Information Coefficient (IC) Analysis

Technical Reference for Quantitative Finance

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Abstract

The Information Coefficient (IC) measures the predictive power of trading signals. This document covers IC fundamentals, Grinold's Fundamental Law, statistical testing, and practical implementation. We emphasize practical formulas and industry applications over detailed derivations.

Contents

1 Mathematical Foundation

1.1 Definition

Information Coefficient

The IC is the correlation between a predictive signal s and subsequent returns r:

$$\text{IC} = \text{Corr}(s_t, r_{t+h}) \tag{1}$$

In cross-sectional form (across N assets at time t):

$$\text{IC}_t = \text{Corr}\left(\{s_{i,t}\}_{i=1}^N, \{r_{i,t+h}\}_{i=1}^N\right) \tag{2}$$

1.2 Pearson vs. Spearman IC

Pearson IC measures linear correlation:

$$\text{IC}_t^{\text{Pearson}} = \frac{\sum_{i=1}^N (s_{i,t} - \bar{s}_t)(r_{i,t+h} - \bar{r}_{t+h})}{\sqrt{\sum_{i=1}^N (s_{i,t} - \bar{s}_t)^2}\sqrt{\sum_{i=1}^N (r_{i,t+h} - \bar{r}_{t+h})^2}} \tag{3}$$

Spearman IC uses rank correlation:

$$\text{IC}_t^{\text{Spearman}} = 1 - \frac{6\sum_{i=1}^N d_{i,t}^2}{N(N^2-1)} \tag{4}$$

where $d_{i,t} = \text{rank}(s_{i,t}) - \text{rank}(r_{i,t+h})$.

Why Spearman IC is Preferred

1. **Robustness to outliers**: Extreme returns don't distort the metric
2. **Non-linear relationships**: Captures monotonic but non-linear patterns
3. **Long-short portfolios**: Most strategies care about *ranking*, not exact predictions

1.3 IC Statistics

Mean IC (average predictive power):

$$\overline{\text{IC}} = \frac{1}{T}\sum_{t=1}^T \text{IC}_t \tag{5}$$

IC Standard Deviation (stability):

$$\sigma_{\text{IC}} = \sqrt{\frac{1}{T-1}\sum_{t=1}^T (\text{IC}_t - \overline{\text{IC}})^2} \tag{6}$$

IC Information Ratio (consistency):

$$\text{IC\_IR} = \frac{\overline{\text{IC}}}{\sigma_{\text{IC}}} \tag{7}$$

IC_IR Matters More Than Raw IC

A signal with $\mathrm{IC} = 0.05$ and $\sigma_{\mathrm{IC}} = 0.02$ ($\mathrm{IC\_IR} = 2.5$) is far more valuable than $\mathrm{IC} = 0.08$ with $\sigma_{\mathrm{IC}} = 0.10$ ($\mathrm{IC\_IR} = 0.8$).
Rule of Thumb: $\mathrm{IC\_IR} > 0.5$ is acceptable; $\mathrm{IC\_IR} > 1.0$ indicates robust signal.

2 Grinold's Fundamental Law

The Fundamental Law of Active Management

$$\mathrm{IR} = \mathrm{IC} \times \sqrt{\mathrm{BR}} \tag{8}$$

where:

- IR = Information Ratio (excess return / tracking error)
- IC = Information Coefficient (signal quality)
- BR = Breadth (number of independent bets per year)

2.1 Key Implications

1. **Small IC, Large IR**: With $\mathrm{IC} = 0.03$ and $\mathrm{BR} = 500$: $\mathrm{IR} = 0.03 \times \sqrt{500} \approx 0.67$
2. **Breadth amplifies skill**: Trading more assets or higher frequency magnifies small edge
3. **Square root dampening**: Doubling breadth only increases IR by $\sqrt{2} \approx 1.41$

2.2 Extended Law with Transfer Coefficient

$$\mathrm{IR} = \mathrm{TC} \times \mathrm{IC} \times \sqrt{\mathrm{BR}} \tag{9}$$

where $\mathrm{TC} = \mathrm{Corr}(\text{optimal weights}, \text{actual weights})$ measures implementation efficiency. $\mathrm{TC} < 1$ due to constraints (long-only, position limits, transaction costs).

2.3 IC to Expected Return

Signal-Return Relationship

For standardized signal $z_s = (s - \mu_s)/\sigma_s$:

$$\boxed{\mathbb{E}[r - \mu_r \mid s] = \mathrm{IC} \cdot \sigma_r \cdot z_s} \tag{10}$$

A one-standard-deviation signal generates expected return of $\mathrm{IC} \times \sigma_r$.

2.4 IC Interpretation Guide

Table 1: Typical IC Values and Interpretations

IC Range	Assessment	Implication
< 0.01	Negligible	Likely noise
$0.01 - 0.02$	Weak	May contribute in ensemble
$0.02 - 0.05$	Good	Tradeable primary signal
$0.05 - 0.10$	Strong	Verify for overfitting
> 0.10	Exceptional	Likely data error or lookahead bias

IC Above 0.10 is Suspicious

In liquid equity markets, IC > 0.10 is extremely rare. Investigate for:

- **Lookahead bias**: Signal using future information
- **Survivorship bias**: Only analyzing surviving stocks
- **Data errors**: Incorrect signal-return alignment

3 IC Stability Analysis

3.1 Rolling IC

Rolling IC computes IC over moving windows to visualize time-varying predictive power:

$$\mathrm{IC}_t^{\mathrm{roll}} = \mathrm{Corr}\left(\{s_{i,\tau}\}_{\tau=t-W+1}^{t}, \{r_{i,\tau+h}\}_{\tau=t-W+1}^{t}\right) \tag{11}$$

3.2 IC Decay

Signals decay over time. The IC decay function:

$$\mathrm{IC}(h) = \mathrm{Corr}(s_t, r_{t\to t+h}) \tag{12}$$

Typical patterns:

- **Momentum**: Peaks at 1-12 months
- **Mean-reversion**: Peaks at 1-5 days
- **Technical**: Rapid decay within days

IC Half-Life: The horizon at which IC decays to half its peak:

$$\mathrm{IC}(\tau_{1/2}) = \frac{1}{2} \cdot \mathrm{IC}_{\max} \tag{13}$$

3.3 Regime-Conditional IC

IC varies dramatically across market regimes:

$$\mathrm{IC}^{\mathrm{regime}} = \mathbb{E}[\mathrm{IC}_t \mid \mathrm{regime}_t = k] \tag{14}$$

Example: Momentum IC by volatility regime:

VIX Regime	Mean IC	IC Std	IC_IR
Low (< 15)	0.048	0.031	1.55
Medium (15-25)	0.035	0.042	0.83
High (> 25)	0.012	0.068	0.18

4 Statistical Tests for IC

4.1 T-Test for IC Mean

IC T-Statistic

$$t = \frac{\overline{\text{IC}}}{\sigma_{\text{IC}}/\sqrt{n}} = \text{IC\_IR} \times \sqrt{n} \tag{15}$$

Critical values (two-tailed):

- $|t| > 1.96$: Significant at 5%
- $|t| > 2.58$: Significant at 1%
- $|t| > 3.29$: Significant at 0.1%

Example 4.1. *With* $\overline{\text{IC}} = 0.03$, $\sigma_{\text{IC}} = 0.04$, $n = 252$ *days:*

$$t = 0.03 \times \frac{\sqrt{252}}{0.04} = 11.9 \tag{16}$$

Highly significant ($p < 0.001$).

4.2 Newey-West Adjustment

Daily IC values are autocorrelated. Newey-West provides HAC standard errors:

$$\hat{\sigma}^2_{\text{NW}} = \hat{\gamma}_0 + 2\sum_{j=1}^{L} w_j \hat{\gamma}_j \tag{17}$$

where $\hat{\gamma}_j$ is lag-j autocovariance and $w_j = 1 - j/(L+1)$ is the Bartlett kernel.

4.3 Multiple Testing Correction

Bonferroni: For m features, $\alpha_{\text{adj}} = \alpha/m$

FDR (Benjamini-Hochberg): Less conservative, controls proportion of false positives.

5 Practical Implementation

5.1 Our Feature Set

Table 2: Feature IC Ranges in Our Pipeline

Feature	Description	IC	IC_IR
`kf_innovation`	Kalman filter error	0.02-0.04	0.4-0.8
`mom_63`	63-day momentum	0.02-0.04	0.5-0.9
`vol_21`	21-day volatility	0.01-0.02	0.2-0.4
`rev_3`	3-day reversal	0.01-0.02	0.2-0.5

5.2 Walk-Forward Framework

Walk-Forward IC Calculation

For each evaluation date t:

1. Training: $[1, t-21]$ (all history up to 21 days before)
2. Gap: 21 days (prevent lookahead bias)
3. Evaluation: Cross-sectional IC at time t

5.3 Feature Selection Criteria

1. Minimum IC: $|\overline{\text{IC}}| > 0.01$
2. Minimum IC_IR: $|\text{IC\_IR}| > 0.25$
3. Hit rate: $P(\text{IC}_t > 0) > 0.52$
4. Stability: Rolling IC doesn't change sign frequently

6 Practical Considerations

The IC-Profitability Gap

Positive IC does **not** guarantee profits. The path from IC to PnL includes:

1. **Transaction costs**: Eating gross returns
2. **Market impact**: Large orders moving prices
3. **Implementation lag**: Signals decay while trading
4. **Risk management**: Position sizing and stops

6.1 Break-Even IC

Minimum IC for Profitability

$$\text{IC}_{\text{min}} \approx \frac{c \cdot \tau}{\sigma_p \cdot \sqrt{\text{BR}}} \tag{18}$$

where c = cost per trade, τ = turnover, σ_p = portfolio vol, BR = breadth.

Example 6.1. *With* $c = 0.001$ *(10 bps),* $\tau = 12$*,* $\sigma_p = 0.10$*,* $\text{BR} = 500$*:*

$$\text{IC}_{min} \approx \frac{0.012}{2.24} \approx 0.005 \tag{19}$$

6.2 Ensemble IC

$$\text{IC}_{\text{ensemble}} \leq \sqrt{\sum_{i=1}^{k} \text{IC}_i^2} \tag{20}$$

Equality only when features are uncorrelated.

6.3 Overfitting and IC Shrinkage

IC Shrinkage Rule of Thumb

Expect out-of-sample IC to be approximately:

$$\mathrm{IC}_{\mathrm{OOS}} \approx \frac{\mathrm{IC}_{\mathrm{IS}}}{1+\sqrt{d/n}} \tag{21}$$

For 50 features, 2000 observations: expect ∼14% shrinkage.

7 Summary and Key Formulas

7.1 IC Analysis Checklist

1. Compute both Pearson and Spearman IC—prefer Spearman
2. Report IC mean, std, and IC_IR
3. Test statistical significance (Newey-West adjusted)
4. Analyze IC stability (rolling, regime-conditional)
5. Examine IC decay for optimal holding period
6. Correct for multiple testing
7. Compare in-sample vs. out-of-sample IC
8. Account for transaction costs

7.2 Key Formulas

Concept	**Formula**
Information Coefficient	$\mathrm{IC} = \mathrm{Corr}(s, r)$
IC Information Ratio	$\mathrm{IC\_IR} = \overline{\mathrm{IC}}/\sigma_{\mathrm{IC}}$
Fundamental Law	$\mathrm{IR} = \mathrm{IC} \times \sqrt{\mathrm{BR}}$
Extended Law	$\mathrm{IR} = \mathrm{TC} \times \mathrm{IC} \times \sqrt{\mathrm{BR}}$
Expected Return	$\mathbb{E}[r \mid s] = \mathrm{IC} \cdot \sigma_r \cdot z_s$
T-statistic	$t = \mathrm{IC\_IR} \times \sqrt{n}$
Break-even IC	$\mathrm{IC}_{\mathrm{min}} \approx c \cdot \tau / (\sigma_p \cdot \sqrt{\mathrm{BR}})$

7.3 Common Pitfalls

Avoid These Mistakes

1. Lookahead bias in signal construction
2. Survivorship bias (only analyzing survivors)
3. Selection bias (reporting only good features)
4. Ignoring IC volatility (high variance = unreliable)
5. Ignoring transaction costs
6. Static analysis (IC changes over regimes)

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