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Kirkland, April 28th, 2022

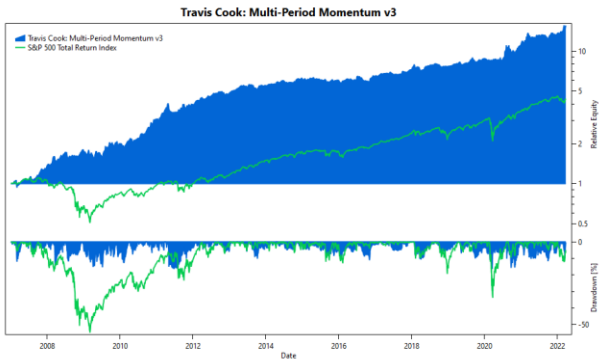
Hello Travis,

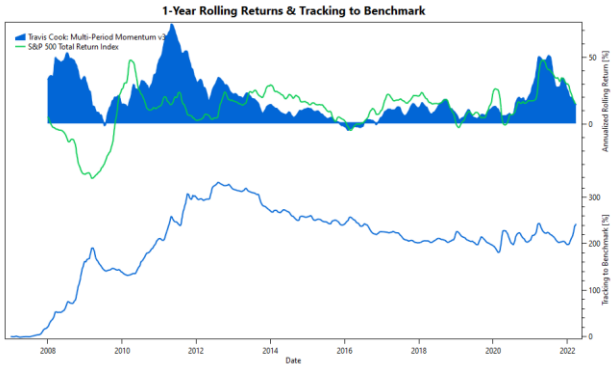
Please find our thoughts and observations regarding the implementation of the ETF-rotatation strategies.

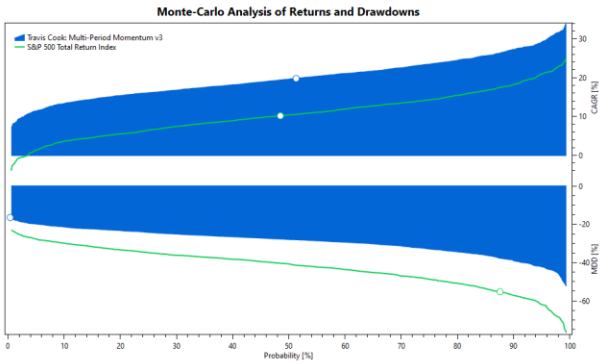
Thank you,
Best regards.

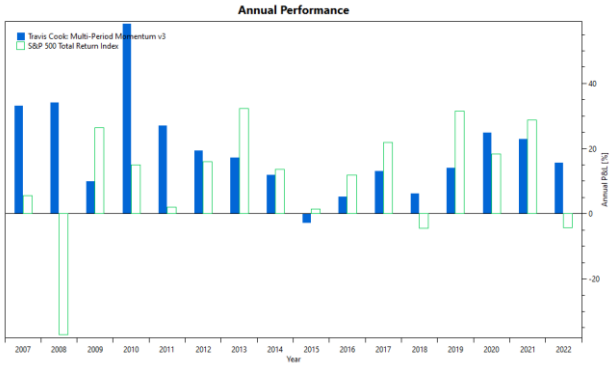
Felix Bertram

Recap









Metric		Travis Cook: Multi-Period Momentum v3	S&P 500 Total Return Index
Simulation Start	01/02/2007	$1,000.00	$1,000.00
Simulation End	03/25/2022	$15,621.95	$4,369.55
Simulation Period	15.2 years		
Compound Annual Growth Rate		19.79%	10.17%
Stdev of Returns (Monthly, Annualized)		15.10%	18.32%
Maximum Drawdown (Daily)		16.39%	55.25%
Maximum Flat Days		434.00 days	1637.00 days
Sharpe Ratio (Rf=T-Bill, Monthly, Annualizec		1.12	0.46
Beta (To Benchmark, Monthly)		0.19	- benchmark -
Ulcer Index		5.13%	13.84%
Ulcer Performance Index (Martin Ratio)		3.85	0.73

The strategy now handily outperforms the S&P 500 (in the long term) while at the same time substantially reducing risk. We notice fast reactions to market sell-offs, including 2018, 2020, and 2022. Also, we notice that the strategy had positive returns in very year but 2015. With these properties, periods of relative underperformance, e.g. between 2012 and 2018, are probably tolerable, as the strategy adds value nonetheless.

Porting to AmiBroker

Portfolio Backtests

AmiBroker's portfolio backtester is very simplistic. Our biggest complaint when implementing asset rotation strategies are:

- The asset's ranking score is only considered when opening positions, or when falling below a constant worst-rank-held threshold.
- The backtester does not offer a simple mechanism to rebalance all holdings to their nominal allocations.

To implement strategies with these features, a custom backtest procedure is required. While it is possible to implement virtually any strategy using this feature, it remains a kludge. Our main complaints are:

- The custom backtest procedure makes the strategy code hard to follow. This is because the custom backtest procedure follows a completely different programming paradigm, and part of its code directly contradicts the effect of statements in the 'classic' part of the code. As an example, the classic code might initiate a position, which is later filtered or adjusted by the custom backtest procedure.
- The custom backtest procedure makes the code brittle. This is because it forces duplication of functionality, e.g., determining an order's fill price, which may result in inconsistent treatment.
- AmiBroker does not offer a debugger. Given the complexity and error-proneness of the custom backtest procedure, this results in poorly tested code and potentially subpar code quality.

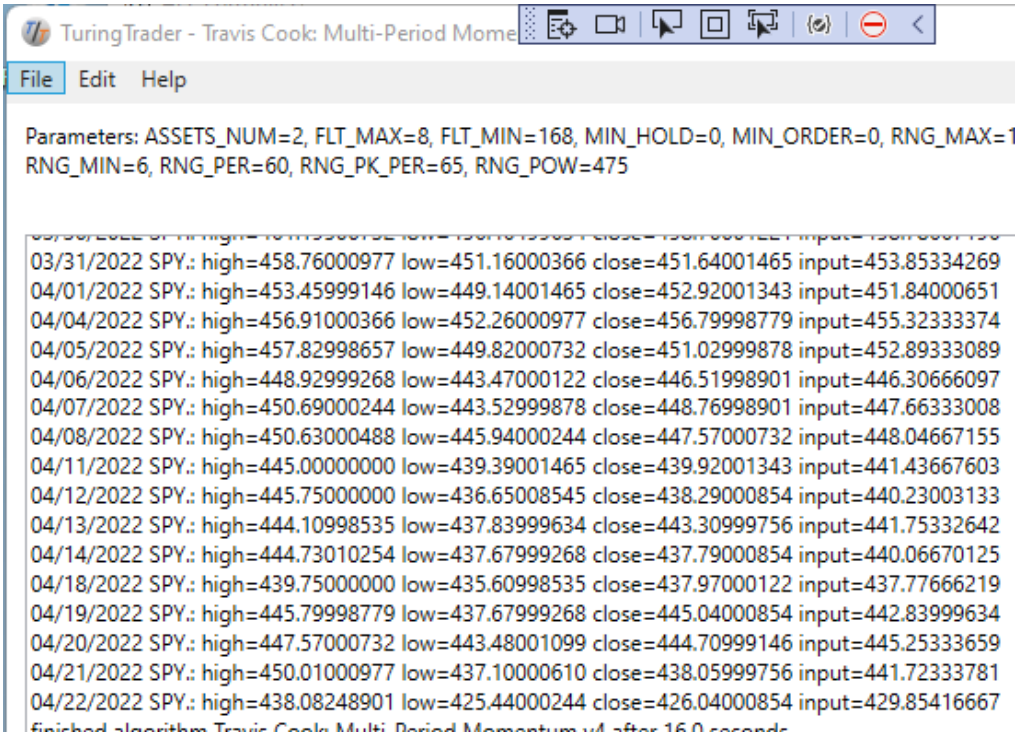
In our opinion, the custom backtest procedure is an after-thought to an engine that had reached the end of its lifecycle due to its overly simplistic approach. The features of the AmiBroker platform do not reflect the complexity and subtleties associated with the custom backtest procedure, and the requirements serious software development has.

In any case, we managed to get the procedure implemented and are reasonably confident that it works as intended. Most likely, we should revisit the Bond-Rotation strategy and upgrade it with the same procedure.

Floating Point Resolution

Porting a strategy to a new platform is never trivial. We can expect a number of little differences between platforms, and oftentimes these little differences add up in unexpected ways, leading to very different outcomes. After all, Chaos theory certainly applies to trading systems.

Initially, we ported the algorithm verbatim. However, we quickly noticed significant deviations in performance. We tracked these issues down to the precision of floating point calculations.


TuringTrader - Travis Cook: Multi-Period Mome
File
Edit
Help
Parameters: ASSETS_NUM=2, FLT_MAX=8, FLT_MIN=168, MIN_HOLD=0, MIN_ORDER=0, RNG_MAX=1
RNG_MIN=6, RNG_PER=60, RNG_PK_PER=65, RNG_POW=475
03/31/2022 SPY.: high=458.76000977 low=451.16000366 close=451.64001465 input=453.85334269
04/01/2022 SPY.: high=453.45999146 low=449.14001465 close=452.92001343 input=451.84000651
04/04/2022 SPY.: high=456.91000366 low=452.26000977 close=456.79998779 input=455.32333374
04/05/2022 SPY.: high=457.82998657 low=449.82000732 close=451.02999878 input=452.89333089
04/06/2022 SPY.: high=448.92999268 low=443.47000122 close=446.51998901 input=446.30666097
04/07/2022 SPY.: high=450.69000244 low=443.52999878 close=448.76998901 input=447.66333008
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04/12/2022 SPY.: high=445.75000000 low=436.65008545 close=438.29000854 input=440.23003133
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04/20/2022 SPY.: high=447.57000732 low=443.48001099 close=444.70999146 input=445.25333659
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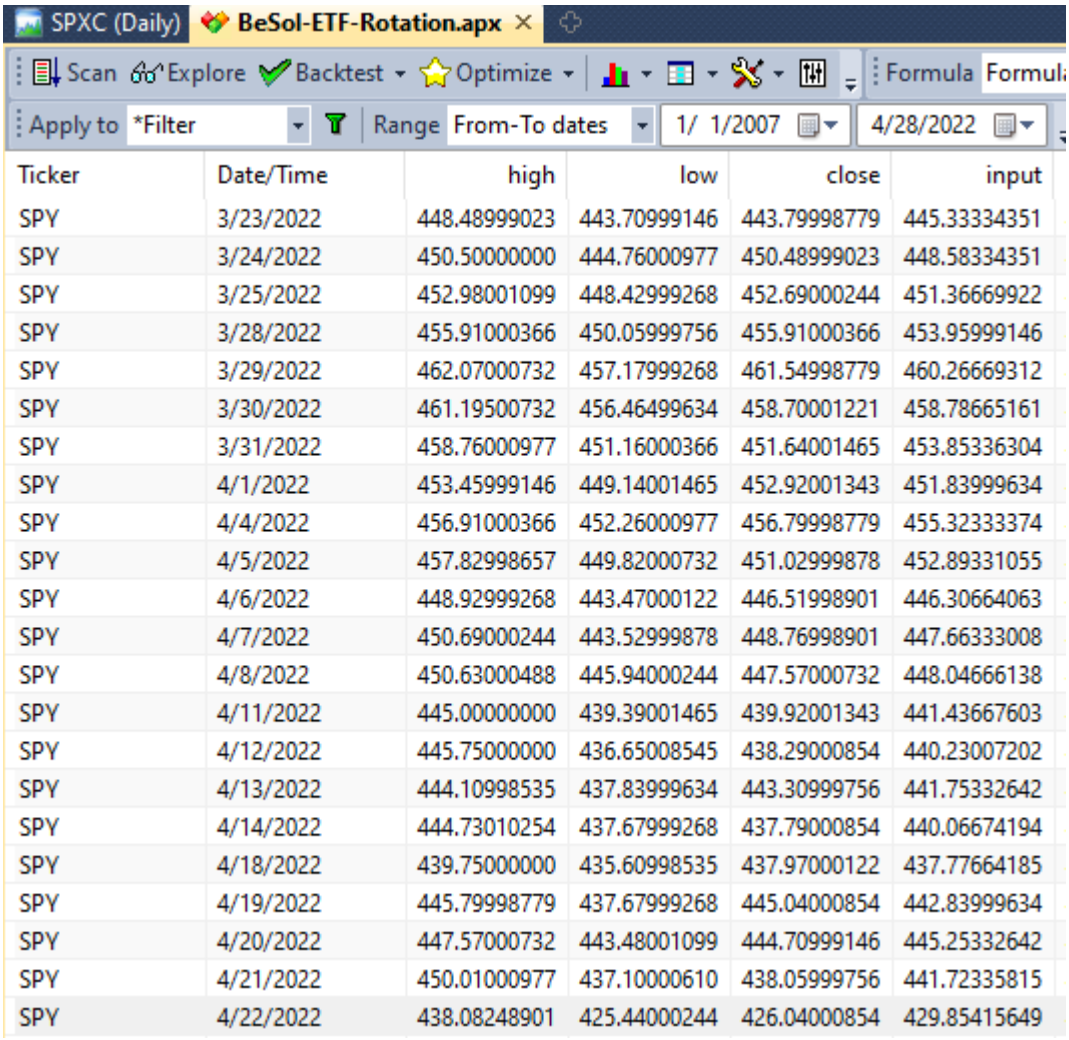
04/22/2022 SPY.: high=438.08248901 low=425.44000244 close=426.04000854 input=429.85416667



Ticker	Date/Time	high	low	close	input
SPY	3/23/2022	448.48999023	443.70999146	443.79998779	445.33334351
SPY	3/24/2022	450.50000000	444.76000977	450.48999023	448.58334351
SPY	3/25/2022	452.98001099	448.42999268	452.69000244	451.36669922
SPY	3/28/2022	455.91000366	450.05999756	455.91000366	453.95999146
SPY	3/29/2022	462.07000732	457.17999268	461.54998779	460.26669312
SPY	3/30/2022	461.19500732	456.46499634	458.70001221	458.78665161
SPY	3/31/2022	458.76000977	451.16000366	451.64001465	453.85336304
SPY	4/1/2022	453.45999146	449.14001465	452.92001343	451.83999634
SPY	4/4/2022	456.91000366	452.26000977	456.79998779	455.32333374
SPY	4/5/2022	457.82998657	449.82000732	451.02999878	452.89331055
SPY	4/6/2022	448.92999268	443.47000122	446.51998901	446.30664063
SPY	4/7/2022	450.69000244	443.52999878	448.76998901	447.66333008
SPY	4/8/2022	450.63000488	445.94000244	447.57000732	448.04666138
SPY	4/11/2022	445.00000000	439.39001465	439.92001343	441.43667603
SPY	4/12/2022	445.75000000	436.65008545	438.29000854	440.23007202
SPY	4/13/2022	444.10998535	437.83999634	443.30999756	441.75332642
SPY	4/14/2022	444.73010254	437.67999268	437.79000854	440.06674194
SPY	4/18/2022	439.75000000	435.60998535	437.97000122	437.77664185
SPY	4/19/2022	445.79998779	437.67999268	445.04000854	442.83999634
SPY	4/20/2022	447.57000732	443.48001099	444.70999146	445.25332642
SPY	4/21/2022	450.01000977	437.10000610	438.05999756	441.72335815
SPY	4/22/2022	438.08248901	425.44000244	426.04000854	429.85415649

The screenshots illustrate what's happening here. We can see that both platforms show the exact same data for the high, low, and closing prices of SPY, at least with 8 digits after the decimal point.

However, the calculation of the input variable, the typical price calculated as (H+L+C)/3, shows a loss of precision. As it seems, AmiBroker only preserves a precision of 4 digits after the decimal point while TuringTrader's precision is much higher.

Upon further investigation, we found that AmiBroker is only using single-precision floating point arithmetic, while TuringTrader is using double-precision. See AmiBroker Knowledge Base » About floating point arithmetic

What is troubling here is that these errors quickly add up. Single-precision arithmetic has about 7 significant digits. In order to calculate daily returns, we need to subtract quotes from each other. With SPY trading around 400, this subtraction will remove 3 digits of precision, leaving us with less than 4. Daily variations are on the order of 1%, requiring 2 digits – which illustrates how inadequate AmiBroker's arithmetic is for the problem we are trying to solve.

```
04/01/2022 SPY.: sc=0.01296592 r=-0.00015189 ema1=0.00023604 ema2=0.00028228 mom=0.00018980
04/04/2022 SPY.: sc=0.01297076 r=0.00035615 ema1=0.00023760 ema2=0.00028170 mom=0.00019349
04/05/2022 SPY.: sc=0.01297061 r=-0.00001070 ema1=0.00023438 ema2=0.00028109 mom=0.00018766
04/06/2022 SPY.: sc=0.01296927 r=-0.00009843 ema1=0.00023006 ema2=0.00028042 mom=0.00017969
04/07/2022 SPY.: sc=0.01296821 r=-0.00007815 ema1=0.00022606 ema2=0.00027972 mom=0.00017240
04/08/2022 SPY.: sc=0.01296576 r=-0.00018044 ema1=0.00022079 ema2=0.00027896 mom=0.00016263
04/11/2022 SPY.: sc=0.01293960 r=-0.00194695 ema1=0.00019274 ema2=0.00027784 mom=0.00010764
04/12/2022 SPY.: sc=0.01286742 r=-0.00557163 ema1=0.00011857 ema2=0.00027579 mom=-0.00003865
04/13/2022 SPY.: sc=0.01283269 r=-0.00279391 ema1=0.00008119 ema2=0.00027329 mom=-0.00011091
04/14/2022 SPY.: sc=0.01280232 r=-0.00250707 ema1=0.00004806 ema2=0.00027041 mom=-0.00017429
04/18/2022 SPY.: sc=0.01276794 r=-0.00291626 ema1=0.00001021 ema2=0.00026709 mom=-0.00024667
04/19/2022 SPY.: sc=0.01275968 r=-0.00071259 ema1=0.00000099 ema2=0.00026369 mom=-0.00026172
04/20/2022 SPY.: sc=0.01275927 r=-0.00003588 ema1=0.00000052 ema2=0.00026033 mom=-0.00025930
04/21/2022 SPY.: sc=0.01275639 r=-0.00025009 ema1=-0.00000268 ema2=0.00025698 mom=-0.00026234
04/22/2022 SPY.: sc=0.01270586 r=-0.00448968 ema1=-0.00005969 ema2=0.00025296 mom=-0.00037234
```

Ticker	Date/Time	sc	r	ema1	ema2	mom
SPY	3/23/2022	0.01259363	0.00250229	-0.00017551	0.00033276	-0.00068378
SPY	3/24/2022	0.01263987	0.00457799	-0.00011543	0.00032709	-0.00055794
SPY	3/25/2022	0.01270307	0.00593175	-0.00003861	0.00032245	-0.00039966
SPY	3/28/2022	0.01280119	0.00856346	0.00007151	0.00031924	-0.00017622
SPY	3/29/2022	0.01293255	0.01043636	0.00020555	0.00031777	0.00009334
SPY	3/30/2022	0.01299513	0.00462095	0.00026293	0.00031705	0.00020881
SPY	3/31/2022	0.01299844	0.00023899	0.00026262	0.00031635	0.00020890
SPY	4/1/2022	0.01299634	-0.00015188	0.00025723	0.00031558	0.00019889
SPY	4/4/2022	0.01300128	0.00035601	0.00025852	0.00031484	0.00020220
SPY	4/5/2022	0.01300113	-0.00001067	0.00025502	0.00031406	0.00019598
SPY	4/6/2022	0.01299976	-0.00009847	0.00025042	0.00031323	0.00018762
SPY	4/7/2022	0.01299868	-0.00007814	0.00024615	0.00031236	0.00017995
SPY	4/8/2022	0.01299618	-0.00018050	0.00024061	0.00031143	0.00016979
SPY	4/11/2022	0.01296944	-0.00194703	0.00021223	0.00031014	0.00011433
SPY	4/12/2022	0.01289568	-0.00557190	0.00013764	0.00030791	-0.00003263
SPY	4/13/2022	0.01286018	-0.00279411	0.00009994	0.00030524	-0.00010536
SPY	4/14/2022	0.01282914	-0.00250719	0.00006649	0.00030218	-0.00016919
SPY	4/18/2022	0.01279399	-0.00291641	0.00002833	0.00029867	-0.00024201
SPY	4/19/2022	0.01278555	-0.00071265	0.00001886	0.00029510	-0.00025738
SPY	4/20/2022	0.01278513	-0.00003588	0.00001816	0.00029156	-0.00025524
SPY	4/21/2022	0.01278218	-0.00025007	0.00001473	0.00028802	-0.00025856
SPY	4/22/2022	0.01273053	-0.00448977	-0.00004262	0.00028381	-0.00036904
SPY	4/25/2022	0.01265904	-0.00656628	-0.00012520	0.00027863	-0.00052903
SPY	4/26/2022	0.01258245	-0.00755330	-0.00021866	0.00027237	-0.00070970
SPY	4/27/2022	0.01251904	-0.00672865	-0.00030016	0.00026521	-0.00086553

At the core of our algorithm is a newly-designed low-pass filter, which dynamically adjusts its lookback period to the volatility of the asset. The two tables above compare the results between TuringTrader and AmiBroker. As it stands, AmiBroker's filter output deviates from TuringTrader by several percent. As these deviations are induced by lack of precision, we have to assume that they are random noise – the very variable we aim to eliminate with our new indicator.

Universe

The Strategy uses a fairly broad universe of ETFs. During development, we heavily relied on TuringTrader's featureset to backfill the quotes for some of these ETFs, most importantly XLC and XLRE. Because AmiBroker is missing these features, the backtest will miss these choices in early years, and substitute them with other assets. Consequently, the results of the strategy will always differ between the platforms.

Re-Optimization

To compensate at least partially for the issues outlined above, we re-optimized the strategy. As a result, many parameters slightly differ between the platforms. However, it is comforting to see that the newly optimized parameters are quite close to those used on the TuringTrader platform. Also, the characteristics of the strategy, most importantly the shape of the equity curve, its drawdowns, and tracking to benchmark are very similar. We interpret this as evidence that the methodology and the parameter set are sufficiently stable.

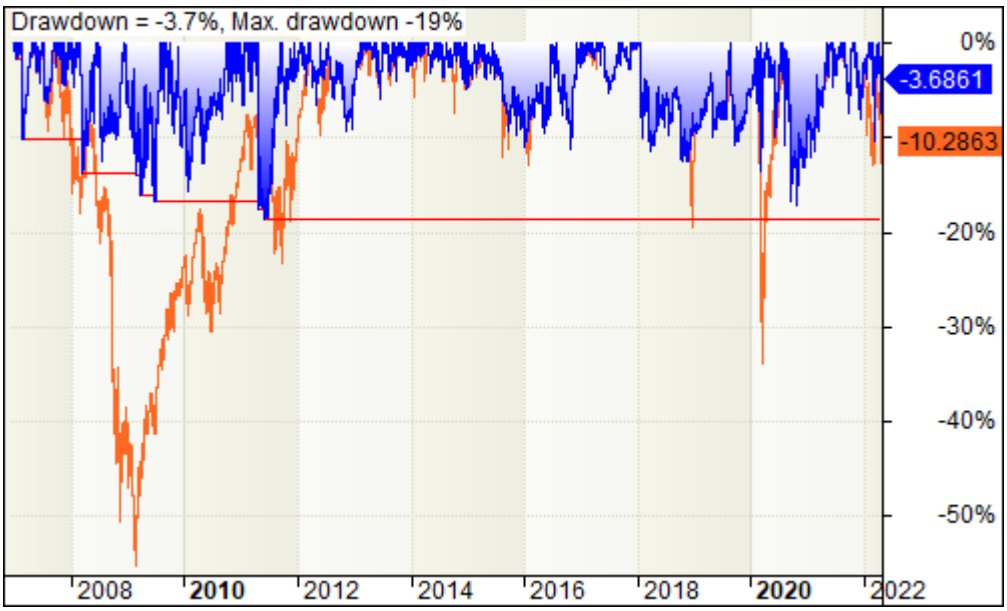
Results

Statistics

Statistics				
	All trades	**Long trades**	**Short trades**	**Buy&Hold ($SPXTR)**
Initial capital	10000.00	10000.00	10000.00	10000.00
Ending capital	106949.96	106949.96	10000.00	41317.49
Net Profit	96949.96	96949.96	0.00	31317.49
Net Profit %	969.50%	969.50%	0.00%	313.17%
Exposure %	99.46%	99.46%	0.00%	100.00%
Net Risk Adjusted Return %	974.76%	974.76%	N/A	313.17%
Annual Return %	16.72%	16.72%	0.00%	9.70%
Risk Adjusted Return %	16.81%	16.81%	N/A	9.70%
Total transaction costs	9.86	9.86	0.00	0.02
All trades	493	493 (100.00 %)	0 (0.00 %)	1
Avg. Profit/Loss	196.65	196.65	N/A	31317.49
Avg. Profit/Loss %	1.05%	1.05%	N/A	313.18%
Avg. Bars Held	16.65	16.65	N/A	3859.00
Winners	273 (55.38 %)	273 (55.38 %)	0 (0.00 %)	1 (100.00 %)
Total Profit	180591.98	180591.98	0.00	31317.49
Avg. Profit	661.51	661.51	N/A	31317.49
Avg. Profit %	3.28%	3.28%	N/A	313.18%
Avg. Bars Held	21.15	21.15	N/A	3859.00
Max. Consecutive	10	10	0	1
Largest win	13198.15	13198.15	0.00	31317.49
# bars in largest win	131	131	0	3859
Losers	220 (44.62 %)	220 (44.62 %)	0 (0.00 %)	0 (0.00 %)
Total Loss	-83642.02	-83642.02	0.00	0.00
Avg. Loss	-380.19	-380.19	N/A	N/A
Avg. Loss %	-1.72%	-1.72%	N/A	N/A
Avg. Bars Held	11.07	11.07	N/A	N/A
Max. Consecutive	8	8	0	0
Largest loss	-3812.23	-3812.23	0.00	0.00
# bars in largest loss	26	26	0	0
Max. trade drawdown	-11047.85	-11047.85	0.00	-10655.00
Max. trade % drawdown	-29.50	-29.50	0.00	-55.25
Max. system drawdown	-14834.52	-14834.52	0.00	-10655.00
Max. system % drawdown	-18.55%	-18.55%	0.00%	-55.25%
Recovery Factor	6.54	6.54	N/A	2.94
CAR/MaxDD	0.90	0.90	N/A	0.18
RAR/MaxDD	0.91	0.91	N/A	0.18
Profit Factor	2.16	2.16	N/A	N/A
Payoff Ratio	1.74	1.74	N/A	N/A
Standard Error	4873.41	4873.41	0.00	3903.20
Risk-Reward Ratio	1.05	1.05	N/A	0.53
Ulcer Index	5.97	5.97	0.00	13.83
Ulcer Performance Index	1.90	1.90	N/A	0.31

Equity Curve

Drawdown



Rolling Returns

Tracking to Benchmark

Profit & Loss

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr%
2007	1.9%	1.9%	-3.4%	5.8%	3.4%	-2.5%	1.5%	0.9%	7.4%	7.7%	-1.1%	6.4%	**33.4%**
2008	5.1%	9.8%	-7.0%	2.0%	4.8%	7.1%	-8.3%	1.2%	1.0%	-1.6%	6.5%	5.5%	**27.4%**
2009	-7.4%	-1.4%	-1.6%	4.3%	1.2%	-4.1%	6.3%	7.9%	0.7%	-5.9%	6.4%	-7.6%	**-2.9%**
2010	-3.2%	1.7%	5.4%	-1.3%	-1.0%	4.3%	-1.8%	3.9%	1.3%	6.5%	8.1%	8.7%	**37.0%**
2011	-2.5%	13.3%	6.6%	13.0%	-15.6%	-1.6%	4.3%	7.7%	9.1%	-3.0%	1.4%	2.6%	**36.6%**
2012	1.8%	2.8%	5.2%	-2.2%	2.5%	-0.8%	2.1%	-4.2%	2.3%	-2.4%	-2.6%	0.3%	**4.6%**
2013	5.8%	2.8%	4.0%	3.8%	-1.0%	-2.2%	4.2%	-1.6%	3.3%	5.9%	2.0%	2.3%	**32.8%**
2014	0.2%	1.7%	2.7%	4.7%	0.1%	1.7%	-1.5%	2.6%	-2.3%	4.3%	1.1%	1.6%	**18.0%**
2015	-1.2%	1.3%	1.2%	-2.2%	1.6%	-0.4%	0.5%	-4.2%	-2.0%	3.4%	-1.3%	-0.8%	**-4.3%**
2016	-2.2%	2.9%	1.5%	1.0%	-4.7%	5.9%	2.9%	-5.9%	1.0%	-4.3%	6.1%	2.0%	**5.5%**
2017	1.6%	3.4%	-0.5%	0.9%	3.6%	-3.1%	0.4%	2.4%	2.6%	0.9%	1.6%	2.2%	**17.2%**
2018	7.6%	-4.0%	-3.2%	-0.4%	2.8%	-1.7%	0.6%	3.4%	-1.6%	-5.4%	0.5%	2.8%	**0.8%**
2019	0.2%	1.4%	0.7%	2.4%	-3.3%	0.4%	-1.0%	10.2%	-7.3%	2.1%	1.6%	2.5%	**9.4%**
2020	0.7%	-0.1%	2.8%	0.8%	-1.2%	-3.0%	18.1%	10.9%	-13.4%	-2.9%	6.3%	1.6%	**18.9%**
2021	-1.7%	0.6%	5.5%	2.6%	2.0%	1.6%	1.4%	1.7%	-6.6%	9.7%	-1.7%	1.9%	**17.5%**
2022	2.4%	4.8%	4.9%	3.6%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**16.6%**
Avg	**0.6%**	**2.7%**	**1.5%**	**2.4%**	**-0.3%**	**0.1%**	**2.0%**	**2.4%**	**-0.3%**	**1.0%**	**2.3%**	**2.1%**	

With these results, we summarize the strategy as follows:

- In typical years, returns are slightly lower than the S&P 500, but outperforms a 60/40
- In prolonged recessions, the strategy wins over the S&P 500
- Drawdowns are significantly lower than the S&P 500
- The strategy performs well in fast-moving markets
- The strategy performs well in environments of rising yields

With these characteristics, the strategy might not meet the requirements of aggressive investors, but is certainly a good fit for a balanced investment approach.

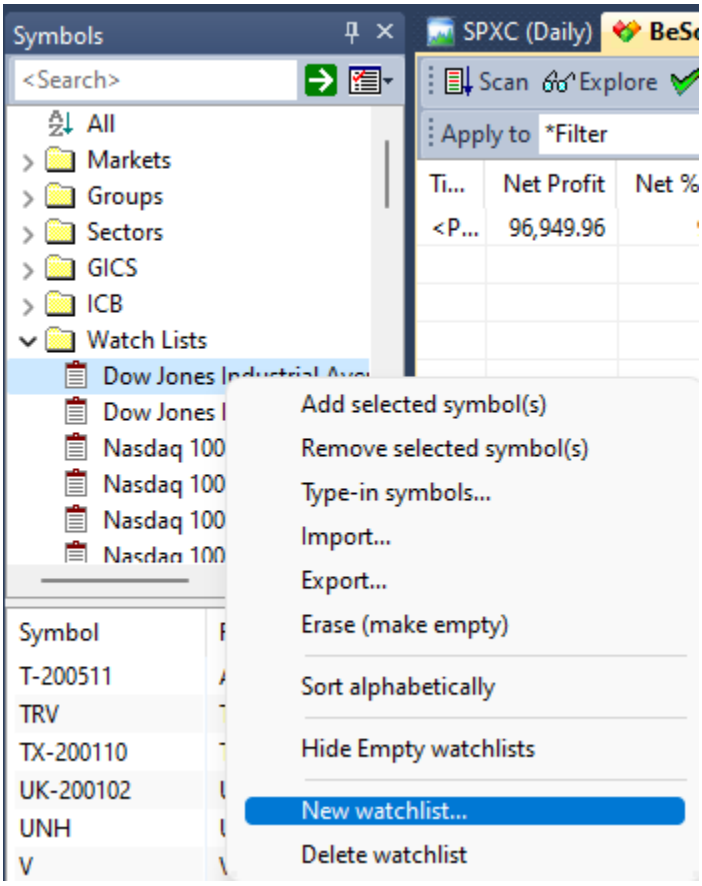
Some of the ETFs used in the universe are trading in relatively small volumes. In our opinion, trading volume of ETFs has much less significance than the trading volume of stocks. This difference stems from the continuous creation and redemption of ETF shares through the authorized participants. Because shares are created in creation units of typically 50k shares, we assume that the participants have enough shares in their inventory to satisfy orders, even if these exceed the daily traded volume.

Installation

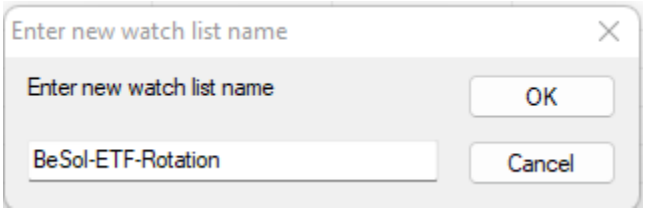
To install the strategy, perform the following steps:

Create Watchlist

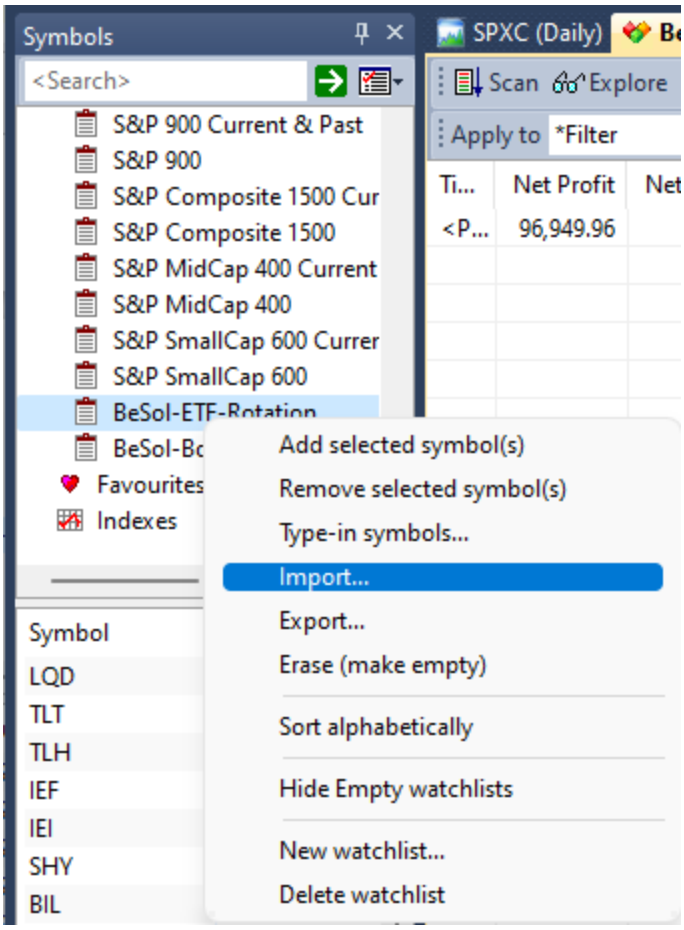
The strategy works on a pre-defined universe. The strategy code makes no explicit assumptions about this universe. Therefore, additions, removals or substitutions of assets can easily be made and do not require any code changes.



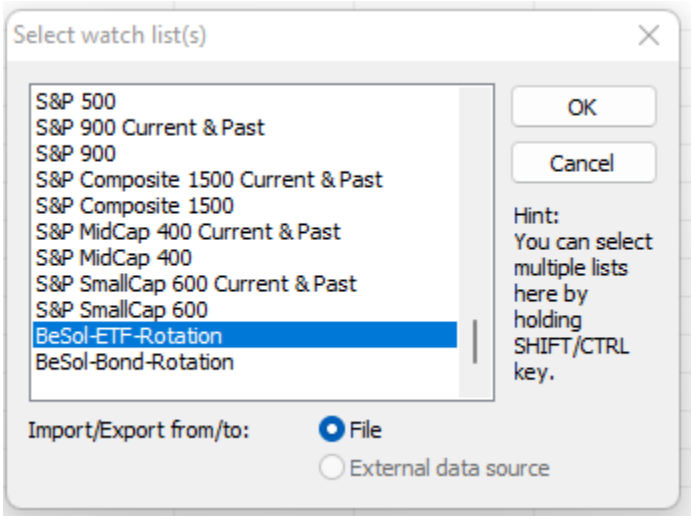
Right-click under *Watch Lists* and select *New watchlist*.



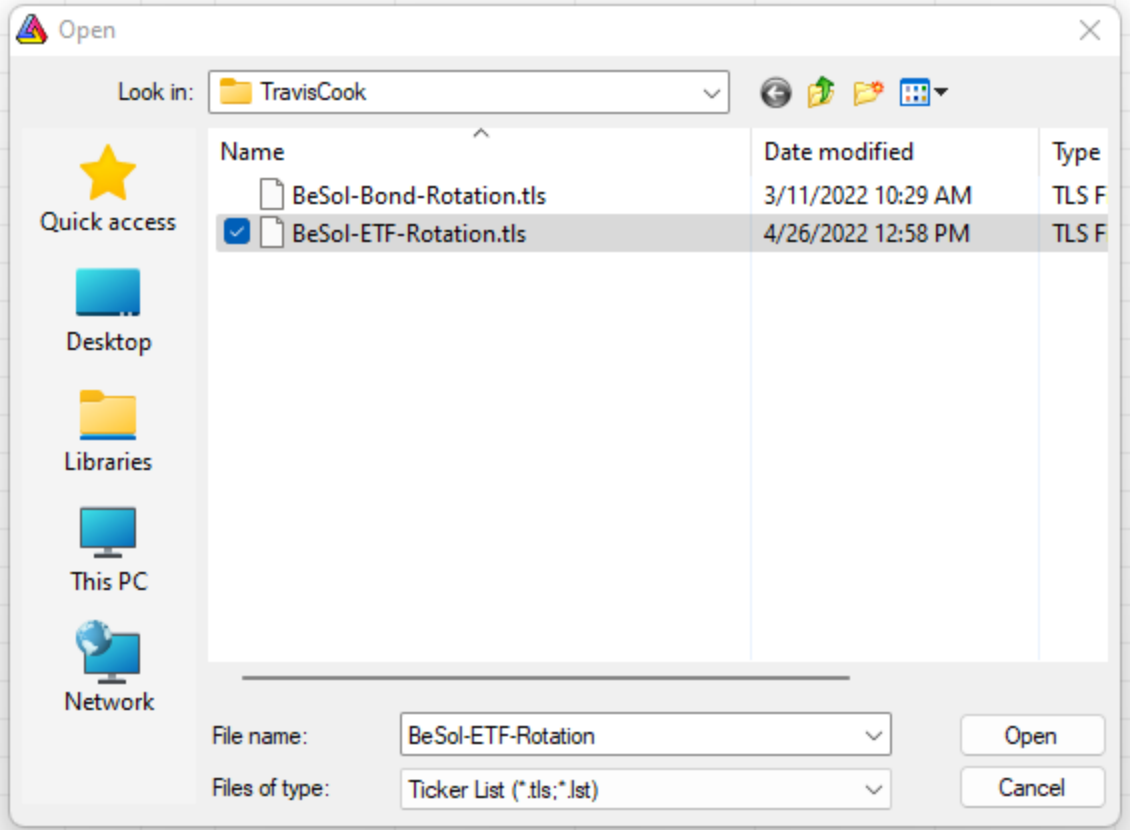
When prompted for the name of the new watch list enter *BeSol-ETF-Rotation*.



Find your newly created watchlist, right click and select *Import*.



When prompted to select the watch list, you should find *BeSol-ETF-Rotation* pre-selected. Click *OK* to confirm.



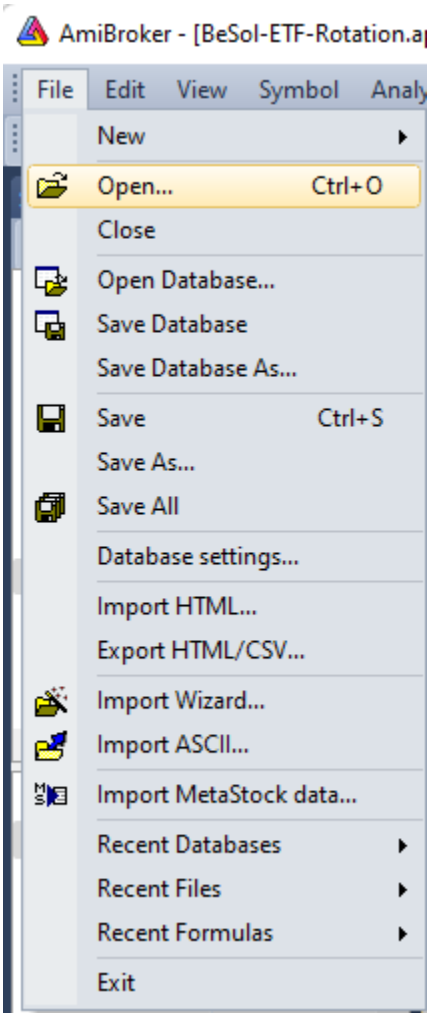
Navigate to the file *BeSol-ETF-Rotation.tls* which we provided and click *Open*.

Symbol	Full name
XLB	Materials Sele.
XLC	Communicati.
XLE	Energy Select .
XLF	Financial Selec
XLI	Industrial Sele.
XLK	Technology Se
XLP	Consumer Sta
XLRE	Real Estate Sel
XLU	Utilities Select
XLV	Health Care Se
XLY	Consumer Dis

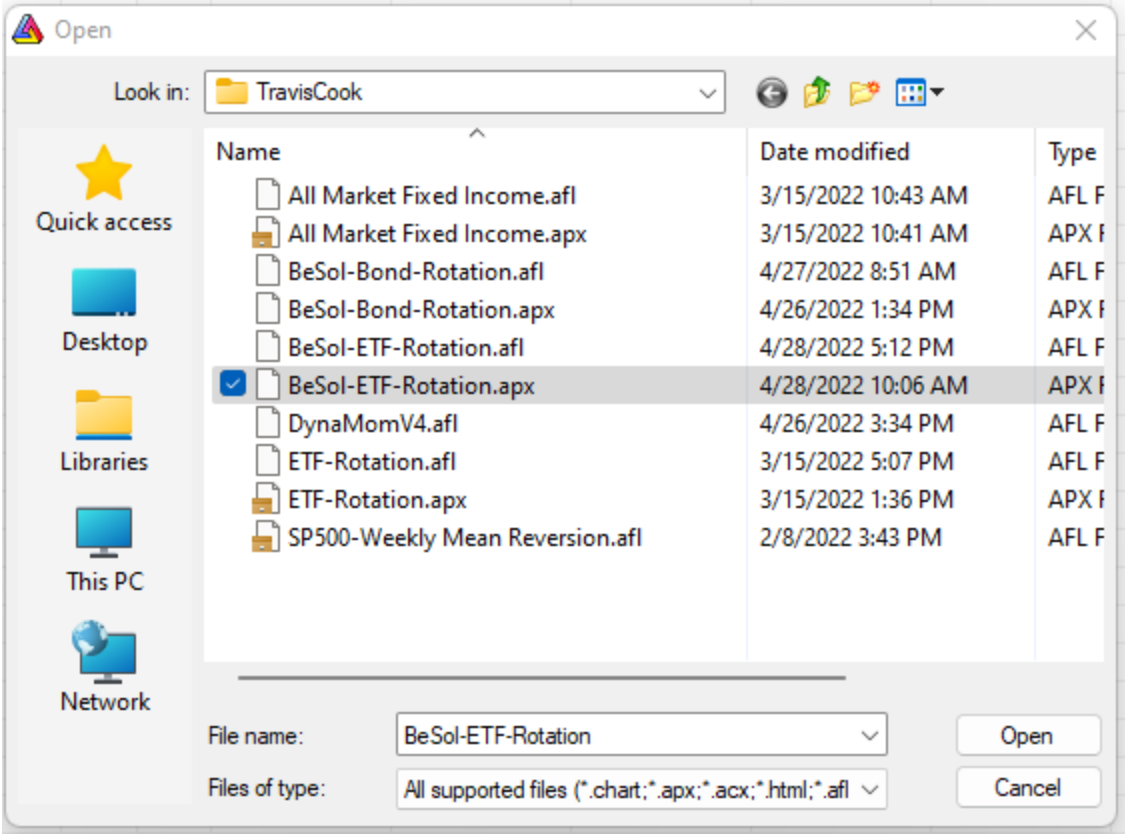
You should see the watchlist populated with the following symbols:

- Sectors: XLB, XLC, XLE, XLF, XLI, XLK, XLP, XLRE, XLU, XLV, XLY
- Factors: SPY, SPYG, SPYV, MDY, MDYG, MDYV, SLY, SLYG, SLYV
- Fixed Income: HYG, LQD, TLT, TLH, IEF, IEI, SHY, BIL
- Commodities: DBC, GLD, SLV

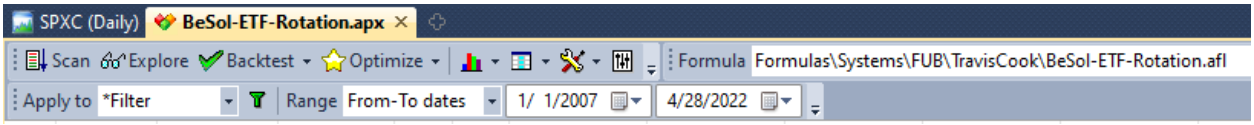
Import the strategy



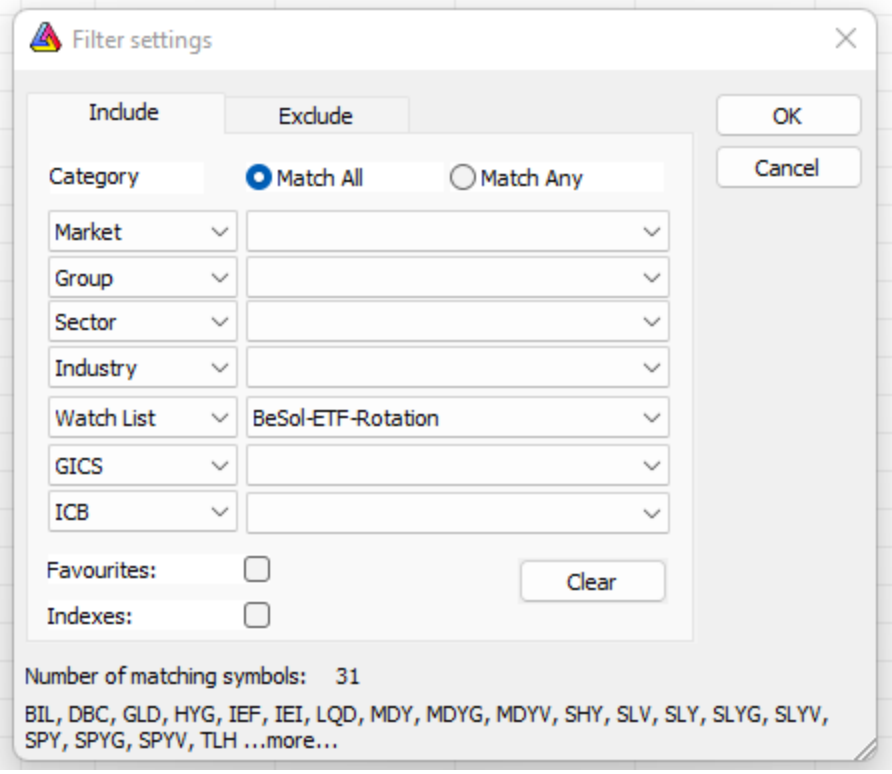
Open the *File* menu and click *Open*.



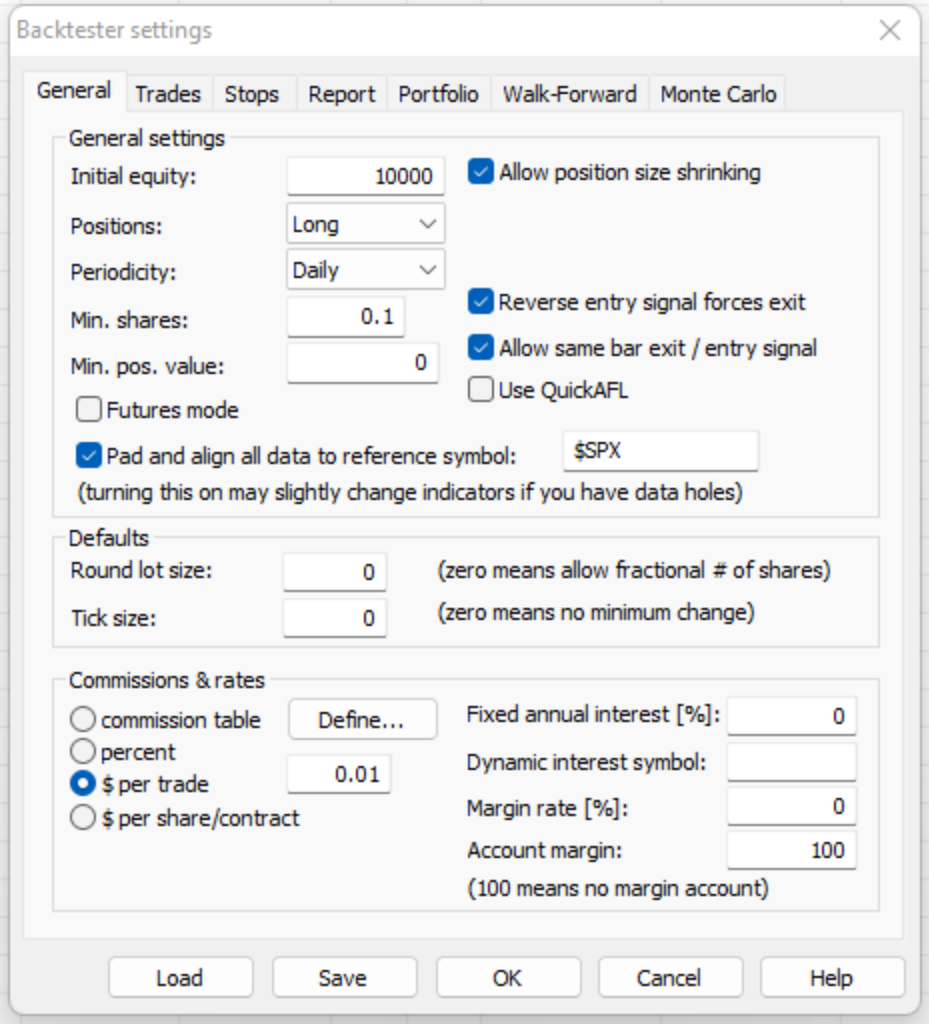
Select the file *BeSol-ETF-Rotation.apx*.



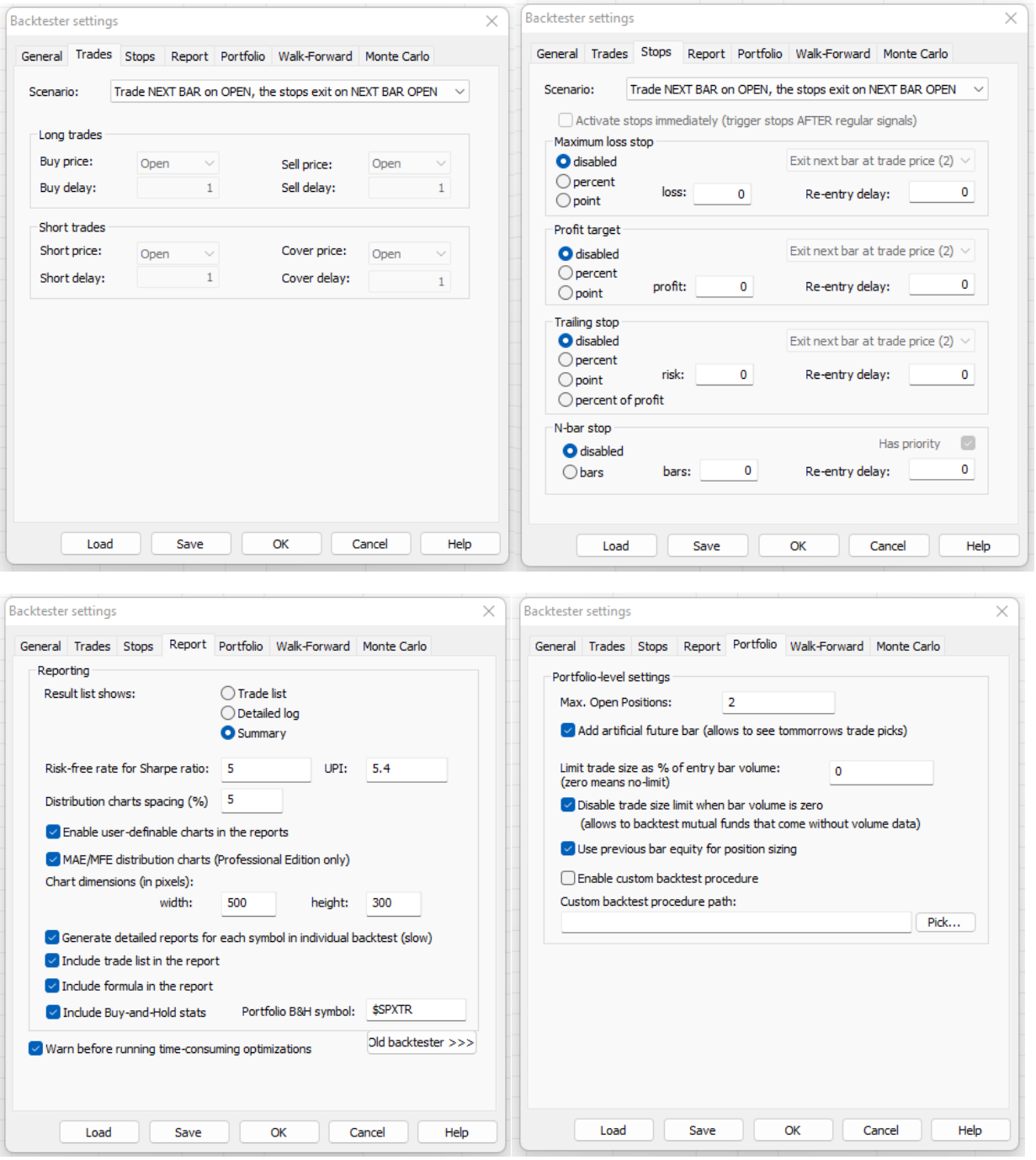
Confirm that the strategy is applied to a *Filter*, that the backtest range is *From-To dates*, and that the dates are set up as desired.



Confirm that the *BeSol-ETF-Rotation* watchlist is selected in the *Filter settings*.



Confirm the *Backtester settings*. Unlike our bond rotation, this strategy reads almost all of its parameters from the *Backtester settings* dialog. It is therefore crucial that these settings are correct.



You should now be able to run the strategy and see the same results we saw with our development environment.