# Backtest Graphics

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**Abstract**  The **backtestGraphics** package does not run backtests but instead creates an interactive graphical interface to present backtest results. The user can visualize backtest results for different financial instruments, such as equities, futures, and credit default swaps. The left panel of the interface displays summary performance statistics and the right panel shows interactive plots of profit and loss (P&L), net market value (NMV) and gross market value (GMV). Because a single backtest may contain multiple strategies and overlapping portfolios, the **backtestGraphics** package also allows the user to look at results for different strategies, substrategies, and overlapping portfolios.

## Introduction

Backtesting is the process of testing trading strategies on prior time horizons to measure the effectiveness of the strategy. It helps investors understand and optimize their trading strategies [Campbell et al. (2008)]. For more on backtesting, *Quantitative Value* [Gray and Carlisle (2013)] is a good introductory book. Notice that **backtestGraphics** does not run backtests, but presents the backtest results graphically.

The package contains three data frames with backtest information on commodity futures, equity, and credit default swaps (CDS): `commodity`, `equity`, and `credit`. These data frames are all valid to pass into the `backtestGraphics` function.

The Shiny interface in **backtestGraphics** allows the user to look at her backtest results [Chang et al. (2015)]. Summary statistics, including average gross market value (GMV), number of instruments, cumulative and annualized profit and loss (P&L), sharpe ratio, best and worst months, are displayed in the "Summary" tab in the sidebar panel. More detailed information, including the top three drawdowns and three best and worst performers, are shown in the "Detail" tab. Interactive plots of cumulative P&L, daily P&L, net market value (NMV) and GMV are displayed in the main panel. The user can easily zoom in to look at any specific time period on the plots.

Backtests vary in complexity. A simple backtest employs a single strategy in a single portfolio while a more complex backtest uses multiple strategies and substrategies. The user can also create overlapping portfolios for different (sub)strategies at different time periods. The **backtestGraphics** package has two dropdown menus for different strategies and portfolios, which allow the user to subset her backtest results accordingly.

## Data

The package contains three data frames which are backtest results for commodity futures, equities and CDS, respectively: `commodity`, `equity` and `credit`.

Start with `equity`:

```
Source: local data frame [9 x 5]
```

```
    name       date sector       nmv        pnl
   (chr)     (date)  (chr)     (dbl)      (dbl)
1   A.Z 2005-05-02    MAT -131926.1   3158.4525
2  ABFS 2005-05-02    IND -131926.1  -4058.6214
3  ABS. 2005-05-02    CNS -131926.1   -733.2929
4   A.Z 2005-05-03    MAT -128767.7   3644.3684
5  ABFS 2005-05-03    IND -135984.7   -335.9721
6  ABS. 2005-05-03    CNS -132659.4    733.2935
7   A.Z 2005-05-04    MAT -125123.3  -1457.7478
8  ABFS 2005-05-04    IND -136320.7  -1595.8684
9  ABS. 2005-05-04    CNS -131926.1  -2466.5317
```

- `name` column contains the name for each stock.
- `date` column contains the trading date. The column should be `Date` type.

- `sector` column contains the sector of each stock.
- `nmv` column contains NMV of each stock at the beginning of each trading day. Make sure all values are converted into the same currency.
- `pnl` column contains P&L of each stock. The P&L can be raw P&L or adjusted P&L after transaction fees. Make sure all values are converted into the same currency.

Now look at `commodity`:

```
Source: local data frame [5 x 11]

              name     id       date     sector portfolio   strategy  substrategy
             (chr)  (chr)     (date)      (chr)     (int)      (chr)        (chr)
1            brent     CO 2003-02-03     energy         1 Strategy 1 Strategy 1.1
2            brent     CO 2003-02-03     energy         6 Strategy 1 Strategy 1.2
3     cattle feeder   FC 2003-02-03   livestock         1 Strategy 3 Strategy 3.1
4        cbt wheat     W 2003-02-03 agriculture         1 Strategy 3 Strategy 3.2
5        cbt wheat     W 2003-02-07 agriculture         1 Strategy 3 Strategy 3.2
Variables not shown: gmv (dbl), nmv (dbl), pnl (dbl), contract (dbl)
```

Columns, such as `name`, `date`, `sector`, `nmv`, and `pnl`, have the same meaning as the ones in `equity`. `id` column contains ID information for different commodities. `contract` column contains the number of contracts of each commodity at the beginning of each trading day; this column is optional. `gmv` is the GMV at the start of each trading day; this column is also optional.

Notice that this data frame is more complex: `strategy` column contains different backtest strategies, and `portfolio` column shows different portfolios under each strategy. If there is a finer division of strategies, the data frame can also contain a `substrategy` column. `backtestGraphics` function will subset the input data frame according to different selections in dropdown menus. These columns are optional.

Finally, look at `credit`:

```
Source: local data frame [10 x 7]

              name       date          sector   strategy   gmv        nmv
             (chr)     (date)           (chr)      (chr) (dbl)      (dbl)
1    AA.Senior.5 2008-10-01 Basic Materials       daily 9e+06 259259.3
2    AA.Senior.5 2008-10-01 Basic Materials     monthly 9e+06 259259.3
3    AA.Senior.5 2008-10-01 Basic Materials   quarterly 9e+06 259259.3
4   ABY.Senior.5 2008-10-01 Basic Materials       daily 9e+06 259259.3
5   ABY.Senior.5 2008-10-01 Basic Materials     monthly 9e+06 259259.3
6   ABY.Senior.5 2008-10-01 Basic Materials   quarterly 9e+06 259259.3
7    AA.Senior.5 2008-10-02 Basic Materials       daily 9e+06 170731.7
8   ABY.Senior.5 2008-10-02 Basic Materials       daily 9e+06 170731.7
9    AA.Senior.5 2008-10-03 Basic Materials       daily 9e+06 170731.7
10  ABY.Senior.5 2008-10-03 Basic Materials       daily 9e+06 170731.7
Variables not shown: pnl (dbl)
```

Most of the columns are the same as those in `equity` and `commodity`. Notice that the `strategy` column here is used to denote backtest results for different trading frequencies. One important note is that users must provide all backtest observations for each instrument, even when the position on the instrument is held and unchanged. This is because `backtestGraphics` uses the time gap between each observation to determine the trading frequency and calculate annualized statistics.

## Use `backtestGraphics`

To use `backtestGraphics`, the user is required to pass in a data frame with information on date, ID/name, NMV and P&L. Optional information can also be passed into `backtestGraphics`, such as both instrument name and ID, sector, GMV, number of contracts, strategy, substrategy and portfolio number. We will explain in "Interface" section how to calculate summary statistics and generate plots.

The three data frames in the package have the same column names as the default of `backtestGraphics` function. To look at backtestGraphics interface for `commodity` data, type the following command, and click on the "Visualize" button. Shiny will generate the interface in Figure 1.

```
library(backtestGraphics)
backtestGraphics(x = commodity)
```
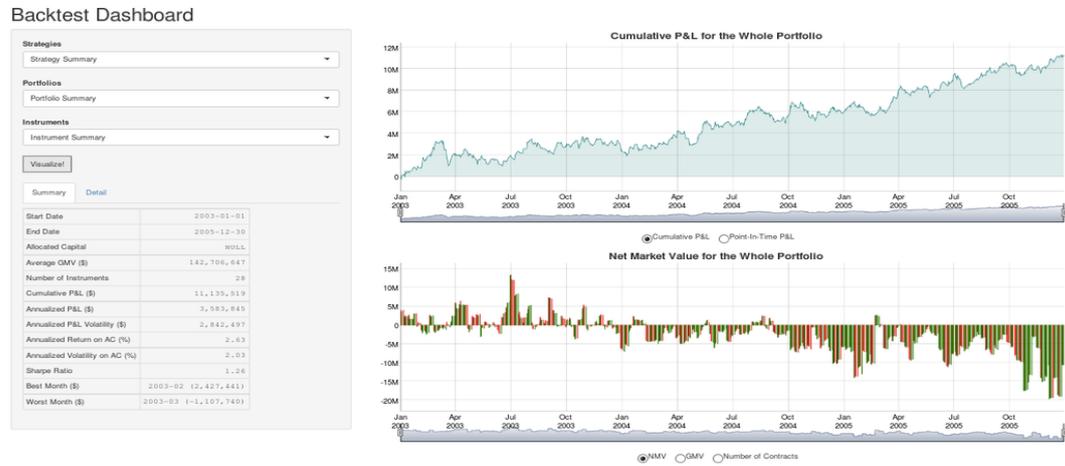


**Figure 1:** `backtestGraphics` interface. This interface contains three dropdown menus at the top-left. The user can click the "Visualize" button to look at summary statistics at the bottom left and interactive plots on the right. The user can also switch between graphs with radio buttons at the bottom of the plots.

## Dropdown Menu

The interface has three dropdown menus for strategies, portfolios and instruments. The user can look at backtest results for a combination of strategy, portfolio, and instrument. If the data frame does not have the strategy column or the portfolio column, the two dropdown menus will be fixed to "Strategy Summary" or "Portfolio Summary". If the user selects a combination that is not available in the data frame, the interface will give an error message and ask the user to select a new combination.

Figure 2 is a screenshot of the interface's dropdown menu.
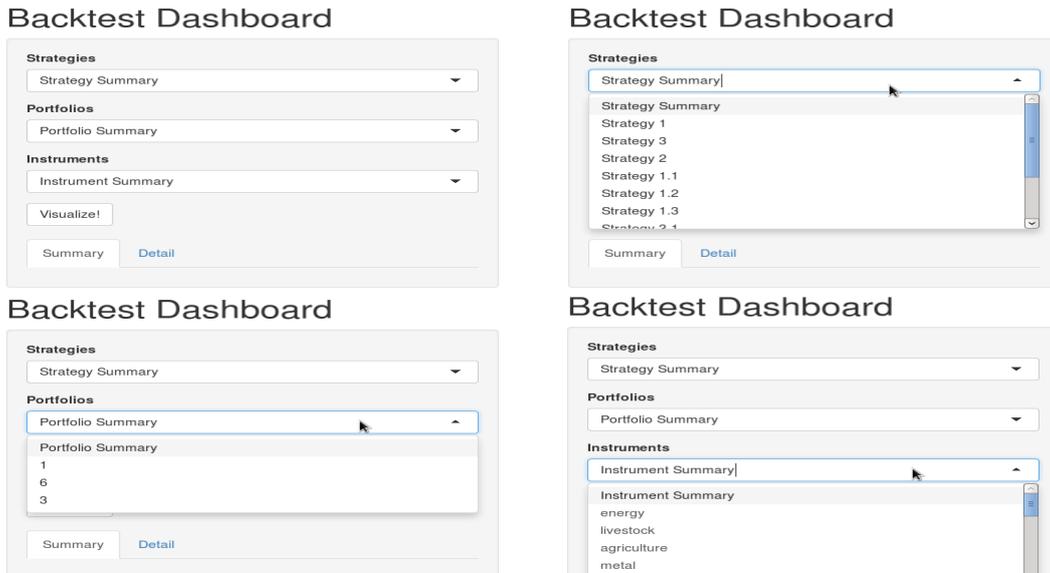
**Figure 2:** Dropdown menu. The user can look at backtest results for a combination of strategies, portfolios and instruments by selecting different choices in the dropdown menus. If the user selects a combination that is not available , the interface will give a clear error message and ask the user to select a new combination.

## "Summary" Tab and "Detail" Tab

The interface has two tabs on the left: "Summary" tab and "Detail" tab. "Summary" tab shows summary statistics of the user-specified data, while "Detail" tab gives comparison across different instruments and different time periods. This information is calculated from the input data frame every time the user changes her combination of strategy, portfolio and instrument. Note that if the user is looking at data for individual instruments or instrument summary, the best/worst three performers are always selected from the entire portfolio and should remain the same.

## "Summary" Tab

Figure 3 is a screenshot of the "Summary" tab.

| | |
|---|---|
| Start Date | 2003-01-01 |
| End Date | 2005-12-30 |
| Allocated Capital | NULL |
| Average GMV ($) | 142,706,647 |
| Number of Instruments | 28 |
| Cumulative P&L ($) | 11,135,519 |
| Annualized P&L ($) | 3,583,845 |
| Annualized P&L Volatility ($) | 2,842,497 |
| Annualized Return on AC (%) | 2.63 |
| Annualized Volatility on AC (%) | 2.03 |
| Sharpe Ratio | 1.26 |
| Best Month ($) | 2003-02 (2,427,441) |
| Worst Month ($) | 2003-03 (-1,107,740) |

**Figure 3:** "Summary" tab with commodity data. After the user clicks on the "Visualize" button, the function slices the data frame and calculates the summary statistics for the specific data subset. These are the main performance statistics.

- Start and End date : The backtest period.
- Allocated Capital : The amount of capital allocated to the portfolio. The function uses this number to calculate return on allocated capital. If the user does not specify allocated capital, this entry will be `NULL` and `backtestGraphics` will use biggest GMV to calculate return on allocated capital.
- Average GMV : Average of GMV over the backtest period. GMV is calculated by taking the absolute values of NMV of each instrument.
- Number of Instruments : The number of different instruments in the data frame or the user-specified subset of the data frame.
- Cumulative P&L : Sum of all P&L over the backtest period.
- Annualized P&L : Average P&L times an annualization factor. The function can observe the date gaps between observations and determine the trading frequency. The assumed annualization factor of daily trading is $\sqrt{252}$. For other trading frequency, the assumed annualization factor is $\sqrt{\frac{365}{date\ gap}}$.
- Annualized P&L volatility : The standard deviation of all annualized P&L's.
- Annualzied Return : Annualized average return on allocated capital. If the user specifies the allocated capital amount, the functon will divide P&L by the allocated capital to calculate average return rates. If not, the function will divide P&L by the biggest GMV in the data. The function then multiplies average return by the annualization factor.
- Sharpe Ratio : A measure of risk-adjusted return. The function divides the mean P&L by the standard deviation of P&L to calculate sharpe ratio. We assume risk-free rate $= 0$.
- Best Month and Worst Month : The month with the highest P&L and the month with the lowest P&L

**"Detail" Tab**

Figure 4 is a screenshot of the "Detail" tab.

**Top Three Drawdowns:**

| Start Date | End Date | P&L ($) |
|---|---|---|
| 2003-03-11 | 2003-06-18 | -2,306,913 |
| 2003-10-30 | 2004-01-09 | -1,770,827 |
| 2004-10-11 | 2004-11-15 | -1,732,102 |

**Three Best Performers:**

| Tickers | P&L ($) |
|---|---|
| JX: tcom kerosene | 2,780,786 |
| FC: cattle feeder | 1,730,847 |
| CL: wti | 1,285,581 |

**Three Worst Performers:**

| Tickers | P&L ($) |
|---|---|
| SB: sugar | -1,085,512 |
| QW: white sugar | -838,242 |
| LH: lean hogs | -579,077 |

**Figure 4:** Detail tab with commodity data. This tab contains information about the best and worst performers, as well as the biggest drawdowns.

- Top three drawdowns : The three biggest declines in P&L from peak to trough. The table contains the start and end dates of the drawdowns as well as the actual values of these drawdowns.
- Best and worst three performers : The best and worst three instruments with three highest and three lowest cumulative P&L's. If the user is looking at the subset of data about an individual instrument or instrument summary, the function will display the best and worst three performers across all instruments. If the user is looking at data about a specific sector, the function will instead display the best and worst three performers in the specified sector.

### Plots

The interface displays interactive plots for cumulative and point-in-time P&L, NMV, GMV and number of contracts. Radio buttons at the bottom allow the user to quickly switch between graphs. The cumulative P&L plot is a filled line chart, and all others are bar charts.

Figure 5 is a screenshot of the plots.

**Figure 5:** Plots with `commodity` data. The plot of P&L is at the top and the plot of market values is at the bottom. Green bars represent profit and red bars represent loss. The user can zoom in on the plots by either selecting the corresponding region with mouse or changing the time slider bar.

The plots are interactive using the **dygraphs** package [Vanderkam and Allaire (2015)]. The user can zoom in to look at any specific time period on the plots. She can either select and drag the corresponding region with mouse, or change the time slider bar beneath the plots. The user can go back to the initial scale by double clicking the plot. Color of the plots is based on the sign of point-in-time P&L. Green bars represent profit and red bars represent loss. If the cursor is hovering above a specific bar, the legends of the plot will give specific values of the date and the response variable of that bar. Note that the data is automatically rounded. For example, a P&L of "2,856,000" will be presented as "2.86M".

Compared to summary statistics, interactive plots are more intuitive because the user can directly visualize the performance of different instruments across adjustable time period. By decomposing the data frame into different sectors and instruments, the user can closely look at profitability of different strategies as well as that of different sectors at different time periods.

## Conclusion

The **backtestGraphics** package creates a simple interface to visualize backtest results of different financial instruments. `backtestGraphics` is the main function that wraps all the calculations and presents results in a graphical interface. The function requires some necessary columns: ID/name, date, P&L, NMV. The user can pass in optional columns to add complication, such as sector, strategy, substrategy, portfolio number, etc.

Inside the package, we provide three default data frames. The user can type the code provided above to test the package.

The interface efficiently displays information about backtest results. The user may look at either the summary statistics or the interactive plots. The user can use the dropdown menus to select different subsets of the backtest data frame. Such selection allows the user to carefully analyze the strengths and weaknesses of different trading strategies, and the interactive plots allow the user to further dive into the historical time period of the backtest.

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