedule generated by the PST it is possible

to impose a different auction calendar. This is particularly useful for the first year of the simulation as it means that the actual auction calendar published as part of the remit can be used. Imposing an auction schedule on the model also provides a means of introducing other types of gilt operations which do not necessarily conform to the same rules on sizing as auctions such as mini-tenders and syndicated offerings.

For each auction the PST uses a variety of criteria to determine whether to launch a new bond or to re-open an existing one. The starting point for the model is to consider for each maturity band if it is possible to re-open the existing benchmark bonds. If this is not possible, the PST next assesses whether there are any other existing bonds that could potentially be re-opened. In the event that there are no existing gilts suitable for re-opening the PST will launch a new benchmark bond with a coupon determined from the yield curve. For conventional gilts, the coupon is set from the nominal forward par yield curve and for index-linked gilts, the coupon is set from the real forward par yield curve. The yield curve model used in the PST is the Variable Roughness Penalty (VRP) model developed by the Bank of England and employed by the DMO since 2007[9].

The coupon dates for new issues are parameters that can be changed in the model. When determining whether existing bonds are suitable for re-opening, the PST references parameters specified in the model for the maximum permissible size of a benchmark bond and also for the maturity window over which the DMO is prepared to re-open a bond. For instance, if the PST is issuing a 10 year bond, existing bonds with a residual maturity of 9.5-10.5 years might be deemed - from a maturity perspective - to be potential candidates for re-opening. The values that these parameters take can be set differently for different maturity bands and different instrument types. If an auction calendar has been imposed on the model it is possible to include as part of this the details on the exact bond to be sold at each auction.

Once the PST has determined which bond is to be sold at each auction it then estimates a clean price for that bond at auction. First it calculates the dirty price, which it estimates as the sum of the net present value (NPV) of the outstanding cash flows on the bond at the time that it is auctioned. The discount factors used to compute the NPV of the cash flows are determined from the nominal yield curve. For index-linked gilts, the future cash flows need to be estimated as they are dependent on the future profile of the Retail Prices Index (RPI). The PST estimates these cash flows by using the inflation term structure derived from the nominal and real yield curves, but as an alternative it is possible to impose a different future profile for the RPI. From the dirty price the PST then subtracts the relevant accrued interest to provide the clean price of the bond at auction.

Once the PST has calculated both the cash that it needs to raise at a given auction and the clean price that is achieved at that auction, it next divides one by the other to obtain the nominal amount sold. Calculating the precise nominal amount in this way means that the model should be able to raise the exact amount of cash required to meet the financing requirement for the year and so ensure that there is no over- or under-funding. However, it does mean that the nominal size of each

[9] For more information on the VRP model see
http://www.bankofengland.co.uk/statistics/yieldcurve/index.htm

auction will not conform to the DMO's operational rules on increments, which are that the nominal size of conventional gilt auctions should be a multiple of £50 million nominal and that the nominal size of index-linked gilt auctions should be a multiple of £25 million nominal. If an auction calendar has been imposed on the model then it is possible to specify as part of this the nominal size and/or the cash amount to be raised at some, or all, of the auctions for the year.

Outputs from the Portfolio Simulation Tool

The PST produces a large range of outputs to illustrate how the debt portfolio changes in the future based on assumptions about the future financing requirement, the instrument and the maturity split of future issuance. The model automatically values every instrument in the portfolio at the end of each financial year and then for each instrument it derives its redemption yield, Macaulay duration, modified duration, interest rate re-fixing period[10] and convexity. These are then used as inputs when the PST computes statistics for the debt portfolio as a whole. In practice, as the PST has been designed to be flexible it is possible to calculate statistics for either the whole portfolio or any subset of it. The portfolio statistics available are extensive and include[11]:

- Percentage of portfolio in each instrument type;
- Percentage of portfolio in each maturity band;
- Market value of the portfolio;
- Uplifted nominal value of the portfolio;
- Average maturity of the portfolio;
- Average redemption yield of the portfolio;
- Average Macaulay duration of the portfolio;
- Average modified duration of the portfolio;
- Average interest rate re-fixing period of the portfolio; and
- Average convexity of the portfolio.

Another important output of the PST is the cash flow schedule that it produces. This provides a complete record of estimated cash inflows from gilt issuance and cash outflows from the gilt portfolio up until the maturity date of the longest dated gilt. The cash outflows calculated by the model are the coupon payments and redemption payments due on each gilt in the portfolio, whilst the inflows are in the form of the cash raised from auctions. The coupon and redemption payments that appear in the schedule reflect any issuance by the PST. Both the total size of each cash flow and the proportion of this cash flow in market hands are calculated and displayed.

Comparing the PST and the Strategic Debt Analysis (SDA) models

As the DMO has an established tool for simulating strategies of debt portfolio issuance - the Strategic Debt Analysis (SDA) model - it is useful to highlight the

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[10] The interest rate re-fixing period for a security is a measure of the time to maturity of the instrument which is calculated by weighting time to each cash flow by the size of the cash flow.

[11] NB: For some statistics it is not appropriate to mix conventional and index-linked gilts to derive a single figure for the entire portfolio. For example, the duration of an index-linked gilt is a measure of its price sensitivity to real interest rates, whilst for a conventional gilt it is a measure of its price sensitivity to nominal interest rates. Consequently, it is misleading to compute a combined duration figure and so the PST produces separate figures for the duration of the index-linked part of the portfolio and the conventional part of the portfolio.

similarities and differences between the PST and the SDA[12]. Like the SDA the PST is a simulation model whose outputs are a function of the inputs and assumptions made. This means that it is not a forecast of the likely gilt portfolio that will exist in the future or over the long-term – rather it is a way to illustrate the portfolio effects of possible gilt issuance decisions. For this reason, the PST will be used alongside the SDA as a 'tool in the toolkit' that the debt management authorities may use to inform issuance decisions alongside other evidence.

The PST does not replicate what the SDA does, rather it complements it. The main differences are as follows: (i) the PST is about analysing the portfolio implications of any given issuance strategy where the issuance strategy can be defined with a high degree of specificity; the SDA is about analysing the costs and risks associated with any given issuance strategy at a much broader level; (ii) the PST allows more granularity in inputs and models the DMO's operational rules more precisely; the SDA is more 'high level', looking at broad splits between conventional issuance maturities that are kept constant over time in each scenario; (iii) the SDA incorporates a measure of risk through the modelling of the economy in the background and thus an evaluation of how different resulting yield curves could affect the cost of debt issuance (with the resulting variation of possible costs providing the risk measure) whereas the PST is much more specific on the cost evaluation but does not provide a measure of risk; and (iv) the way in which real yields are modelled. In the SDA the real yield curve is derived in a mechanical way from the nominal curve whereas the PST is more advanced and models the real curve separately so that when real and nominal curves differ, a more realistic comparison of the costs of issuing certain proportions of index-linked gilts/conventional gilts at a given maturity can be reported.

Illustrative results from the PST

This section presents some illustrative results from the PST and is intended to highlight the types of analysis that the model can be used for. One of the key inputs required by the PST is an estimate or forecast for the CGNCR for each financial year of the simulation. The simulations presented in this chapter are based on the CGNCR projections for the next five years published by HM Treasury at Budget 2009. For completeness, these estimates appear in Table 13.

Table 13
CGNCR projections for future years used in the simulations (£ billion)

Financial Year	2009-10	2010-11	2011-12	2012-13	2013-14
CGNCR estimate	220.8	179	148	120	104

Source: HM Treasury

[12] An explanation of the SDA model appears in Chapter 6 of the DMO Annual Review 2005-06: http://www.dmo.gov.uk/documentview.aspx?docname=publications/annualreviews/gar0506.pdf

The simulations assume that the change in the level of the Treasury bill stock in 2009-10 is £21.6 billion, in line with the financing arithmetic published at Budget 2009. For simplicity, for subsequent years an arbitrary increase of £5.0 billion per year in the Treasury bill stock has been assumed.

Table 14 contains the details of the three alternative gilt issuance strategies that are presented here. In order to model gilt issuance realistically, illustrative maturity splits have been provided for index-linked gilt issuance and for the split between ultra-short and short conventional gilt issuance, even though these do not represent formal splits published in the DMO's remit.

- *Strategy 1:* The 2009-10 remit split.
- *Strategy 2:* The 'reference' issuance strategy is based largely on an even flow assumption about issuance i.e. it issues gilts in roughly equal proportions across the yield curve (short, medium and long maturities).
- *Strategy 3:* Extreme long-term conventional gilt skew (i.e. 100% long-term conventional gilt issuance).

Table 14
Composition of issuance strategies for conventional and index-linked gilts

%	Conventional Gilts				Index-linkedgilts	
	Ultra Short (0-3 yrs)	Short (3-7 yrs)	Medium (7-15 yrs)	Long (15+ yrs)	Medium (7-15 yrs)	Long (15+ yrs)
Strategy 1	1.7	32	31.8	20.9	3.4	10.2
Strategy 2	7.5	17.5	25	25	12.5	12.5
Strategy 3	0	0	100	0	0	0

Completing the issuance programme for 2009-10

Before examining results from simulations five years into the future it is useful to focus on the current financial year. The PST was run for 2009-10 using Strategy 1 (a representation of this year's remit split) and using the DMO's published auction calendar for the year. The model was also provided with the results from all the auctions, mini-tenders and syndicated offerings held up until 20 July 2009 and with the published details of the bonds to be auctioned up until the end of September 2009. In addition, an estimate for the timing, bond and size for any remaining mini-tenders and syndicated offerings in 2009-10 was given to the model. For valuation purposes the yield curve from 20 July 2009 was used.

Chart 14 shows the actual redemption profile at end March 2009. The redemption payments displayed are calculated using the approach employed by HM Treasury when scoring redemptions of gilts in the financing arithmetic. As such, the data displayed are net of government holdings of gilts and, in the case of index-linked gilts, reflect a partial uplift for inflation over the life of each bond. Chart 15 illustrates the simulated redemption profile at the end of March 2010 generated by the PST. Using the PST in this way to generate an estimate of the redemption profile at the end of each financial year helps quickly to highlight how a given issuance strategy can affect this profile and hence the future gross financing requirement.

Chart 14
Redemption profile at end-March 2009

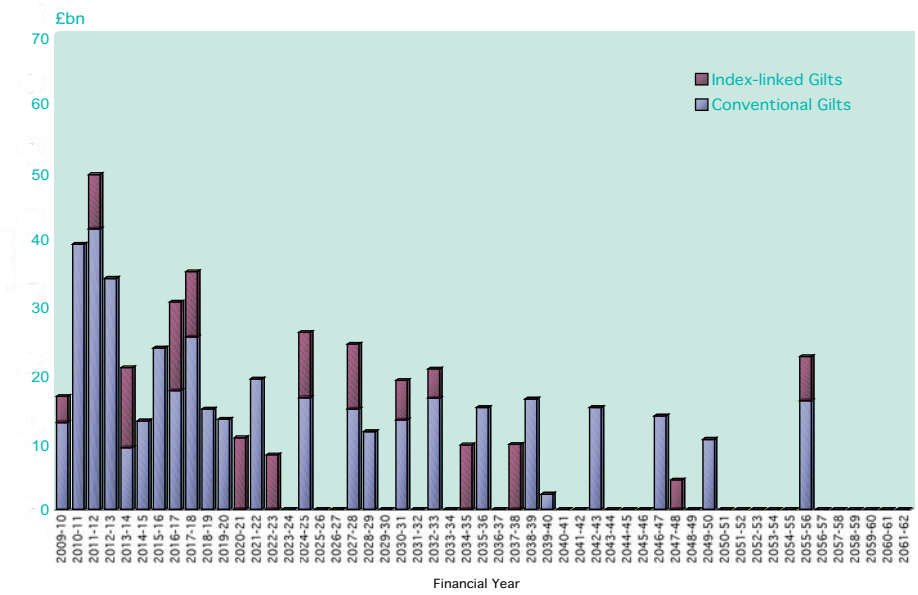
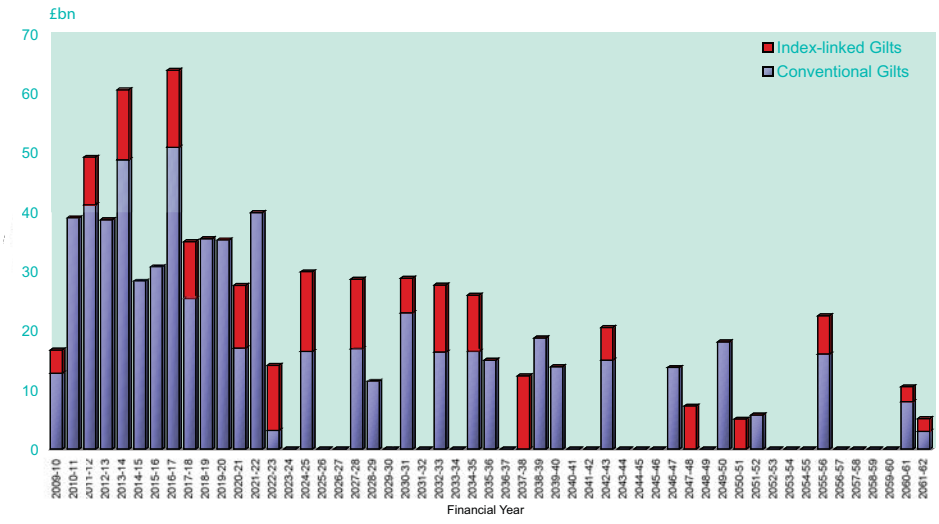
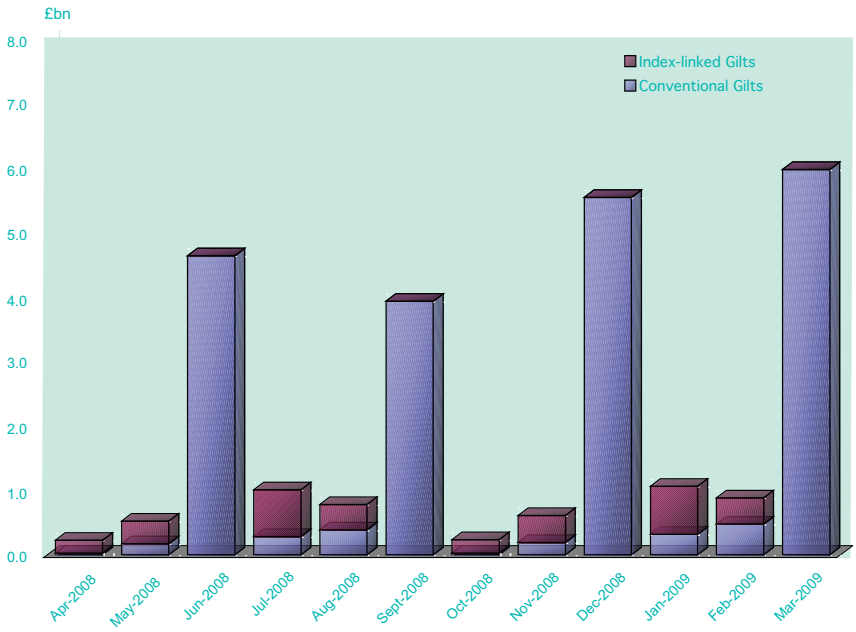


Chart 15
Estimated redemption profile at end-March 2010



As the PST generates a full set of cash flows for the whole gilt portfolio, it is also possible to use it to obtain estimates of coupon payments. For example, Chart 16 illustrates the gross coupon payments for 2008-09 aggregated on a monthly basis. The peaks in March, June, September and December reflect the fact that the overwhelming majority of conventional gilt issuance over the past 12 years has been into bonds paying coupon payments in these months.

Chart 16
Estimated gross gilt coupon payments in 2009-10



At end March 2010 the PST estimates the total size of the gilt portfolio in uplifted nominal terms to be £907 billion, compared with a figure of £713 billion for end March 2009. This significant increase reflects the record size of the gilt issuance programme in 2009-10.

Charts 17 and 18 illustrate how the composition of the debt portfolio (in uplifted nominal terms) is estimated to change over the year. Unsurprisingly, as short and medium maturity conventional gilts account for a larger proportion of the issuance programme in 2009-10 than long conventionals and index-linked gilts, their share in the portfolio increases over the year.

Chart 17
Composition of the debt portfolio at end-March 2009

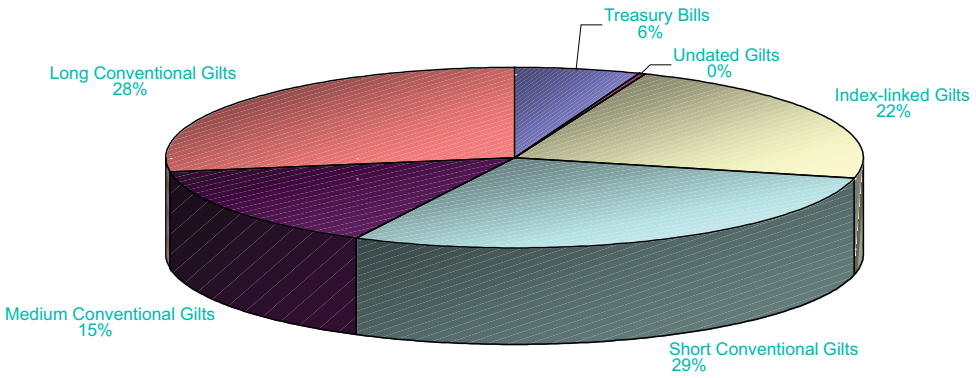
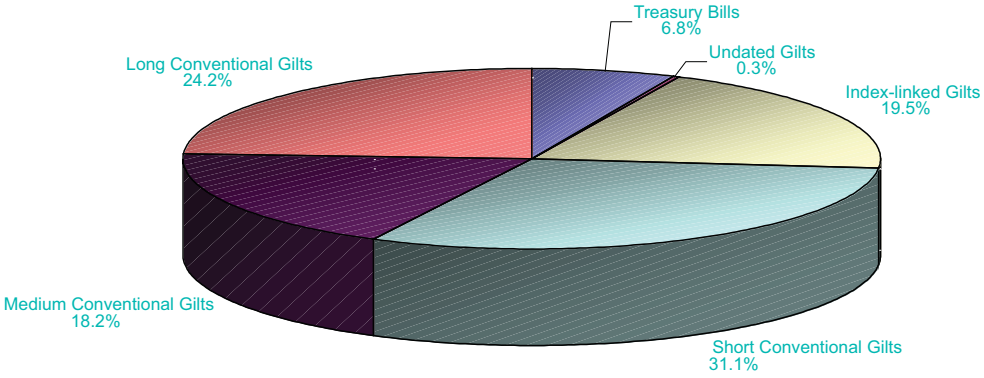


Chart 18
Estimated composition of the debt portfolio at end-March 2010



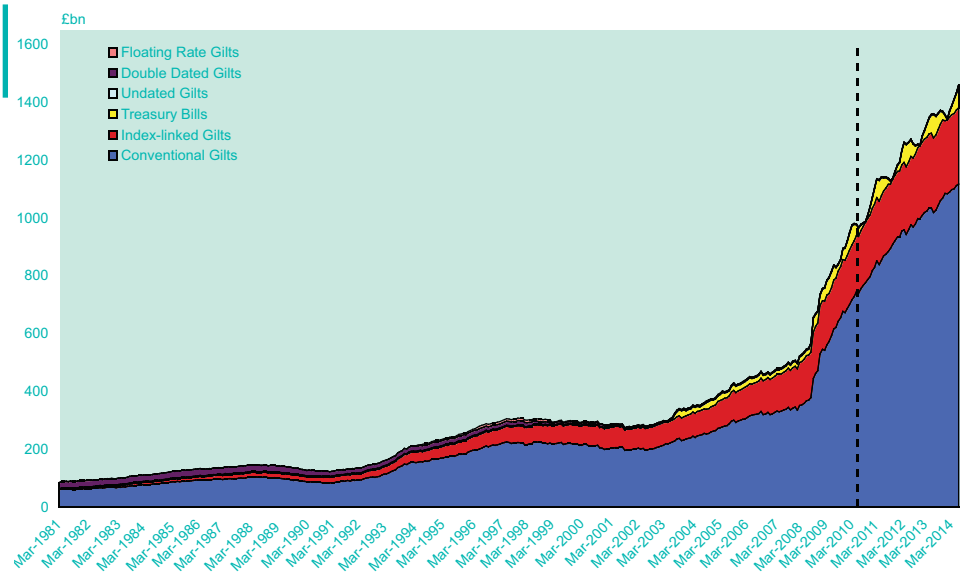
Evolution of the debt portfolio over the next five years

Scenarios 1 to 3 below are based on the respective issuance Strategies 1-3 that were set out earlier. In all three cases, the remainder of 2009-10 is simulated based on the Budget 2009 instrument and maturity splits for the year, but then the following four years are simulated using the splits in Strategies 1-3. The 5 year horizon was chosen because this is the timeframe over which the published HM Treasury projections for the CGNCR is available.

Chart 19 illustrates the growth in the Government debt portfolio since 1981 based on Scenario 1 (i.e. assuming that the issuance plan for 2009-10 is followed this year and in the subsequent four years). The comparable graphs for the other two strategies look broadly similar to this[13], but the rate of growth in the portfolio varies from scenario to scenario, reflecting the point in time in the future at which the cost of redeeming the new debt issued by the PST impacts on the gross financing requirement. Clearly, the split in the portfolio between the different instrument types will also vary with the different strategies.

A significant contributory factor to the increase in the size of the portfolio during 2008-09 were the three instances where gilts were created for the DMO to use as collateral – in cash terms around £115 billion of gilts were created in three operations (£15 billion in April 2008, £50 billion in October and another £50 billion in January 2009). For Chart 19, historical data on the Treasury bill stock were only available from 2003. For the simulated years, the irregular intra-year pattern followed by the Treasury bill stock is due to the fact that the PST only models Treasury bill issuance in a fairly simple way. In particular, all Treasury bills issued are assumed to be of 6 months maturity, with issuance occurring in the last 6 months of the year. This constraint is designed to guarantee that the change in the size of the Treasury bill stock over the year is consistent with the financing arithmetic.

Chart 19
Size of the debt portfolio (in uplifted nominal terms)



[13] And are not charted for this reason.

Charts 20-22 show how the composition of the portfolio (in uplifted nominal terms) changes over this period based on the three different issuance strategies. For illustrative purposes the long conventional part of the portfolio has been split into long (15-35 years) and ultra-long (35+ years) categories. Scenario 1 shows that an annual assumption of 13.6% of annual gilt issuance in index-linked gilts results in them constituting around 18% of the gilt portfolio by 2014; whereas if index-linked gilt issuance is assumed to constitute 25% of gilt issuance (as in Scenario 2), they would represent 24% of the gilt portfolio by 2014. As expected, in Scenario 3, given that all gilt issuance is into conventional gilts, by 2014 the proportion of index-linked gilts in the portfolio falls significantly to 11%.

Chart 20
Changes in the composition of the debt portfolio for Scenario 1

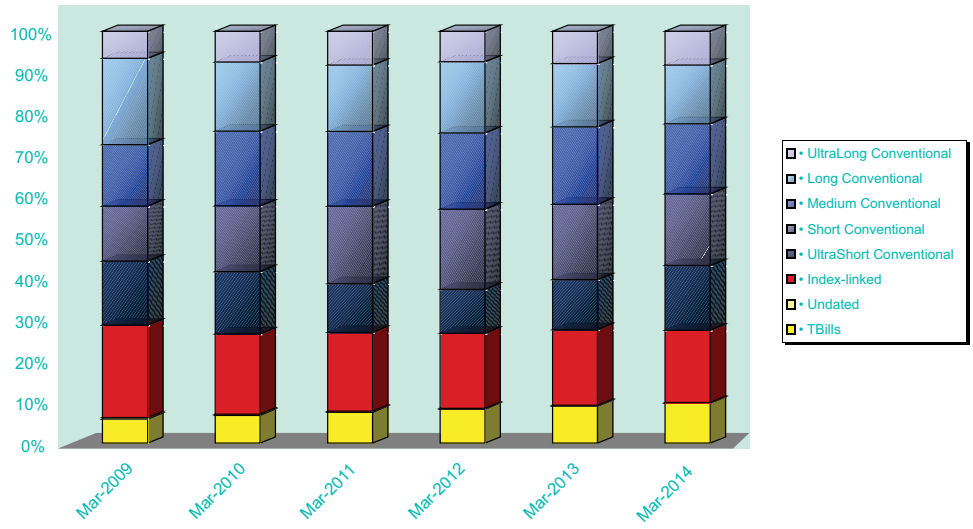


Chart 21
Changes in the composition of the debt portfolio for Scenario 2

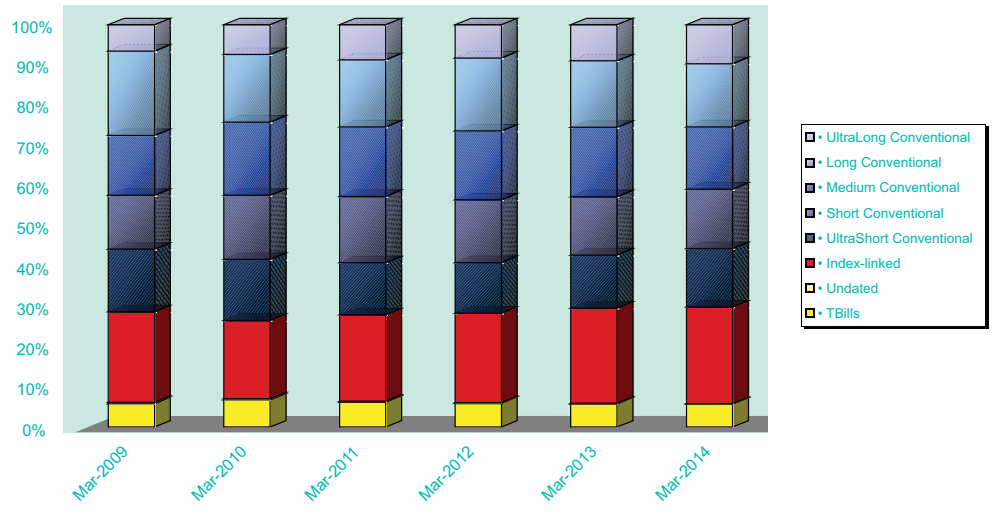


Chart 22
Changes in the composition of the debt portfolio for Scenario 3

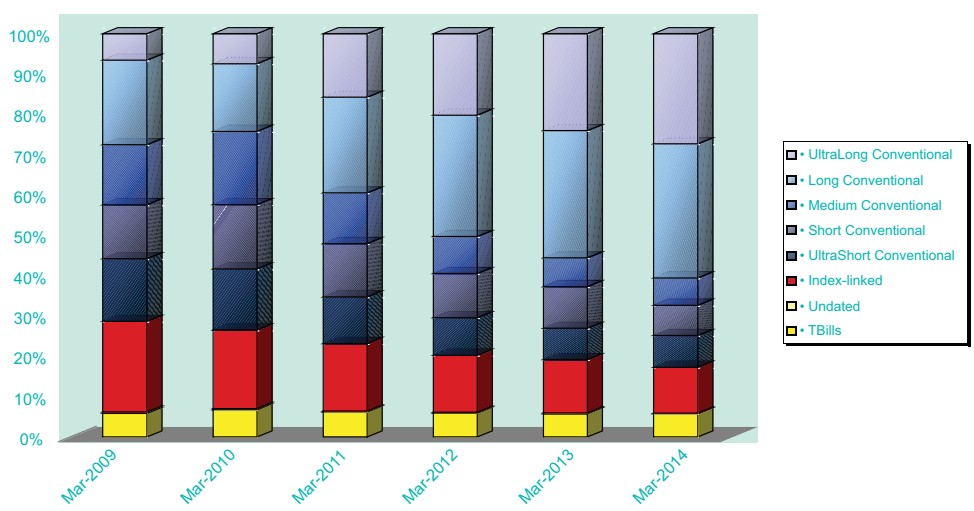


Table 15 compares the composition of the debt portfolio in 2014 based on Scenario 1 (the 2009-10 remit strategy) with that from following Scenario 2 (even flow).

Table 15
Composition of the debt portfolio at end March 2014

Category	Scenario 1	Scenario 2
Treasury Bills	5.7%	5.7%
Undated Gilts	0.2%	0.2%
Index-linked Gilts	18.1%	24.0%
Ultra-short Conventional Gilts	14.3%	14.5%
Short Conventional Gilts	20.1%	14.7%
Medium Conventional Gilts	18.4%	15.5%
Long Conventional Gilts	14.6%	15.7%
Ultra-long Conventional Gilts	8.6%	9.7%

Chart 23 shows how the average maturity of the gilt portfolio changes over time. At end March 2009 the average maturity of the gilt portfolio was 14.1 years and by end March 2010 the PST estimates that this will rise to 14.3 years. In subsequent years, all three scenarios show a further increase in the average maturity of the portfolio. Scenario 1, which is the strategy with least long issuance, leads to the smallest increase in average maturity. By 2014 the average maturity for this scenario was 14.4 years, whereas Scenario 2 results in an average maturity of around 15.8 years. Scenario 3, with its focus purely on long and ultra-long conventional issuance, leads to an average maturity of 24.0 years by 2014.

Chart 23
Average maturity of the gilt portfolio

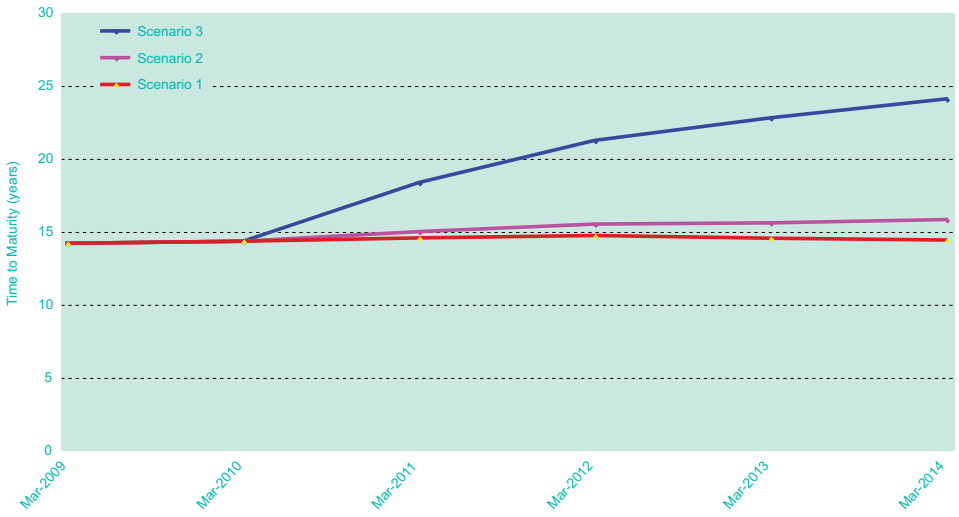


Chart 24 illustrates how the average modified duration of the conventional gilts in the portfolio changes over time[14]. As would be expected, there is a more dramatic change in the average duration for Scenario 3 - where all issuance is in either long or ultra-long conventional gilts - than for the other two scenarios, with the average duration rising from 8.6 years at end-March 2009 to 12.4 years at end-March 2014. In contrast, the other scenarios result in a fall in average duration. In the case of Scenario 1, which has the smallest proportion of long and ultra-long conventional gilt issuance, the duration falls to 7.7 years at end-March 2014, whilst in the case of Scenario 2 the duration falls to 8.3 years.

[14] In addition to standard conventional gilts, double-dated and undated gilts have been included in this calculation.

Chart 24
Average modified duration of conventional gilts

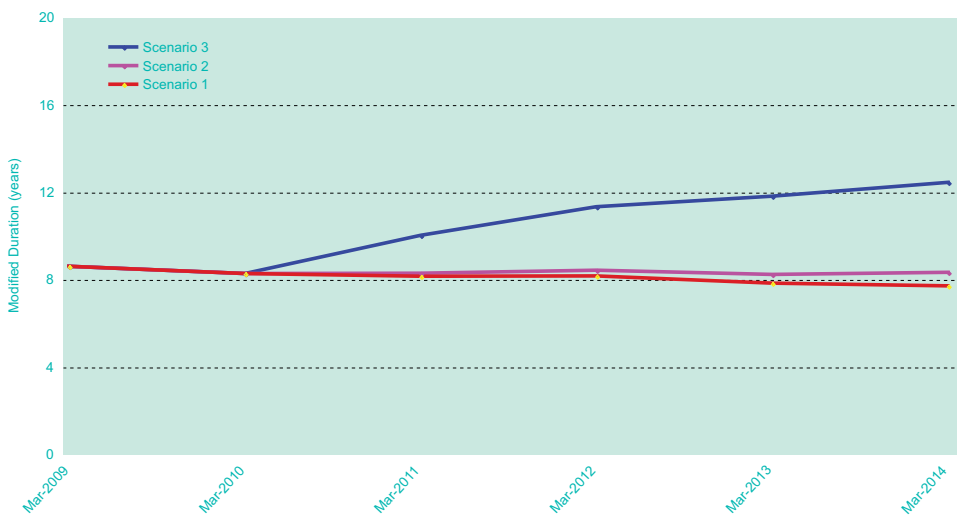
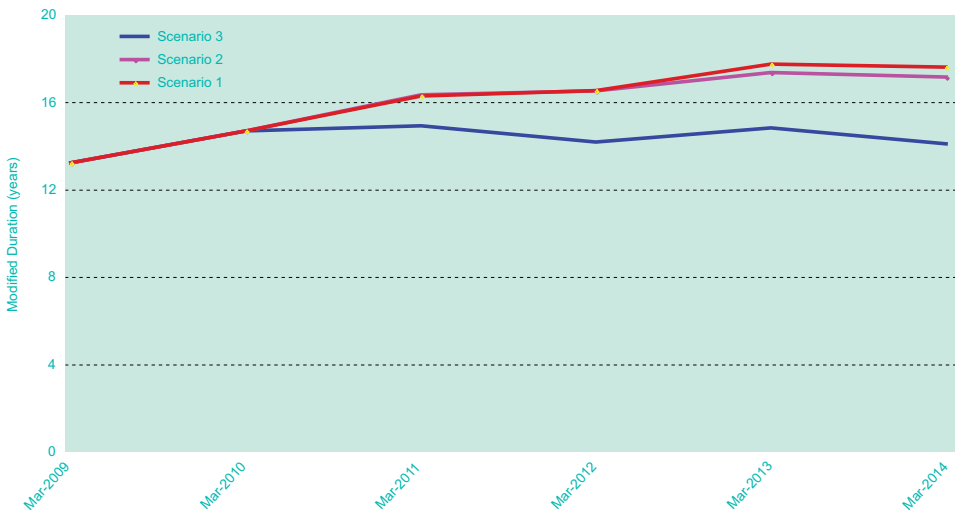


Chart 25 shows how the average modified duration of the index-linked gilts in the portfolio changes over time. At end-March 2009, the average modified duration of index-linked gilts in the portfolio was 13.2 years and by the end of March 2010 the PST suggests that this will rise to 14.6 years. Since no index-linked gilts are issued after March 2010 under Scenario 3, the existing bonds gradually shorten and so the average modified duration falls over time. Scenarios 1 and 2 lead to an increase in the average modified duration of index-linked gilts to 17.8 years and 17.1 years respectively at end-March 2014.

Chart 25
Average modified duration of index-linked gilts



Concluding remarks

The PST is an important new model that assists the DMO and HM Treasury when making debt management decisions. This chapter has highlighted some of the types of analysis that can be conducted using the model. Going forward, simulations produced by the PST will appear on a routine basis in publications produced by the DMO.