Index, Portfolio and Risk Solutions
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Optimizer Series

Control Leverage in the Optimal Portfolio

Leverage is a popular tool portfolio managers use to potentially enhance the returns on their portfolios. One method to achieve leverage is to create a long/short portfolio; we call this financial leverage. When managing against a benchmark, leverage can also be achieved by holding positions that are riskier than those in the benchmark; we call this instrument leverage.

In this note, we show how both types of leverage can be handled by POINT's Optimizer. In particular, we illustrate how they can be managed alongside other quantitative portfolio objectives.

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Introduction

Leverage is a technique used by investors trying to earn higher returns per unit of investment. A common example of a leverage strategy is the 130:30 equity portfolio, in which 130% of the net market value is owned long while 30% is held short. This example of leverage is referred to as financial leverage. For a portfolio managed against a benchmark, another type of leverage can be developed by holding riskier securities than the benchmark – these extra risks are typically associated with amplified returns (compared with the benchmark). A simple way to achieve this position is by holding securities with higher duration or beta with respect to the benchmark. This technique may be used in conjunction with financial leverage. We refer to this as instrument leverage because we choose instruments of a nature similar to those in the benchmark, but with higher volatility profiles. Both types of leverage are frequently used by asset managers and hedge funds in trading strategies that strive for high returns and are willing to incur the additional risk. Managed leverage could greatly enhance the portfolio's performance; however, excessive leverage could also be disastrous in an adverse tail event. For instance, financial leverage could lead to margin calls and forced liquation at adverse prices.

POINT's Optimizer handles both types of leverage and is capable of answering questions such as: Given a hard leverage limit, how should long-short positions be allocated? How much long-short leverage is optimal for a given level of risk aversion? How much excess return may one achieve with risk tolerances higher than the one implied by our benchmark index? We provide examples of how to answer to these and other questions by setting optimization problems with leverage considerations in POINT's optimizer.

Leverage in POINT Optimizer

We assume that the readers are familiar with the basic functionalities of the Barclays' POINT Optimizer [for details see Kumar and Lazanas 2009]. The financial leverage ratio can be set as a hard target constraint in the common constraints window. Alternately, it can also be added as a term in the optimization objective function, by setting the leverage target as a soft constraint [see Kumar (2010) for the treatment of soft constraints]. Instrument leverage is implicitly contained in the TEV that can be added as both an objective term and constraint in the optimization. We provide examples of optimization setups for managing both types of leverage and analyze the resulting portfolios.

Financial Leverage

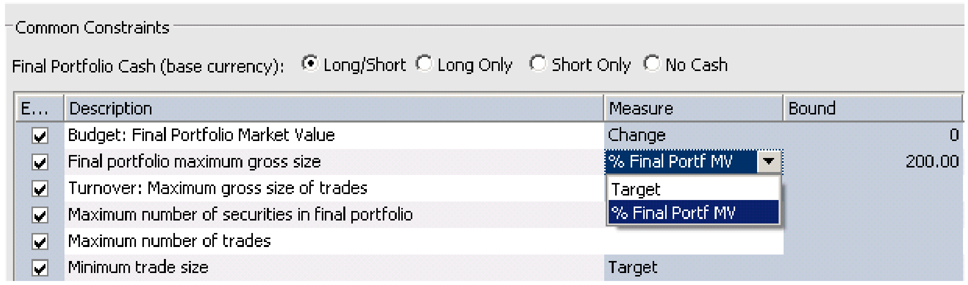
Financial leverage is calculated as the ratio of a portfolio's gross size to its net market value. For cash instruments, such as bonds and stocks, the gross size is simply the sum of the absolute value of the market value across securities. Because market value is not a meaningful measure of size for some derivative instruments, we instead use the duration basis attribute in POINT. Duration basis, based on a derivative's notional exposure, represents a derivative's fully funded market size and is equal to the market value for cash instruments. Portfolio gross size is the sum of the absolute value of the portfolio holdings' duration basis.

Setting the Leverage Target using the Portfolio Gross Size

To introduce leverage into the problem's specification, we start by specifying the maximum gross size (and thereby the leverage) as a common constraint in POINT's optimizer (see Figure 1). Later in the example we illustrate the leverage introduced through a soft constraint instead. Regarding the gross size, the leverage goal can be expressed in base currency units (setting "Measure" = Target) or as a percentage of final portfolio market value (setting "Measure" = % Final Portf MV). For example, to generate a long short 150:50 portfolio with net market value equal to $100,000,000, the constraint on gross size should be equal 200,000,000 using the first measure and 200 (%) using the second.

FIGURE 1

Maximum Gross Size Constraint



Source: Barclays Research

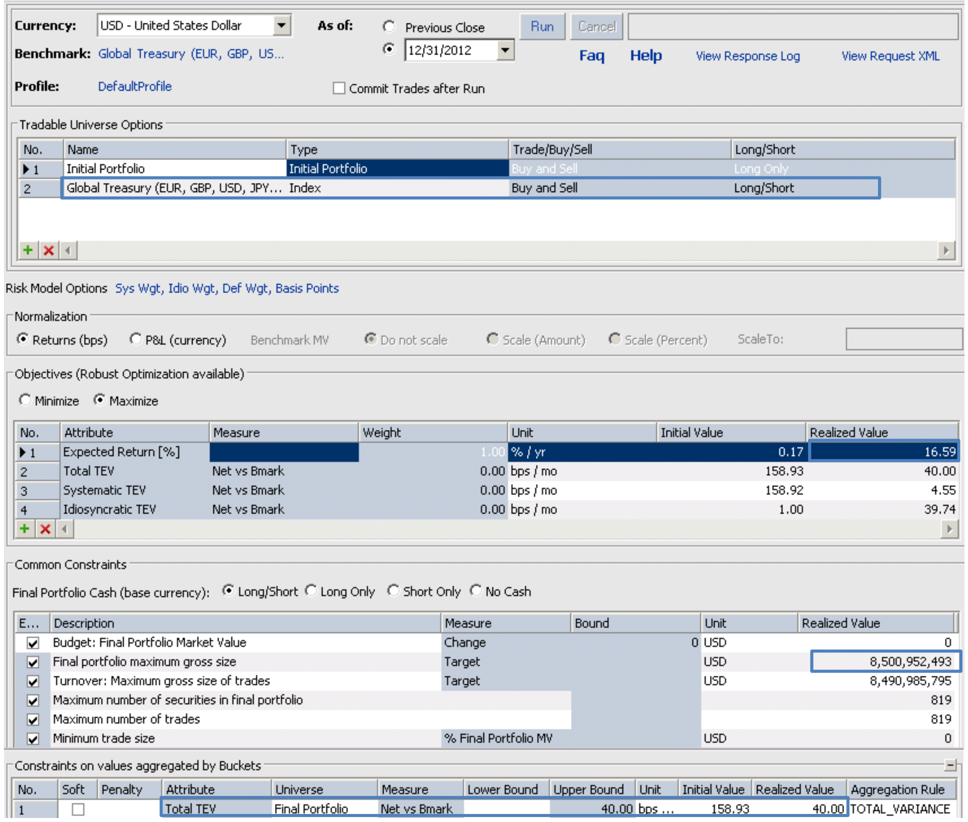
Example 1: Optimization with Financial Leverage Constraint on Cash Bonds

We aim to construct a cash bond portfolio benchmarked to the Global Treasury index (EUR, GBP, USD, and JPY denominated bonds only). We want a portfolio containing bonds from this benchmark only. Therefore, we set the tradable universe to be the benchmark itself. The portfolio is potentially a long/short portfolio. The optimization goal is to deliver a portfolio with the highest expected return possible, where the expected return for each bond is assumed to be its yield to maturity. The initial portfolio is composed by $100,000,000.

Without any additional constraints, the optimizer fails to deliver a feasible solution. It goes long the security with the highest return and short the one with the lowest return, with infinite leverage amount. To limit the potential solution, we set an additional constraint: an upper bound on the risk of the portfolio, specifically tracking error volatility (TEV) no larger than 40bp per month. The solution is now an optimal portfolio that achieves an expected return of 16.59% per year; has a TEV of 40bp per month; has a gross size exceeding 8.5bn; and contains 819 bonds (Figure 2).

FIGURE 2

Optimization Setup – Cash Bonds



Source: Barclays Research

Though theoretically feasible, this portfolio is uninvestable in three ways: first, it has 85x leverage, which is excessive for a typical portfolio; second, it has a large number of bonds, potentially incurring unreasonable transaction costs; and third, it sells bonds short in unrealistic amounts. Shorting bonds is not the most practical way to achieve leverage. Similar results can be achieved in more efficient ways by using derivatives such as futures and swaps.

Example 2: Optimization with Financial Leverage Constraint on Futures

To explore the use of derivatives, we change the tradable universe of the previous example to include instead a set of Treasury futures only. Specifically, the tradable universe contains 18 future contracts on Treasury bonds from the US, euro area, the UK, and Japan. Cash from each of the currencies is also included in the tradable universe, to facilitate matching FX exposure. For each futures contract, the expected return was proxied by the annualized total return of the corresponding cheapest-to-deliver bond over a 3-month unchanged curve scenario (Figure 3) [1]. The expected return of cash is set to be the short-term rate in each currency. Exchange rates are assumed to hold constant during this period.

[1] User can specify expected return through the field USER_EXPECTED_RETURN in the import User Defined Data Fields paste wizard.

FIGURE 3

Tradable Universe – Treasury Futures and Cash

Identifier	Description	Expected Return (%)
TYH13:CBT	10 year Treasury Notes	2.472
3YH13:CBT	3 year Treasury Notes	0.836
FVH13:CBT	5 year Treasury Notes	1.400
TUH13:CBT	2 year Treasury Notes	0.556
FBTPH13:UDE	Euro-BTP	1.483
FOATH13:UDE	Euro-OAT	3.364
FGBXH13:UDE	Euro-BUXL	2.348
FGBLH13:UDE	Euro-BUND	2.804
FGBMH13:UDE	Euro-BOBL	1.592
FGBSH13:UDE	Euro-SCHATZ	0.060
JGB1H13:TKS	10 year JGB	1.288
JMBH13:TKS	5yr JGB	0.384
USH13:CBT	30 year US Treasury Bonds	3.036
WNH13:CBT	US Ultra Long Term Treasury B...	3.120
GH13:LIF	Short Gilt	0.368
HH13:LIF	Medium Gilt	1.900
RH13:LIF	Long Gilt	2.976
FBTSH13:UDE	Short Euro-BTP	2.912
EUR	CASH - European Monetary Unit	0.014
GBP	CASH - Pounds Sterling	0.501
JPY	CASH - Japanese Yen	0.105
USD	CASH - U.S. Dollar	0.154

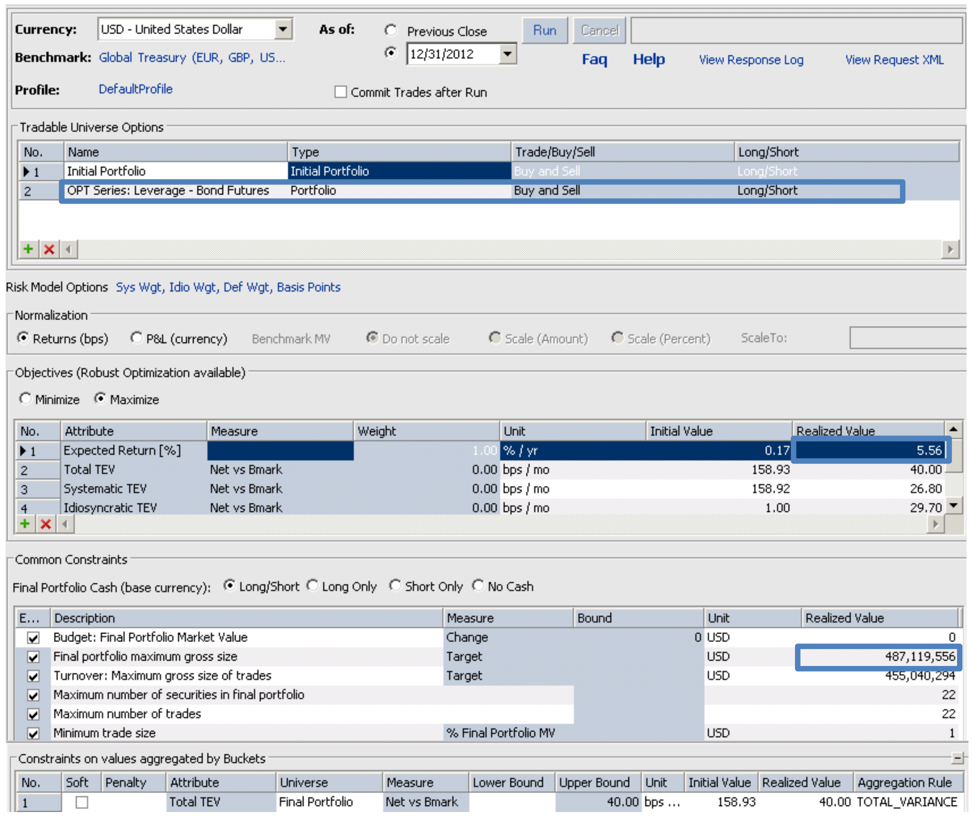
Source: Barclays Research.

Apart from the change in the tradable universe, all other parameters of the optimization problem are maintained: the optimizer select futures to maximize the expected return while keeping the total TEV against the G4 Treasury index less than 40bp per month. As before, the constraint on the total TEV rules out the unbounded solution that concentrates on extreme positions.

When we impose no leverage, the optimal portfolio contains only cash on each of the four currencies, with weights very similar to the benchmark and an expected return of 10bp. The Treasury bonds in the benchmark are exposed to both curve and FX risk factors. On a relative basis, the latter is riskier than the former. Therefore, the optimizer selects cash because it is the only instrument available in the tradable universe that provides FX exposure. Treasury futures, having no market value, hedge only the less important rate risk and are less useful than cash to hedge the benchmark total risk. When we relax the leverage constraint, allowing for unlimited leverage, the optimizer constructs a $487,119,556 (notional) portfolio with an expected return of 5.56%, as shown in Figure 4.

FIGURE 4

Optimization Setup – Unlimited Leverage with Futures



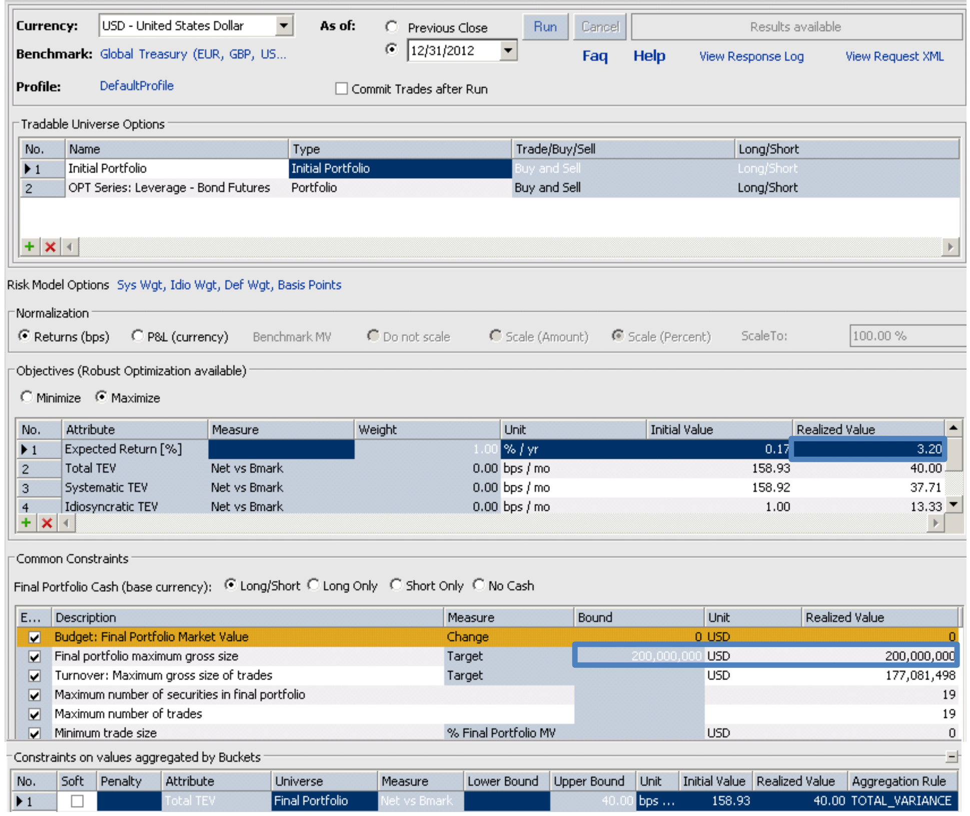
Source: Barclays Research.

Although much more intuitive, the solution above, with almost 5x leverage in our example may still exceed the leverage appetite of most portfolio managers. One may therefore want to impose a direct limit on the maximum leverage. One way to do that using the POINT's Optimizer is by setting the gross size of the final portfolio, as shown before (see Figure 1). Recall that throughout this exercise we have imposed the market value of the final portfolio to be $100mn. By setting its gross size to $200mn, we establish a maximum leverage of 2x.

Figure 5 shows the problem setup and some characteristics of its solution – the final optimal portfolio – under the new leverage constraint. Comparing the solution with the one from the unconstrained case, we can see that the expected return reduces to 3.20% (from 5.56%). Note also that in this case, the leverage constraint reduces the portfolio concentrations on individual instruments. In our example, this leads to the reduction of the idiosyncratic TEV (from 29.7bp to 13.3bp), indicating an improved portfolio diversification.

FIGURE 5

Optimization Setup – 2x Leverage with Futures



Source: Barclays Research

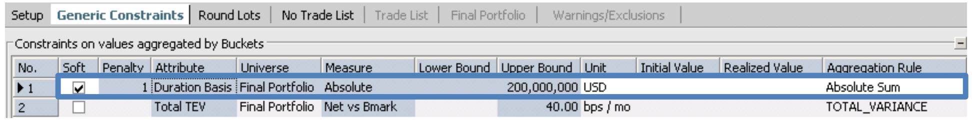
Setting the Leverage Target as a Soft Constraint

Up to this point, we have been setting leverage by controlling the gross size of the portfolio explicitly. POINT offers another way to attain this goal. Leverage can be incorporated by augmenting the mean-variance optimization objective function with a leverage aversion penalty. In POINT's optimizer, this can be achieved by adding a soft constraint on the absolute duration basis of the final portfolio. Soft constraints are appended into the optimization objective function, with a particular penalty term. This term manages how costly it is for the final solution to violate the constraint [see Kumar (2009)].

When setting this constraint, the user should "right-click" and select the absolute sum option under aggregation rule (Figure 6). The user can enter a lower bound and an upper bound for his desired leverage amount. The soft constraint penalty factor expresses the leverage aversion. The higher the penalty value, the higher is the cost given to a leverage constraint violation. In an extreme, a soft constraint with a very large penalty is equivalent to a hard constraint. For illustration, we set the penalty weight to one (its default value).

FIGURE 6

Soft Constraint on Financial Leverage



Setup | Generic Constraints | Round Lots | No Trade List | Trade List | Final Portfolio | Warnings/Exclusions

Constraints on values aggregated by Buckets

No.	Soft	Penalty	Attribute	Universe	Measure	Lower Bound	Upper Bound	Unit	Initial Value	Realized Value	Aggregation Rule
1	☑	1	Duration Basis	Final Portfolio	Absolute		200,000,000	USD			Absolute Sum
2	☐		Total TEV	Final Portfolio	Net vs Bmark		40.00	bps / mo			TOTAL_VARIANCE

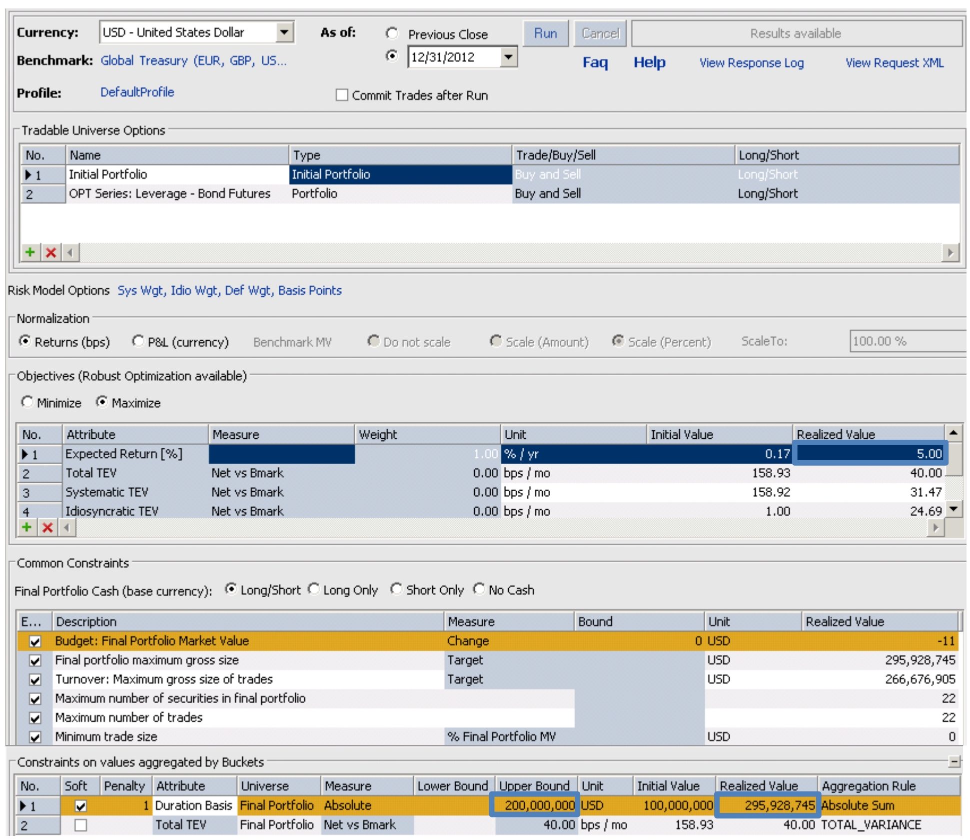
Source: Barclays Research

Example 3: Optimization with Financial Leverage Soft Constraint

To illustrate the soft constraint feature, we modify the setup of Example 2. Specifically, we do not impose any constraint on the gross size on the portfolio. Instead, we use the exact soft constraint as is displayed in Figure 6. The results from this new optimization problem are displayed in Figure 7. The optimal solution breaches the soft target of $200mn gross size by almost 50% (the gross size is $296mn, for a leverage ratio of 3x). The expected return is higher, at 5% (from 3.2% previously) and the idiosyncratic risk also increased. Note that the optimal leverage level is solved together with the optimal portfolio holdings, when using the soft constraint. The POINT optimizer easily incorporates this type of functionality, which is discussed in Jacobs & Levy (2011). An iterative use of this framework – namely by using different values for the penalty violation – allows the user to find the right trade-off between expected return, gross size, and risk.

FIGURE 7

Optimization Setup – 2x Leverage Soft Constraints



Currency: USD - United States Dollar | As of: Previous Close / 12/31/2012 | Run | Cancel | Results available

Benchmark: Global Treasury (EUR, GBP, US... | Faq | Help | View Response Log | View Request XML

Profile: DefaultProfile | Commit Trades after Run

Tradable Universe Options

No.	Name	Type	Trade/Buy/Sell	Long/Short
1	Initial Portfolio	Initial Portfolio	Buy and Sell	Long/Short
2	OPT Series: Leverage - Bond Futures	Portfolio	Buy and Sell	Long/Short

Risk Model Options Sys Wgt, Idio Wgt, Def Wgt, Basis Points

Normalization

Returns (bps) | P&L (currency) | Benchmark MV | Do not scale | Scale (Amount) | Scale (Percent) | ScaleTo: 100.00 %

Objectives (Robust Optimization available)

Minimize | Maximize

No.	Attribute	Measure	Weight	Unit	Initial Value	Realized Value
1	Expected Return [%]		1.00	% / yr	0.17	5.00
2	Total TEV	Net vs Bmark	0.00	bps / mo	158.93	40.00
3	Systematic TEV	Net vs Bmark	0.00	bps / mo	158.92	31.47
4	Idiosyncratic TEV	Net vs Bmark	0.00	bps / mo	1.00	24.69

Common Constraints

Final Portfolio Cash (base currency): Long/Short | Long Only | Short Only | No Cash

E...	Description	Measure	Bound	Unit	Realized Value
☑	Budget: Final Portfolio Market Value	Change	0	USD	-11
☑	Final portfolio maximum gross size	Target		USD	295,928,745
☑	Turnover: Maximum gross size of trades	Target		USD	266,676,905
☑	Maximum number of securities in final portfolio				22
☑	Maximum number of trades				22
☑	Minimum trade size	% Final Portfolio MV		USD	0

Constraints on values aggregated by Buckets

No.	Soft	Penalty	Attribute	Universe	Measure	Lower Bound	Upper Bound	Unit	Initial Value	Realized Value	Aggregation Rule
1	☑	1	Duration Basis	Final Portfolio	Absolute		200,000,000	USD	100,000,000	295,928,745	Absolute Sum
2	☐		Total TEV	Final Portfolio	Net vs Bmark		40.00	bps / mo	158.93	40.00	TOTAL_VARIANCE

Source: Barclays Research

Instrument Leverage

A portfolio consisting of riskier assets than a benchmark (such as stocks with higher beta or bonds with longer durations or higher spreads) can be constructed so that its portfolio forecasted volatility is a specified multiple of the benchmark. This feature is especially useful when the portfolio manager does not have a specific return forecast on the security level, but rather seeks a broad tilt to the portfolio. For instance, an equity manager may forecast positive market returns, and therefore want to increase the beta of its portfolio versus a benchmark. The following example shows how to select riskier assets out of an index in exchange for the potential higher return. The instrument leverage can be applied on its own, or in combination with financial leverage.

Example 4: Optimization with Instrument Leverage

Consider the case of a portfolio manager who is comfortable with the systematic exposures of a particular index. However, given her return targets or risk tolerance, she needs to leverage those exposures. Specifically, suppose that her goal requires twice the volatility of the current benchmark. In what follows we show how to construct this kind of portfolio using POINT's Optimizer.

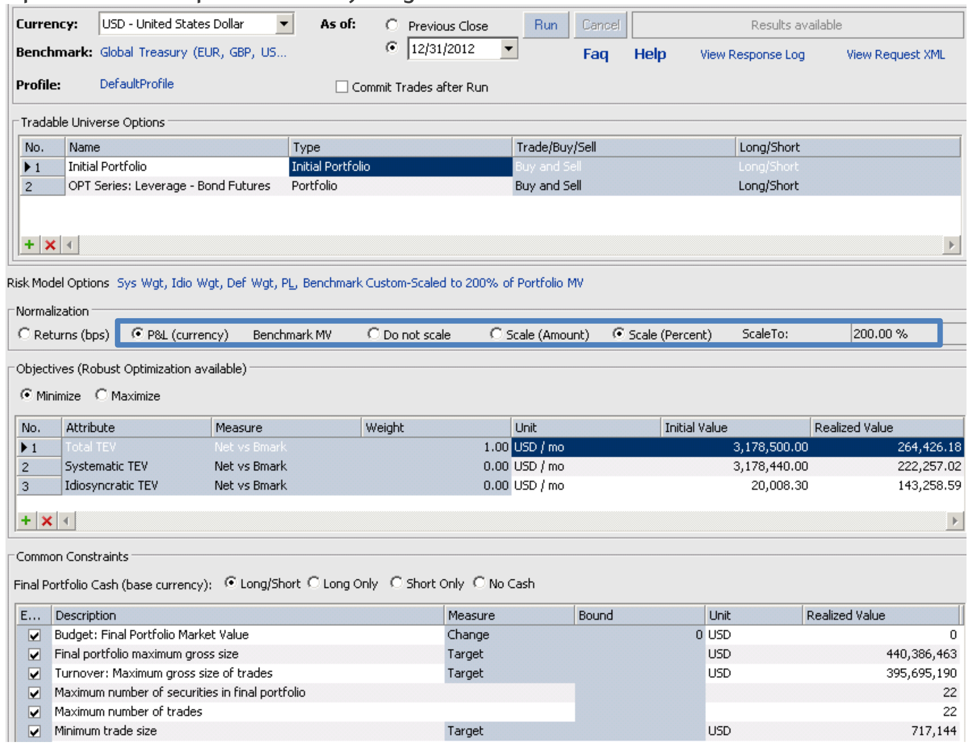
There is one straightforward way to construct a portfolio with the required characteristics: Start by leveraging the required benchmark by shorting cash on that benchmark. For instance, for a 2x levered version of the benchmark, a user can short 50% of the benchmark market value. Then use the optimizer to construct a portfolio tracking the leveraged benchmark. Though simple, this technique involves two steps and needs adjustments as the market value of the benchmark changes. Fortunately, the Optimizer allows a simpler way of performing this exercise.

The Optimizer provides easy manipulation of the treatment of benchmarks along the dimensions required for this exercise. The default optimization set-up is to work with relative market weights (on the return space). This makes the comparison of large market value benchmarks with smaller portfolios meaningful. However, for some exercises, like hedging or liability matching, the absolute size of the benchmark (e.g., liabilities) is the relevant variable. In this case, the optimization can be performed instead with nominal exposures (i.e., in P&L terms). We can use this flexibility to solve the problem at hand.

The P&L normalization option includes a scaling factor for the benchmark market value. The default scale is 100%, meaning the P&L exposures of the benchmark are scaled so to match (on duration basis terms) those of the initial portfolio ($100mn as in the example). By adjusting this factor, the user can target any multiple of the benchmark exposure. In our case, we do that through a minimization of the scaled TEV in P&L space. To construct a portfolio with volatility target leverage of twice the benchmark, P&L normalization should be selected with the scaling set to 200%, so that the $100mn portfolio replicates the risk exposure of a $200mn benchmark, as highlighted in Figure 8.

FIGURE 8

Optimization Setup – 2x Volatility Target



Source: Barclays Research

In this example we use the same $100mn initial portfolio and tradable universe of government bond futures and cash. The objective is set to minimize the Total TEV versus a benchmark that doubles the risk exposures of the G4 Treasury index.

FIGURE 9

Risk and Analytics

	G4 Treasury	1x Vol Target Portfolio	2x Vol Target Portfolio
Risk Metrics			
total Volatility	158.9	158.4	316.7
Systematic Vol	158.9	158.2	316.4
Idiosyncratic Vol	1	7.1	14.2
OAD	7	6	11.9
OASD	6.8	5.9	11.8
OAS	36.5	39	53
FX Exposure			
EUR	29.4	30.6	61.1
JPY	32.9	34.1	68.2
GBP	8.6	7.7	15.4
Expected Return			
	1.2	2.3	4.5
Gross Size			
	1x	2.3x	4.4x

Source: Barclays Research

Figure 9 summarizes the risk metrics and key analytics between the benchmark, the optimized portfolio that replicates 100% of the G4 Treasury index and the optimized portfolio with double risk exposure to that index. The portfolio with 1x target leverage matches well the benchmark across major risk metrics: OAD, OASD and the FX exposures. As expected, the portfolio with 2x target leverage has twice the exposures seen in the benchmark. Consequently the total volatility of the 2x portfolio, at 316.7bp per month, is twice that of the benchmark.

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Jacobs, B. and Levey, K. (2011), “Leverage Aversion and Portfolio Optimality,” *Financial Analysts Journal*, Volume 68, No 5.

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