

ROBUST MULTI-PERIOD PORTFOLIO OPTIMIZATION

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December 12th, 2023 | Optimization Methods

PROBLEM STATEMENT AND DATA

WE ARE USING YAHOO! FINANCE DATA SO SIMULATE A REALISTIC INVESTMENT SCENARIO



SETTING

- 1 Securities to choose from:**
Top 500 NASDAQ securities (by market capitalization)
- 2 Initial endowment:**
\$100,000 with the goal to increase it as high as possible
- 3 Investment horizon:**
One year (11/22 – 10/23) with daily trading opportunities

DATA

Dataset with daily prices and trading volumes for 7,000 stocks and 5,000 ETFs



Pre-processing:

- 1. Remove ETF** data (focus is on diversified stock portfolios)
- 2. Filter for** stocks with **at least 2 years of data**
- 3. Focus on top 500** stocks to lower solving times

APPROACH: BASELINE MODELS

WE USE A MODEL WITH PERFECT INFORMATION AND A NASDAQ INDEX FUND AS UPPER AND LOWER BASELINE



UPPER BASELINE

Variables

$x_{i,t}$: # of stock i bought in t
 $z_{i,t}$: # of stock i held in t
 c_t : cash held in t

Objective

Maximize
final portfolio value $\max_{c,x,z} \sum_{i=1}^n P_{i,T} z_{i,T} + c_T$

Constraints



Transaction logic
(incl. no short selling)

$$z_{i,t} = z_{i,t-1} + x_{i,t} \quad \forall i, t$$
$$z_{i,t-1} + x_{i,t} \geq 0 \quad \forall i, t$$



Cash management
(incl. transaction cost)

$$c_t = c_{t-1} - \sum_{i=1}^n P_{i,t} x_{i,t} - \alpha \sum_{i=1}^n P_{i,t} |x_{i,t}| \quad \forall t$$



Other: portfolio diversification, limit to transaction amount, no leveraged transactions, respect initial endowment

LOWER BASELINE



NASDAQ index fund:

- A fund which imitates the composition of the NASDAQ index
- Investors will generate the average return of all NASDAQ securities

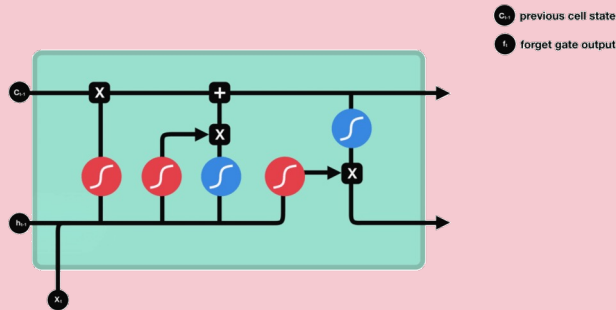
APPROACH: MAIN MODEL

THE MAIN MODEL DIFFERS IN THREE ASPECTS: STOCK PRICES, INVESTOR RISK APPETITE, ROBUSTNESS



1

Stock Prices: Predictions from ML Model



- **LSTM** model provides **predictions** for stock prices
- Introduces distortion and reflects **real-life scenario**

2

Risk Appetite: Modeled by Portfolio Variance

$$\frac{\sum_{i=1}^n \sum_{j=1}^n z_{i,t} \Sigma_{i,j,s} z_{i,t}}{\sum_{i=1}^n z_{i,t} P_{i,t,s}} \leq \sigma^2 \quad \forall t, s$$

- Portfolio **variance relative to the total portfolio value** is **capped** by parameter σ^2
- Represents **risk appetite**
- σ^2 is derived from upper baseline model result

3

Robustness: Included by different scenarios

$$P_{i,t} \rightarrow P_{i,t,s} \quad \text{and} \quad \forall s \in [S]$$

- **Robustness** is applied on stock **price predictions**
- We used modeled different scenarios using an uncertainty set based on the Central Limit Theorem

RESULTS

THE ROBUST MODEL ACHIEVES SIX TIMES THE FINAL PORTFOLIO VALUE OF THE LOWER BASELINE



FINAL PORTFOLIO VALUES

\$2.8m

Upper Baseline Model
Final Portfolio Value

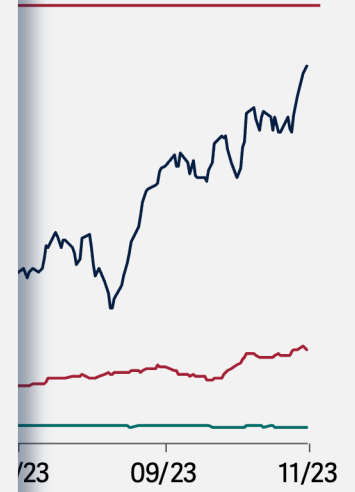
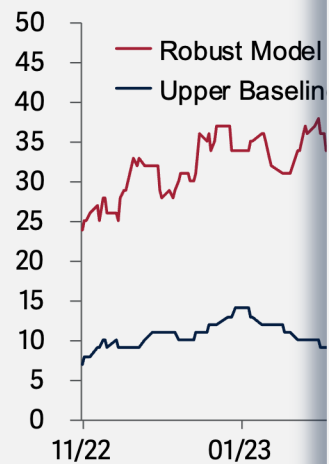
\$730k

Robust Model
Final Portfolio Value

\$120k

Lower Baseline Model
Final Portfolio Value

DIVERSIFICATION



RESULTS

THE ROBUST MODEL ACHIEVES SIX TIMES THE FINAL PORTFOLIO VALUE OF THE LOWER BASELINE



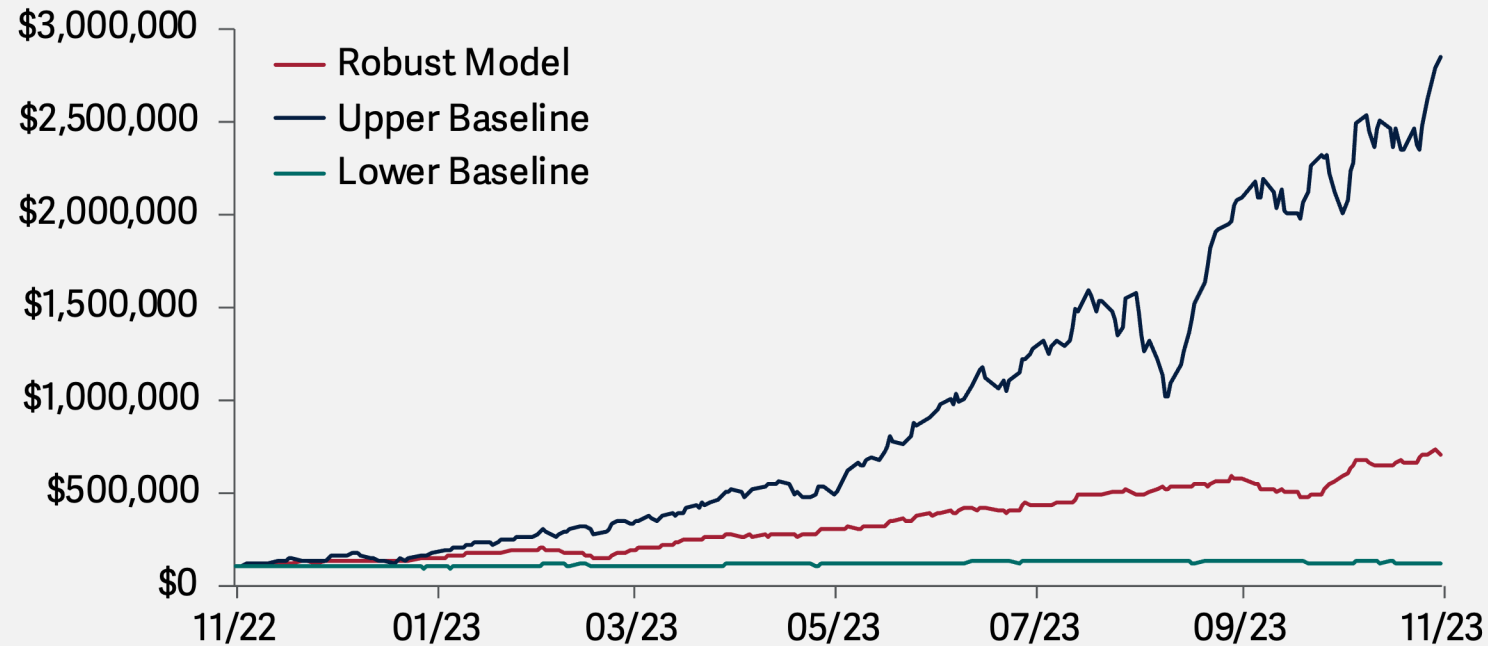
FINAL PORTFOLIO

\$2.8m

\$730k

\$120k

TOTAL PORTFOLIO VALUE OVER TIME



TITLES HELD)

09/23 11/23

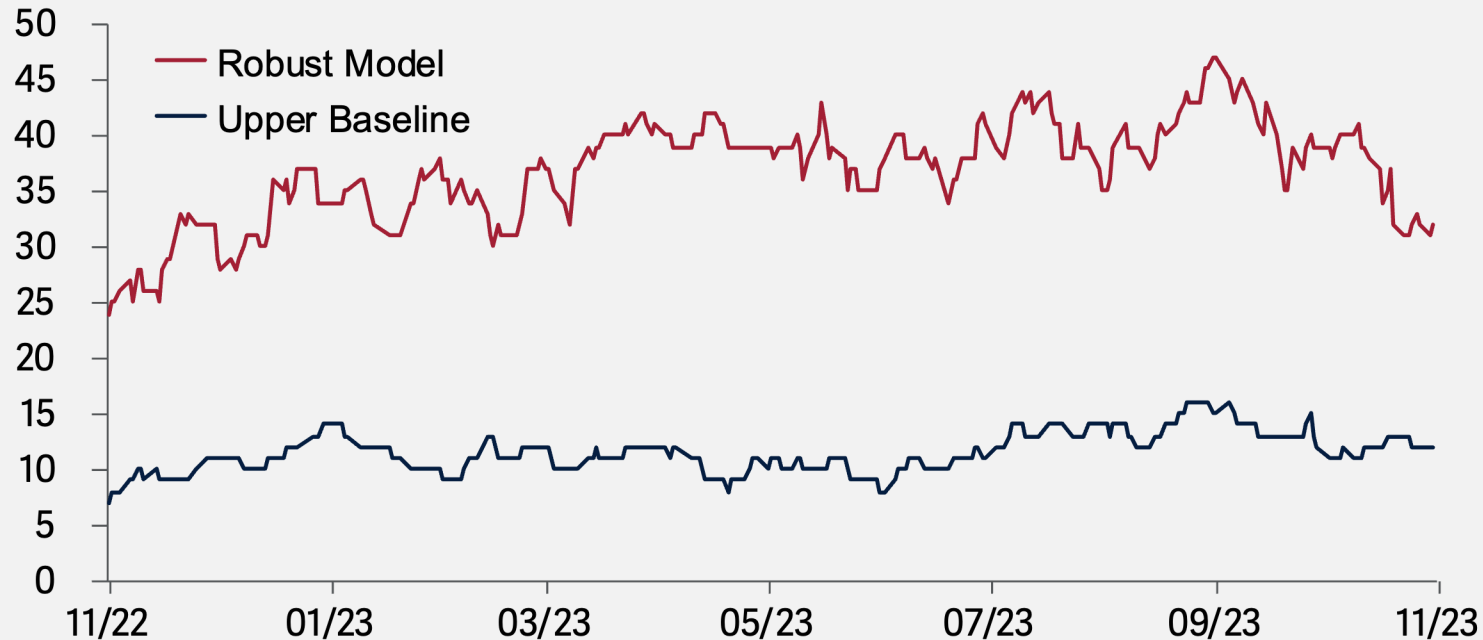
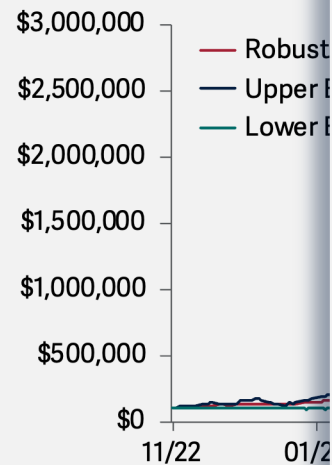
RESULTS

THE ROBUST MODEL ACHIEVES SIX TIMES THE FINAL PORTFOLIO VALUE OF THE LOWER BASELINE



DIVERSIFICATION OVER TIME (NO. OF TITLES HELD)

TOTAL PORTFOLIO



The background of the slide is a blurred financial chart, likely a candlestick chart, with various colored lines (red, green, blue, yellow) and a grid. The chart is tilted and has a soft, out-of-focus appearance.

THANK YOU!

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