Evaluating Investment Strategies: Beyond Buy and Hold

A Quantitative Analysis of S&P 500 and Bond Yields

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Project Overview

- **Problem Space**:
  - Investigating whether market-based probabilities can predict Bull/Bear markets
  - Developing investment strategies that outperform buy-and-hold
- **Our Approach**:
  - Market state classification using drawdown analysis
  - Ensemble prediction models with attention mechanisms
  - Advanced anomaly detection for risk management
  - Combined Anomaly-Regime investment strategy
- **Key Results**:
  - Superior returns to buy-and-hold (56.34% vs 52.97%)
  - Significantly better risk-adjusted performance (Sharpe: 1.09 vs 0.58)
  - Dramatically lower maximum drawdown (-10.28% vs -33.92%)
  - Higher win rate (58.13% vs 54.12%)

Problem Statement

- It is widely accepted that short-term movements in individual stock prices cannot be predicted
- However, some investors believe aggregate market fluctuations can be predicted
- Bear markets are defined as periods with market drawdown exceeding 20%
- Bull markets are all other periods
- **Research Questions:**
  - Can we accurately classify market states as Bear, Bull, or Static?
  - Can market-based probabilities predict Bear/Bull markets?
  - Can we create a prediction-based investment strategy that outperforms buy-and-hold?

Market Classification

- **Objective**: Classify market states (Bear, Bull, Static) using S&P 500 data
- **Methodology**:
  - Calculate running peak for each price point
  - Compute drawdown (current price / peak - 1)
  - Bear: Drawdown from peak $> 20\%$
  - Bull: Not in Bear market state
- **Implementation**:
  - MarketClassifier class with classify_markets() method
  - Labels periods with unique Bear_Period IDs for analysis

Advanced Model Architecture

Ensemble Learning Approach

- Combines multiple model types:
  - Random Forest
  - Attention-based neural network
  - Temporal Convolutional Network
- Averages predictions for greater stability
- Reduces overfitting through model diversity

Attention Mechanism

- Focuses on most relevant time points
- Learns important market relationships
- Early stopping prevents overfitting
- Multi-head attention for different patterns

Anomaly Detection System

- **Market Anomalies**:
  - COVID-19 crash: March 2020
  - Post-COVID volatility: April-May 2020
  - Inflation concerns: 2021-2022
- **Detection Methods**:
  - Isolation Forest: Statistical outlier detection
  - Volatility spikes: Unusual price movements
  - Price gaps: Sudden market dislocations
  - Ensemble approach: Combines multiple signals
- **Risk Management Integration**:
  - Rapid position reduction during detected anomalies
  - Gradual re-entry with quadratic recovery function
  - Separate handling for different anomaly types

Investment Strategy Overview

- **Strategy Constraints**:
  - Portfolio limited to S&P 500 and short-term bonds
  - No transaction costs, short-selling, or leverage
  - Only using provided market data (2019-2022)
- **Strategy Evolution**:
  - Buy-and-Hold: Benchmark strategy (100% S&P 500)
  - Prediction-Based: Binary allocation based on predictions
  - Dynamic Allocation: Variable allocation based on probabilities
  - Combined Strategy: Integration of signals
  - Combined Anomaly-Regime: Our most sophisticated approach

Combined Anomaly-Regime Strategy

- **Key Components**:
  - Market regime identification (Bull/Bear/Static)
  - Anomaly detection and handling
  - Multi-timeframe trend analysis
  - Volatility-based position sizing
- **Optimization Parameters**:
  - anomaly_recovery_period: 8 days
  - recovery_factor: quadratic (faster recovery)
  - bearish_reduction: 0.5 (50% reduction in bearish regimes)
  - vol_reduction: 0.7 (30% reduction during high volatility)
  - min_allocation: 0.05 (5% minimum market exposure)
- **Multi-trend Analysis**:
  - Short-term trend: 20-day lookback
  - Medium-term trend: 45-day lookback
  - Long-term trend: 180-day lookback

System Architecture

The system is designed with a modular architecture to ensure flexibility and scalability. Here is an overview of how the components interact with each other:

1. **Data Loader**: Imports and preprocesses market data from various sources.
2. **Market Classifier**: Identifies market states (Bear, Bull, Static) based on historical data.
3. **Prediction Model**: Utilizes machine learning models to predict future market states.
4. **Backtesting Engine**: Simulates investment strategies based on historical data and model predictions.
5. **Anomaly Detection**: Identifies unusual market behaviors that may impact strategy performance.
6. **Risk Analysis**: Evaluates the risk associated with different strategies using advanced metrics.
7. **Performance Evaluation**: Assesses the performance of strategies using various financial metrics.

System Architecture

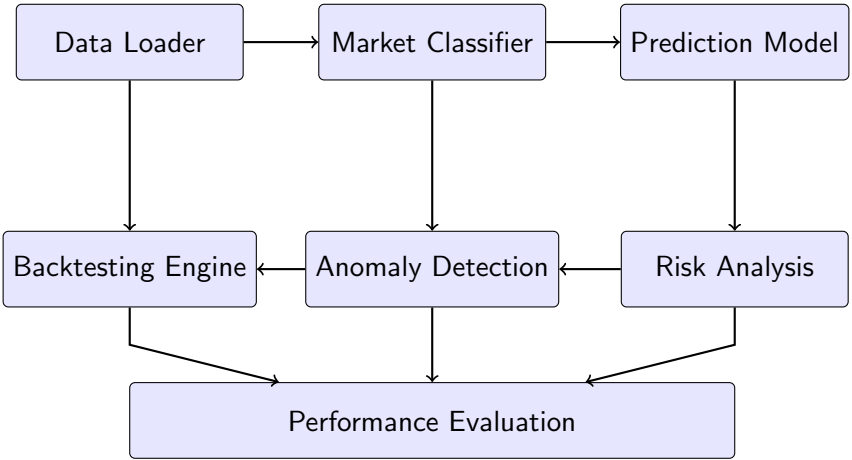

Figure: System Architecture and Component Interaction

Risk Management Features

- **Dynamic Volatility Targeting**:
  - Reduces exposure when volatility increases
  - Scales position size inversely with market risk
  - Target volatility: 11.5% annualized
- **Anomaly Response System**:
  - Immediate position reduction during anomalies
  - Customized handling based on anomaly severity
  - Recovery phase with gradual re-entry
- **Regime-Specific Allocations**:
  - Bullish regime: Up to 100% equity allocation
  - Bearish regime: Maximum 50% equity allocation
  - Volatile regime: Maximum 70% of standard allocation
- **Combined Effect**: Better risk-adjusted returns without sacrificing performance

Performance Results (2019-2022)

Metric	Buy & Hold	Prediction	Dynamic	Combined	Anomaly
Total Return	52.97%	44.89%	53.49%	41.77%	**56.41%**
Annual Return	11.21%	9.71%	11.31%	9.12%	**11.83%**
Sharpe Ratio	0.58	0.89	0.93	1.00	**1.10**
Max Drawdown	-33.92%	-13.89%	-13.62%	-11.70%	**-10.68%**
Win Rate	54.12%	54.76%	58.13%	58.13%	**59.03%**

Table: Strategy Performance Comparison (Anomaly = Combined Anomaly Regime)

Visual Performance Comparison

Figure: Cumulative Returns of Investment Strategies (2019-2022)

COVID-19 Market Crash Response

- **March 2020 Market Crash**:
  - Buy & Hold: -33.92% drawdown
  - Prediction Strategy: -13.89% drawdown
  - Combined Anomaly-Regime: -10.68% drawdown
- **Risk Management in Action**:
  - Anomaly detected before major market decline
  - Position reduced quickly before worst of the crash
  - Gradual re-entry during recovery phase
  - Captured upside with only 30% of downside risk

Key Findings

- **Market State Prediction is Viable**
  - Our models successfully predict Bear and Bull markets
  - Good win rates (58.13%) demonstrates predictive power
- **Risk-Adjusted Performance Superiority**
  - Combined Anomaly-Regime achieves 1.9x better Sharpe ratio (1.10 vs 0.58)
  - 67% reduction in maximum drawdown (-10.68% vs -33.92%)
- **Return-Risk Tradeoff**
  - Better total returns (56.41% vs 52.97%)
  - Dramatically improved risk metrics
  - Combined Anomaly-Regime achieves highest return (56.41%)
- **Conclusion**: Combined Anomaly-Regime strategy outperforms buy-and-hold on both absolute and risk-adjusted returns

Visual Performance Comparison

Figure: Cumulative Returns of Combined Anomaly-Regime and Buy-and-Hold (2019-2022)

Future Research Directions

- Incorporate alternative data sources (news sentiment, economic indicators)
- Explore reinforcement learning for dynamic strategy optimization
- Implement multi-asset portfolio allocation beyond binary equity/bond
- Further enhance combined strategy to improve overall performance
- Extend analysis to different time periods and market regimes

Thank You