Portfolio Rebalance with Tax Optimization

Sean Wiryadi - Advisors: Ali Hirsa, Miao Wang

Abstract

This study extends a dynamic portfolio rebalancing framework by incorporating real-world constraints including tax implications and rebalancing frequency controls. The system employs dollar-based portfolio tracking to enable accurate tax calculations under US tax netting rules, distinguishing between short-term and long-term capital gains. Key improvements include multi-parameter optimization, exponential frequency penalty systems, and tax calculations. Results demonstrate that incorporating tax considerations and rebalancing controls significantly impacts portfolio optimization decisions.

Methodology

Dynamic rebalancing system using Mean-Variance Optimization (MVO) as baseline with Explainability Index (EI=True) aggregation and Bollinger Band triggers (CVaR=False). Multi-parameter Nelder-Mead optimization determines optimal parameter combinations across rolling periods.

MVO Baseline: Calculate mean-variance optimal weights with transaction costs
Trigger Analysis: Explainability Index aggregates multiple performance signals
Decision Engine: Online learning algorithms with trigger-based rebalancing decisions
Optimization: Nelder-Mead algorithm optimizes six parameters simultaneously
Tax Calculation: Apply US tax rules to actual portfolio transactions

Parameter Optimization
Six-parameter simultaneous optimization: min_rank_change, trigger_delta_1, trigger_delta_2, ow_advice_cutoff, ow_reward, ow_momentum using Nelder-Mead algorithm with frequency penalty integration.

Enhanced Methods

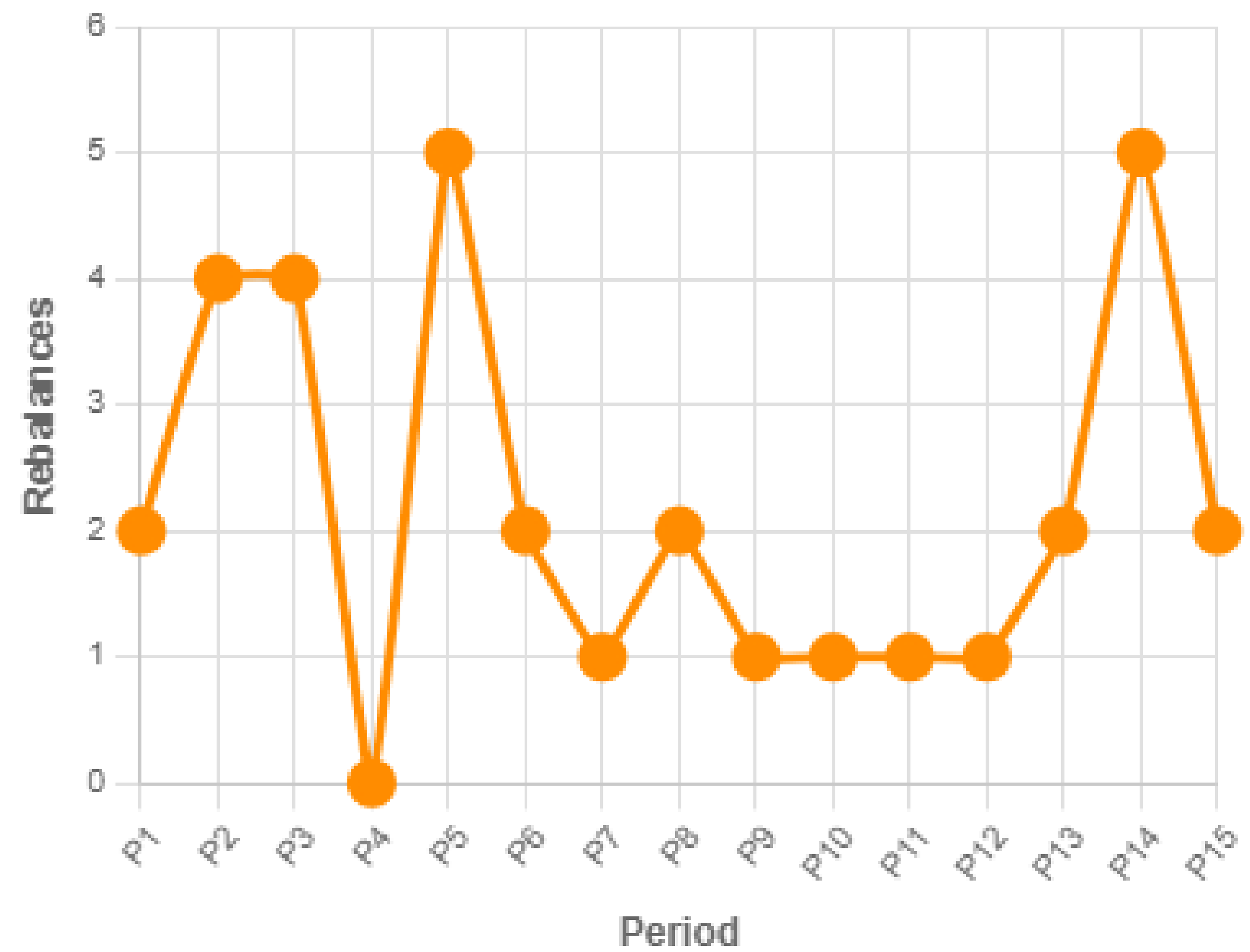
Dollar-Based Portfolio Tracking
Dollar-amount tracking alongside percentage weights for accurate tax calculations
Precise cost basis tracking and realistic gain/loss calculations based on actual transaction amounts

Non-Negative Portfolio Constraints
target_x = max(target_x, 0.0) followed by normalization
Ensures realistic long-only portfolios while maintaining optimal allocation properties

Frequency Penalty Integration
effective_reward = ow_reward × (1 - frequency_penalty)
where frequency_penalty = base_penalty × (penalty_multiplier)^excess_rebalances
Modifies trigger learning ability to discourage excessive trading

Tax Implementation
Short-term gains (≤365 days): 40% tax rate
Long-term gains (>365 days): 20% tax rate
Cost basis tracking with purchase date updates
$3,000 annual loss deduction
Taxable Gain = Amount Sold × ((Current Price - Cost Basis Price) / Cost Basis Price)

Period	Dynamic 3-Yr %	Dynamic Ann %	Static Ann %	Equal Wt Ann %	Rebalances
2005-2008	16.4	5.21	4.91	10.01	2
2006-2009	13.1	4.18	-2.39	-1.80	4
2007-2010	23.5	7.31	4.58	2.45	4
2008-2011	27.5	8.43	8.43	4.94	0
2009-2012	35.8	10.74	5.08	15.14	5
2010-2013	12.4	3.97	2.37	9.16	2
2011-2014	28.9	8.84	3.14	7.94	1
2012-2015	14.3	4.56	2.69	9.66	2
2013-2016	8.8	2.85	1.99	5.16	1
2014-2017	16.7	5.29	4.55	4.61	1
2015-2018	15.2	4.84	3.21	6.26	1
2016-2019	8.1	2.63	2.61	4.99	1
2017-2020	15.6	4.98	4.57	7.77	2
2018-2021	24.8	7.67	3.54	7.16	5
2019-2022	28.9	8.82	7.31	12.44	2



Parameter	Mean	Range
min_rank_change	8.92	7.12-10.75
trigger_delta_1	0.75	0.39-1.46
trigger_delta_2	-0.94	-1.89 to -2.44
ow_advice_cutoff	0.49	0.17-0.89
ow_reward	1.04	1.01-1.22
ow_momentum	0.55	0.24-0.84

Note: Initial attempts to optimize these parameters proved counterproductive as optimizer would set values to encourage rather than discourage rebalancing.

Results

Dynamic strategy's 6.09% annualized return vs 4.13% static represents a 47% improvement in performance.

87% outperformance rate of Dynamic against Static (13/15 periods) indicates systematic advantage rather than random variation

Crisis period (2008-2011) zero rebalancing suggests system correctly identified high volatility regime.

Recovery period maximum rebalancing (5x) indicates opportunistic behavior during favorable conditions.

Limitations

Tax Model Simplifications: The tax implementation uses simplified cost basis tracking where each asset's basis resets to the most recent purchase price. This approach, while providing realistic calculations based on actual market data, does not capture the complexity of partial position sales with multiple cost basis layers that occur in practice.

Portfolio Scale Constraints: The $10,000 initial portfolio size limits the practical impact of the $3,000 annual loss deduction, making this important tax benefit underutilized relative to real-world portfolios.

Rebalancing Penalty Optimization: The framework's rebalancing penalty mechanism produced negative rather than positive penalties in some periods, indicating implementation issues that may have reduced rather than controlled rebalancing frequency as intended. This suggests the penalty structure requires refinement to consistently discourage excessive trading.

Transaction Cost Omission: The framework does not incorporate transaction costs such as bid-ask spreads, commission fees, or market impact costs, which would reduce returns in practical implementation and potentially alter optimal rebalancing frequencies.

Future Works

Enhanced Tax Implementation: Implementing higher initial portfolio values ($100,000+) would better utilize the $3,000 loss deduction and provide more realistic tax optimization results. Advanced Optimization Techniques: Integration of genetic algorithms alongside Nelder-Mead could provide more robust parameter discovery.

Transaction Cost Integration: Incorporating realistic transaction costs including bid-ask spreads, commission fees, and market impact would provide more accurate performance assessment and potentially alter optimal rebalancing strategies.

Alternative Objectives: Integration of risk-adjusted performance metrics (Sharpe ratio, maximum drawdown, tail risk measures) could improve portfolio efficiency beyond simple return maximization while maintaining tax awareness.

Columbia Engineering