# AIM 08 Performance measurement

AIM 08.2 Single-factor risk-adjusted performance

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## Risk-adjusted performance

- Context:
  - Risk-adjusted performance evaluation is critical in investment management.
    - Can active portfolio managers outperform benchmarks after accounting for risk and management fees?

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# Risk-adjusted performance

- Purpose:
  - Discuss four traditional portfolio performance measures are based on CAPM.
    - Two are based on CML.
      - Sharpe ratio
      - M-squared
    - Two are based on SML.
      - Treynor ratio
      - Jensen's alpha

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# Risk-adjusted performance

- Purpose:
  - Discuss two other measures are ad hoc, albeit intuitive.
    - One is based on excess return regression.
      - Treynor/Black appraisal ratio
    - One is based on ad hoc measure of risk.
      - Sortino ratio
  - Introduce concept called portable alpha.
    - Direct by-product of Jensen's alpha.

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## CAPM assumptions

- Markowitz (*JF* 1952) assumed *n* risky assets.
- Tobin (*REST* 1958) showed link between diminishing positive marginal utility of wealth and risk averse indifference curves.
- Sharpe (*JF* 1964) added risk-free cash equivalents to set of securities in capital market.
  - Assumed individuals can borrow or lend at risk-free interest rate, *r*.

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## CAPM results/predictions

- CAPM has three main results.
  - 1. Capital market line (*)

$$E_P = r + \left(E_M - r\right)\left(\frac{\sigma_P}{\sigma_M}\right)$$

  - 2. Composition of market portfolio

$$X_i = V_i / V_M$$

  - 3. Security market line (*)

$$E_i = r + \left(E_M - r\right)\beta_i$$

(*) denotes two CAPM results that are foundation of traditional performance measures.

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# Total risk measures

- Two measures are based on total risk (CML).

| | Expectations | Realizations |
|---|---|---|
| *Sharpe ratio* | $E(SR) \equiv \frac{E_S - r}{\sigma_S} = \frac{E_M - r}{\sigma_M}$ | $SR \equiv \frac{\bar{R}_S - \bar{R}_F}{\hat{\sigma}_S} = \frac{\bar{R}_M - \bar{R}_F}{\hat{\sigma}_M}$ |
| *M – squared* | $E(M^2) \equiv E_S - r - \left(\frac{E_M - r}{\sigma_M}\right)\sigma_S = 0$ | $M^2 \equiv \bar{R}_S - \bar{R}_F - \left(\frac{\bar{R}_M - \bar{R}_F}{\hat{\sigma}_M}\right)\hat{\sigma}_S$ |

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# Systematic risk measures

- Two measures are based on beta (SML).

| | Expectations | Realizations |
|---|---|---|
| *Treynor ratio* | $E(TR) \equiv \frac{E_S - r}{\beta_S} = E_M - r$ | $TR \equiv \frac{\bar{R}_S - \bar{R}_F}{\hat{\beta}_S} = \bar{R}_M - \bar{R}_F$ |
| *Jensen's alpha* | $E(\alpha) \equiv E_S - r - (E_M - r)\beta_S = 0$ | $\hat{\alpha} \equiv \bar{R}_S - \bar{R}_F - (\bar{R}_M - \bar{R}_F)\hat{\beta}_S$ |

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# Appraisal ratio

- Measures risk-adjusted reward from active management.
  - Jensen's alpha divided by residual risk (i.e., standard error of regression estimate).

$$AR = \frac{\hat{\alpha}}{\hat{\sigma}_{\varepsilon}}$$

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# Sortino ratio

- Measures Sharpe ratio using down-side risk.
  - CAPM assumes individuals are equally unhappy about large positive returns as large negative returns.
  - Some argue that only latter matters.
  - Define risk as:

$$\sigma_{S,semi-deviation} = \sqrt{\frac{\sum_{t=1}^{T} \min\left(R_{S,t} - R_{F,t}, 0\right)^2}{T}}$$

$$\text{Sortino ratio} = \frac{\bar{R}_S - \bar{R}_F}{\hat{\sigma}_{S,semi-deviation}}$$

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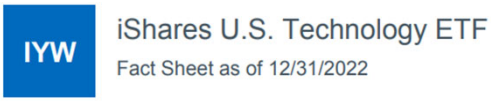
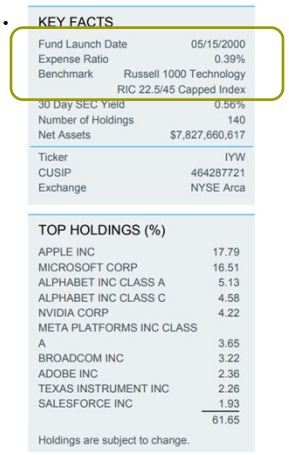
# Illustration

- Asked to evaluate risk-adjusted performance of iShares US Technology ETF (IYW).
  - Support file: IYW fact sheet.pdf



KEY FACTS

| | |
|---|---|
| Fund Launch Date | 05/15/2000 |
| Expense Ratio | 0.39% |
| Benchmark | Russell 1000 Technology RIC 22.5/45 Capped Index |
| 30 Day SEC Yield | 0.56% |
| Number of Holdings | 140 |
| Net Assets | $7,827,660,617 |
| Ticker | IYW |
| CUSIP | 464287721 |
| Exchange | NYSE Arca |

TOP HOLDINGS (%)

| | |
|---|---|
| APPLE INC | 17.79 |
| MICROSOFT CORP | 16.51 |
| ALPHABET INC CLASS A | 5.13 |
| ALPHABET INC CLASS C | 4.58 |
| NVIDIA CORP | 4.22 |
| META PLATFORMS INC CLASS A | 3.65 |
| BROADCOM INC | 3.22 |
| ADOBE INC | 2.36 |
| TEXAS INSTRUMENT INC | 2.26 |
| SALESFORCE INC | 1.93 |
| | 61.65 |

Holdings are subject to change.

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# Data

- Download 3 years of daily total return index data from Bloomberg.
  - Eliminated non-US trading days.
  - Support file: IYW analysis.xlsx
    - IYW: iShares Technology ETF
    - VOO: Vanguard S&P 500 ETF
    - SPX: S&P 500 index
    - VTI: Vanguard Total Stock Market ETF
    - CRSPTMT: CRSP Total market index

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# Analysis

- Compute summary statistics.

| Return summary statistics | | | | | | |
|---|---|---|---|---|---|---|
| Description | IYW | VOO | SPX | VTI | CRSPTMT | EFFR |
| *n* | 756 | 756 | 756 | 756 | 756 | 756 |
| Mean (daily) | 0.00035 | 0.00029 | 0.00029 | 0.00027 | 0.00027 | 0.00003 |
| StDev (daily) | 0.02080 | 0.01608 | 0.01611 | 0.01627 | 0.01645 | 0.00006 |
| Skewness | -0.43874 | -0.73061 | -0.74355 | -0.74483 | -0.83969 | 3.44605 |
| Autocorrelation | -0.18844 | -0.20893 | -0.21618 | -0.18298 | -0.19878 | 0.57987 |
| Minimum | -0.14646 | -0.12487 | -0.12761 | -0.12082 | -0.13128 | 0.00000 |
| Median | 0.00138 | 0.00094 | 0.00094 | 0.00088 | 0.00085 | 0.00000 |
| Maximum | 0.10701 | 0.09109 | 0.08977 | 0.09066 | 0.09036 | 0.00048 |
| Mean (annual) | 8.79% | 7.34% | 7.36% | 6.74% | 6.76% | 0.72% |
| StDev (annual) | 33.02% | 25.53% | 25.57% | 25.83% | 26.12% | 0.09% |
| CAGR | 9.19% | 7.62% | 7.64% | 6.97% | 6.99% | 0.72% |
| HPR | 30.17% | 24.63% | 24.72% | 22.42% | 22.46% | 2.18% |

Tech ETF had higher return than S&P 500 ETF but at greater risk.

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# Analysis

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ETFs had lower returns than benchmark.

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# Analysis

- Compute correlations.

**Correlation matrix**

| | IYW | VOO | SPX | VTI | CRSPTMT | EFFR |
|---|---|---|---|---|---|---|
| IYW | 1 | 0.925 | 0.927 | 0.926 | 0.927 | -0.055 |
| VOO | 0.925 | 1 | 0.999 | 0.996 | 0.996 | -0.045 |
| SPX | 0.927 | 0.999 | 1 | 0.996 | 0.997 | -0.046 |
| VTI | 0.926 | 0.996 | 0.996 | 1 | 0.999 | -0.048 |
| CRSPTMT | 0.927 | 0.996 | 0.997 | 0.999 | 1 | -0.049 |
| EFFR | -0.055 | -0.045 | -0.046 | -0.048 | -0.049 | 1 |

Cash equivalents return uncorrelated with stock market.

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# Analysis

- Compute correlations.

**Correlation matrix**

| | IYW | VOO | SPX | VTI | CRSPTMT | EFFR |
|---|---|---|---|---|---|---|
| IYW | 1 | 0.925 | 0.927 | 0.926 | 0.927 | -0.055 |
| VOO | 0.925 | 1 | 0.999 | 0.996 | 0.996 | -0.045 |
| SPX | 0.927 | 0.999 | 1 | 0.996 | 0.997 | -0.046 |
| VTI | 0.926 | 0.996 | 0.996 | 1 | 0.999 | -0.048 |
| CRSPTMT | 0.927 | 0.996 | 0.997 | 0.999 | 1 | -0.049 |
| EFFR | -0.055 | -0.045 | -0.046 | -0.048 | -0.049 | 1 |

Stock market indexes are highly correlated.

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# Analysis

- Compute correlations.

**Correlation matrix**

| | IYW | VOO | SPX | VTI | CRSPTMT | EFFR |
|---|---|---|---|---|---|---|
| IYW | 1 | 0.925 | 0.927 | 0.926 | 0.927 | -0.055 |
| VOO | 0.925 | 1 | 0.999 | 0.996 | 0.996 | -0.045 |
| SPX | 0.927 | 0.999 | 1 | 0.996 | 0.997 | -0.046 |
| VTI | 0.926 | 0.996 | 0.996 | 1 | 0.999 | -0.048 |
| CRSPTMT | 0.927 | 0.996 | 0.997 | 0.999 | 1 | -0.049 |
| EFFR | -0.055 | -0.045 | -0.046 | -0.048 | -0.049 | 1 |

Tech ETF is less than perfectly correlated because it is not as well diversified.

- Tactical allocation or market timing strategy.
  - Your decision; not active manager's.
  - IYW is passive portfolio of tech stocks.

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# Analysis

- Compute IYW performance measures.

**Risk-adjusted performance**

| Description | VOO | SPX | VTI | CRSPTMT |
|---|---|---|---|---|
| *n* | 756 | 756 | 756 | 756 |
| Sharpe ratio - portfolio | 0.0154 | 0.0154 | 0.0154 | 0.0154 |
| Sharpe ratio - market | 0.0163 | 0.0164 | 0.0147 | 0.0146 |
| M-squared | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Treynor ratio - portfolio | 0.0003 | 0.0003 | 0.0003 | 0.0003 |
| Treynor ratio - market | 0.0003 | 0.0003 | 0.0002 | 0.0002 |
| Jensen's alpha | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Appraisal ratio | 0.0007 | 0.0006 | 0.0047 | 0.0051 |
| Sortino ratio - portfolio | 0.0211 | 0.0211 | 0.0211 | 0.0211 |
| Sortino ratio - market | 0.0221 | 0.0222 | 0.0198 | 0.0196 |
| M-squared - CAGR | -0.49% | -0.51% | 0.37% | 0.44% |
| Jensen's alpha - CAGR | 0.15% | 0.12% | 0.94% | 1.00% |

When benchmarked to tradable S&P 500 (VOO ETF) or S&P 500 benchmark, poor risk-adjusted performance.

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# Analysis

- Compute IYW performance measures.

| Risk-adjusted performance | | | | |
|---|---|---|---|---|
| Description | VOO | SPX | VTI | CRSPTMT |
| *n* | 756 | 756 | 756 | 756 |
| Sharpe ratio - portfolio | 0.0154 | 0.0154 | 0.0154 | 0.0154 |
| Sharpe ratio - market | 0.0163 | 0.0164 | 0.0147 | 0.0146 |
| M-squared | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Treynor ratio - portfolio | 0.0003 | 0.0003 | 0.0003 | 0.0003 |
| Treynor ratio - market | 0.0003 | 0.0003 | 0.0002 | 0.0002 |
| Jensen's alpha | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Appraisal ratio | 0.0007 | 0.0006 | 0.0047 | 0.0051 |
| Sortino ratio - portfolio | 0.0211 | 0.0211 | 0.0211 | 0.0211 |
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| | | | | |
| M-squared - CAGR | -0.49% | -0.51% | 0.37% | 0.44% |
| Jensen's alpha - CAGR | 0.15% | 0.12% | 0.94% | 1.00% |

When benchmarked to tradable total market index (VTI ETF) or CRSPTMT benchmark, good risk-adjusted performance.

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# Analysis

- Compute IYW performance measures.

| Risk-adjusted performance | | | | |
|---|---|---|---|---|
| Description | VOO | SPX | VTI | CRSPTMT |
| *n* | 756 | 756 | 756 | 756 |
| Sharpe ratio - portfolio | 0.0154 | 0.0154 | 0.0154 | 0.0154 |
| Sharpe ratio - market | 0.0163 | 0.0164 | 0.0147 | 0.0146 |
| M-squared | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Treynor ratio - portfolio | 0.0003 | 0.0003 | 0.0003 | 0.0003 |
| Treynor ratio - market | 0.0003 | 0.0003 | 0.0002 | 0.0002 |
| Jensen's alpha | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Appraisal ratio | 0.0007 | 0.0006 | 0.0047 | 0.0051 |
| Sortino ratio - portfolio | 0.0211 | 0.0211 | 0.0211 | 0.0211 |
| Sortino ratio - market | 0.0221 | 0.0222 | 0.0198 | 0.0196 |
| | | | | |
| M-squared - CAGR | -0.49% | -0.51% | 0.37% | 0.44% |
| Jensen's alpha - CAGR | 0.15% | 0.12% | 0.94% | 1.00% |

Ratios like Sharpe ratio and Treynor have little economic appeal.

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# Analysis

- Compute IYW performance measures.

| Risk-adjusted performance | | | | |
|---|---|---|---|---|
| Description | VOO | SPX | VTI | CRSPTMT |
| *n* | 756 | 756 | 756 | 756 |
| Sharpe ratio - portfolio | 0.0154 | 0.0154 | 0.0154 | 0.0154 |
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| M-squared - CAGR | -0.49% | -0.51% | 0.37% | 0.44% |
| Jensen's alpha - CAGR | 0.15% | 0.12% | 0.94% | 1.00% |

Investors/managers want outperformance expressed in annualized return percentage.

$$CAGR = e^{daily\ outperformance\ \text{x}\ 252} - 1$$

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# Attributes of benchmark

- Must be all-inclusive.
  - Should not use S&P 500.
  - Leaves VTI and CRSPTMT.
- Must be investable (or tradable).
  - Leaves VTI.
- Must account for costs.
  - VTI returns are after management fees (i.e., expense ratio).
- Must have liquid market.
  - Bid/ask spread is $0.01 (or less).

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# Isolate alpha

- Suppose you want gains from tech stocks, not gains or losses from overall market.
  - Can you isolate returns from your tactical decision?

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# Isolate alpha

- Measure relative market risk, $\beta$, using VTI.
- Supporting sheet: Portable alpha
  - Beta is 1.18355.

| Excess return regression - VTI | |
|---|---|
| Benchmark index | IYW |
| $n$ | 756 |
| $\alpha$ | 0.00004 |
| s( $\alpha$ ) | 0.00029 |
| $\beta$ | 1.18355 |
| s($\beta$) | 0.01759 |
| R-squared | 0.8573 |
| Adj. R-squared | 0.8571 |
| Std error of estimate | 0.00786 |
| | |
| $t$ -ratio ($H_0$: $\alpha$ =0) | 0.13 |
| $t$ -ratio ($H_0$: $\beta$=1) | 10.44 |

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## Isolate alpha

- Create hedged portfolio by short selling VTI.
  - Call it "Alpha portfolio."
  - Amount to short sell is 1.18355 VTI return.
  - Invest cash generated in cash equivalents.
  - Support sheet: Portable alpha

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## Isolate alpha

- Consider short selling market ETF against your tactical allocation to IYW.
  - Excess return regress produces estimates of alpha and beta.

$$R_{S,t} - R_{F,t} = \alpha_S + \beta_S \left( R_{M,t} - R_{F,t} \right) + \varepsilon_{S,t}$$

  - By OLS regression assumptions,

$$\bar{R}_S = \hat{\alpha} + \bar{R}_F + \hat{\beta}_S \left( \bar{R}_M - \bar{R}_F \right)$$

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# Isolate alpha

- Hedged portfolio return is

$$\begin{aligned}\bar{R}_S &= \hat{\alpha} + \bar{R}_F + \hat{\beta}_S\left(\bar{R}_M - \bar{R}_F\right) - \bar{R}_F - \hat{\beta}_S\left(\bar{R}_M - \bar{R}_F\right) \\ &= \hat{\alpha}\end{aligned}$$

- Net amount invested is 0.
  - Purchase of IYW is fully financed with short sale of VTI.
  - Have funds to invest.

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# Isolate alpha

- Regress alpha portfolio return on VTI.

| Excess return regression - VTI | |
|---|---|
| Benchmark index | Alpha |
| $n$ | 756 |
| $\alpha$ | 0.00004 |
| s( $\alpha$ ) | 0.00029 |
| $\beta$ | 0.00000 |
| s($\beta$) | 0.01759 |
| R-squared | 0.0000 |
| Adj. R-squared | -0.0013 |
| Std error of estimate | 0.00786 |
| $t$ -ratio ($H_0$: $\alpha$ =0) | 0.13 |
| $t$ -ratio ($H_0$: $\beta$ =0) | 0.00 |

No stock market risk.

Isolated and retained alpha from tactical decision.

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# Portable alpha

- For active funds, alpha measures manager's skill.
  - Skill can be isolated by creating hedged portfolio:
    - Short sell passively managed market index ETF.
      - Effectively turns portfolio into investment whose expected excess return equals alpha with no investment.
    - Sell futures on market index.
      - Effectively turns portfolio into investment whose expected excess return equals alpha plus risk-free rate earned on original investment amount.

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# Portable alpha benchmarks

- Portable alpha requires actively-traded market price risk factor.
  - For stocks, use:
    - All-inclusive, inexpensive, total market index ETP like VTI.
    - Futures contract written on broad-based index like S&P 500 futures (CME).
  - For bonds, use:
    - All-inclusive, inexpensive, total market index ETP like BND.
    - Futures contract written on broad-based index like Treasury bond futures (CBT).

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# BOND

- Illustration: Currently hold Pimco's BOND ETF.
  - Believe intermediate- and long-term interest rates are about to fall.
  - Want to immunize bond price risk exposure while maintaining Pimco's ability to generate positive alpha in BOND.
  - Support file: BOND.xlsx

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# BOND

- Illustration: Check BOND's past returns.

| Summary statistics | | | | |
|---|---|---|---|---|
| *Description* | BOND | BND | VTI | EFFR |
| *n* | 2,701 | 2,701 | 2,701 | 2,701 |
| Mean (daily) | 0.000106 | 0.000062 | 0.000469 | 0.000034 |
| StDev (daily) | 0.002887 | 0.003080 | 0.011199 | 0.000056 |
| Skewness | -1.8232 | -1.5591 | -0.8256 | 3.3457 |
| Autocorrelation | 0.0474 | 0.0067 | -0.1060 | 0.5120 |
| Minimum | -0.0428 | -0.0559 | -0.1208 | 0.0000 |
| Median | 0.0003 | 0.0002 | 0.0007 | 0.0000 |
| Maximum | 0.0198 | 0.0413 | 0.0907 | 0.0005 |
| Mean (annual) | 2.68% | 1.57% | 11.81% | 0.86% |
| StDev (annual) | 4.58% | 4.89% | 17.78% | 0.09% |
| CAGR | 2.71% | 1.59% | 12.53% | 0.87% |
| HPR | 33.24% | 18.36% | 254.49% | 9.70% |

BOND has substantially greater return and lower risk than BND.

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# BOND

- Illustration: Check BOND's correlations.

| Correlation matrix | | | | |
|---|---|---|---|---|
| | BOND | BND | VTI | EFFR |
| BOND | 1 | 0.863 | 0.104 | -0.016 |
| BND | 0.863 | 1 | 0.073 | -0.024 |
| VTI | 0.104 | 0.073 | 1 | -0.036 |
| EFFR | -0.016 | -0.024 | -0.036 | 1 |

Only way to earn abnormal return is to take on residual risk.

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# BOND

- Illustration: Compute risk-adjusted performance.

| Risk-adjusted performance | |
|---|---|
| Description | BOND |
| *n* | 2,701 |
| Sharpe ratio - portfolio | 0.024916 |
| Sharpe ratio - market | 0.009133 |
| M-squared | 0.000046 |
| Treynor ratio - portfolio | 0.000089 |
| Treynor ratio - market | 0.000028 |
| Jensen's alpha | 0.000049 |
| Appraisal ratio | 0.033747 |
| Sortino ratio - portfolio | 0.033183 |
| Sortino ratio - market | 0.012352 |
| M-squared - CAGR | 1.16% |
| Jensen's alpha - CAGR | 1.25% |

BOND substantially outperforms on annualized basis.

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# BOND

- Illustration: Short sell BND against long position in BOND to generate daily alpha return.

| Regressions on BND | | |
|---|---|---|
| | **BOND** | **Alpha** |
| $n$ | 2,701 | 2,701 |
| $\alpha$ | 0.000049 | 0.000049 |
| s( $\alpha$ ) | 0.000028 | 0.000028 |
| $\beta$ | 0.809242 | 0.000000 |
| s($\beta$) | 0.009103 | 0.009103 |
| R-squared | 0.7454 | 0.0000 |
| Adj. R-squared | 0.7453 | -0.0004 |
| Std error of estimate | 0.00146 | 0.00146 |

Run regression of excess return of BOND on excess return of BND.

For every dollar invested in BOND, sell 0.809242 dollars in BND.

$$\alpha_t = XR_{BOND,t} - 0.781603 \times XR_{BND,t}$$

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# BOND

- Illustration: Short sell BND against long position in BOND to generate daily alpha return.

| Regressions on BND | | |
|---|---|---|
| | **BOND** | **Alpha** |
| $n$ | 2,701 | 2,701 |
| $\alpha$ | 0.000049 | 0.000049 |
| s( $\alpha$ ) | 0.000028 | 0.000028 |
| $\beta$ | 0.809242 | 0.000000 |
| s($\beta$) | 0.009103 | 0.009103 |
| R-squared | 0.7454 | 0.0000 |
| Adj. R-squared | 0.7453 | -0.0004 |
| Std error of estimate | 0.00146 | 0.00146 |

No long-term interest rate risk (i.e., market risk) remains.

Outperformance does.

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# Portable alpha

- Alpha portfolio has no investment and no market risk but has abnormal return.
  - Alpha portfolio is called *alpha engine* in practice.
  - Term *portable* arises from fact that alpha engine can now be attached to another asset category.
  - Buy VTI with funds and will have abnormal stock market performance.
    - Why? Abnormal performance in high market cap stocks is unusual, and investment manager is rewarded on outperformance.

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# BOND (continued)

- Buy VTI with investment funds (cash generated from short sale) while holding alpha portfolio.

| Regression on VTI | |
|---|---|
| | **Alpha+VTI** |
| $n$ | 2,701 |
| $\alpha$ | 0.000045 |
| s( $\alpha$ ) | 0.000028 |
| $\beta$ | 1.010690 |
| s($\beta$) | 0.002496 |
| R-squared | 0.983801 |
| Adj. R-squared | 0.983795 |
| Std error of estimate | 0.001453 |

Why isn't alpha equal to 0.000049 and beta equal to one?

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## Lesson summary

- Active fund return is attributable to:
  - Market risk exposures: Betas (not just stock market)
  - Investment skills: Portable alpha
- Do not need manager to create market risk exposures.
  - Can create cheaply using futures or passive ETPs.

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## Lesson summary

- Described four traditional risk-adjusted performance measures.
  - Two are based on total volatility.
    - Sharpe ratio
    - M-squared
  - Two are based on beta.
    - Treynor ratio
    - Jensen alpha

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## Lesson summary

- Discussed two other measures are ad hoc, albeit intuitive.
  - One is based on excess return regression.
    - Treynor/Black appraisal ratio
  - One is based on ad hoc measure of risk.
    - Sortino ratio
- Introduced concept called portable alpha.
  - Direct by-product of Jensen's alpha.
  - Can transport alpha (i.e., outperformance) across asset categories.

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## Lesson summary

- Understand source of portable alpha.
  - Why are prices incorrect and what forces then to correct?

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