Trading Strategy Backtesting Simulation

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This notebook demonstrates three different trading strategies applied to stock data, each starting with **$100,000** in capital:

1. **Trend Following Strategy** - Moving average crossover
2. **Mean Reversion Strategy** - Bollinger Band mean reversion
3. **Cross-Asset Arbitrage Strategy** - Pairs trading between correlated assets

Capital: Each strategy begins with exactly $100,000 for fair comparison.

Setup & Data Loading

```
%load_ext autoreload
%autoreload 2
from market_data_loader import MarketDataLoader
from oms import OrderManagementSystem
from order_book import LimitOrderBook
from position_tracker import PositionTracker
from strategies.trend_following   import run_backtest as tf_backtest
from strategies.mean_reversion    import run_backtest as mr_backtest
from strategies.arbitrage         import run_backtest as arb_backtest
from order import Order
import pandas as pd

loader = MarketDataLoader(interval="1d", period="1mo")
oms = OrderManagementSystem()
tracker = PositionTracker(starting_cash=100000)  #  All strategies start with $100,000
book = LimitOrderBook("AAPL")
```

```
The autoreload extension is already loaded. To reload it, use:
  %reload_ext autoreload
```

Historical Data

Load 25 years of AAPL daily price data for backtesting all strategies.

```
# Load historical data for backtesting
hist = loader.get_history("AAPL",
                          start="2000-06-01",
                          end="2025-07-01")

print(f"Loaded {len(hist)} days of AAPL data")
print(f"Date range: {hist.index[0].strftime('%Y-%m-%d')} to {hist.index[-1].strftime('%Y-%m-
print(f"Sample data:")
print(hist.head())
```

```
[**********************100%**********************]  1 of 1 completed

Downloading data for AAPL from 2000-06-01 to 2025-07-01 with interval 1d
Loaded 6307 days of AAPL data
Date range: 2000-06-01 to 2025-06-30
Sample data:
Price                      last_price      high       low      open     volume
Date
2000-06-01 00:00:00+00:00    0.669645  0.672932  0.603901  0.614233  903840000
2000-06-02 00:00:00+00:00    0.695473  0.749476  0.668706  0.704395  792848000
2000-06-05 00:00:00+00:00    0.686081  0.715665  0.673871  0.701108  323668800
2000-06-06 00:00:00+00:00    0.697821  0.726936  0.678568  0.691012  525481600
2000-06-07 00:00:00+00:00    0.725527  0.728814  0.688428  0.703456  337019200
```

Strategy 1: Trend Following

Strategy Description: Moving average crossover strategy that generates buy signals when short-term MA crosses above long-term MA, and sell signals when it crosses below.

Parameters: - Short window: 10 days - Long window: 50 days - Max position: 100 shares

```python
# Run trend following backtest
# Now you can specify which stock to trade!
tf_signals, tf_trades, tf_metrics = tf_backtest(
    hist,
    symbol="AAPL",  #  Choose your stock here: "AAPL", "MSFT", "GOOGL", etc.
    short_win=10,
    long_win=50,
    risk_params={"max_pos":100}
)

print(f"  Trend Following Results (AAPL):")
print(f"Generated {len(tf_signals)} signals")
print(f"Executed {len(tf_trades)} trades")
print(f"Total Return: {tf_metrics['total_return']:.2%}")
print(f"Max Drawdown: {tf_metrics['max_drawdown']:.2%}")
print(f"Sharpe Ratio: {tf_metrics['sharpe_ratio']:.2f}")

# Process trades through tracker for visualization
tf_tracker = PositionTracker(starting_cash=100000)
for trade in tf_trades:
    tf_tracker.update(trade)

print(f"\nSample signals:")
print(tf_signals.head())
```

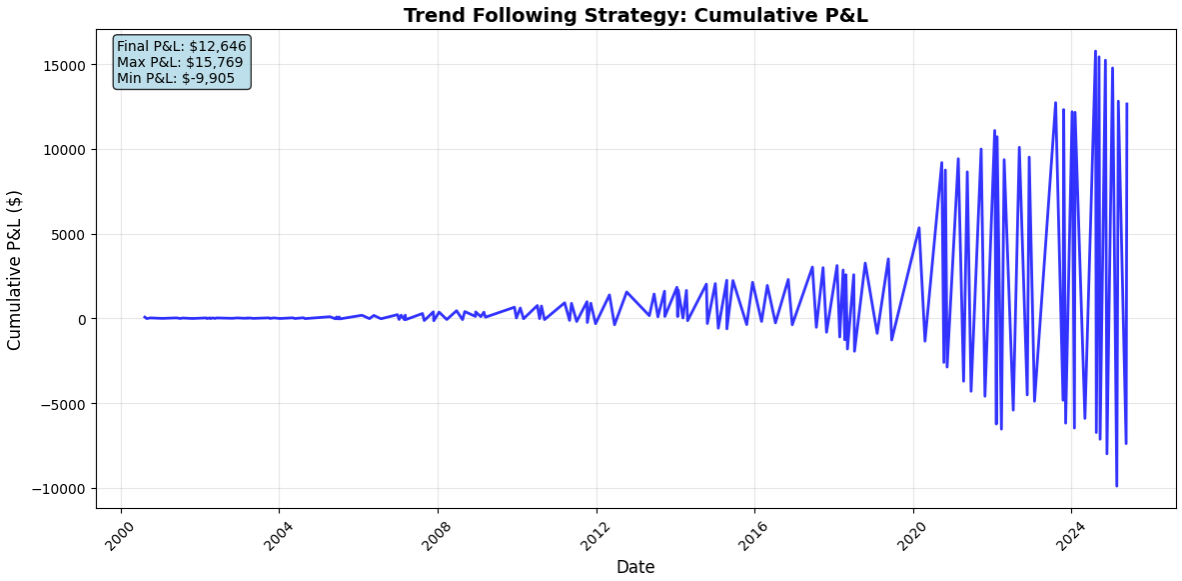
```
  Trend Following Results (AAPL):
Generated 161 signals
Executed 161 trades
Total Return: 4.78%
Max Drawdown: -22.18%
Sharpe Ratio: -131.22

Sample signals:
Price                      last_price      high       low      open  \
Date
2000-08-10 00:00:00+00:00    0.714726  0.727874  0.711908  0.721300
2000-08-28 00:00:00+00:00    0.872510  0.886598  0.857483  0.860301
2000-09-29 00:00:00+00:00    0.386947  0.435786  0.381313  0.423576
2001-01-18 00:00:00+00:00    0.280819  0.281758  0.264852  0.267670
2001-05-30 00:00:00+00:00    0.297236  0.311962  0.290023  0.311962

Price                         volume  ma_short   ma_long  signal  prev_signal
```

```
Date
2000-08-10 00:00:00+00:00   251714400  0.722521  0.762522      -1          0.0
2000-08-28 00:00:00+00:00   359004800  0.787584  0.781310       1         -1.0
2000-09-29 00:00:00+00:00  7421640800  0.786880  0.796070      -1          1.0
2001-01-18 00:00:00+00:00  1227010400  0.257809  0.254737       1         -1.0
2001-05-30 00:00:00+00:00   777078400  0.343640  0.345009      -1          1.0
```

Trend Following Equity Curve

```python
import matplotlib.pyplot as plt

# Get trend following blotter and create equity curve
tf_blotter = tf_tracker.get_blotter()

if not tf_blotter.empty:
    tf_blotter["cum_pnl"] = tf_blotter["cash_flow"].cumsum()

    plt.figure(figsize=(12, 6))
    plt.plot(tf_blotter["timestamp"], tf_blotter["cum_pnl"],
             color='blue', linewidth=2, alpha=0.8)
    plt.title("Trend Following Strategy: Cumulative P&L", fontsize=14, fontweight='bold')
    plt.xlabel("Date", fontsize=12)
    plt.ylabel("Cumulative P&L ($)", fontsize=12)
    plt.grid(True, alpha=0.3)
    plt.xticks(rotation=45)

    # Add performance metrics as text
    final_pnl = tf_blotter["cum_pnl"].iloc[-1]
    max_pnl = tf_blotter["cum_pnl"].max()
    min_pnl = tf_blotter["cum_pnl"].min()

    plt.text(0.02, 0.98, f'Final P&L: ${final_pnl:,.0f}\nMax P&L: ${max_pnl:,.0f}\nMin P&L: $
             transform=plt.gca().transAxes, fontsize=10, verticalalignment='top',
             bbox=dict(boxstyle='round', facecolor='lightblue', alpha=0.8))

    plt.tight_layout()
    plt.show()

    print(f"  Trend Following Summary:")
    print(f"  Final P&L: ${final_pnl:,.2f}")
    print(f"  Number of trades: {len(tf_blotter)}")
```

```
else:
    print("  No trades executed for trend following strategy")
```




```
Trend Following Summary:
 Final P&L: $12,646.06
 Number of trades: 161
```

Strategy 2: Mean Reversion

Strategy Description: Bollinger Band mean reversion strategy that buys when price crosses below the lower band and sells when price returns to the middle band or crosses above the upper band.

Parameters: - Bollinger window: 20 days - Number of standard deviations: 2.0 - Max position: 100 shares

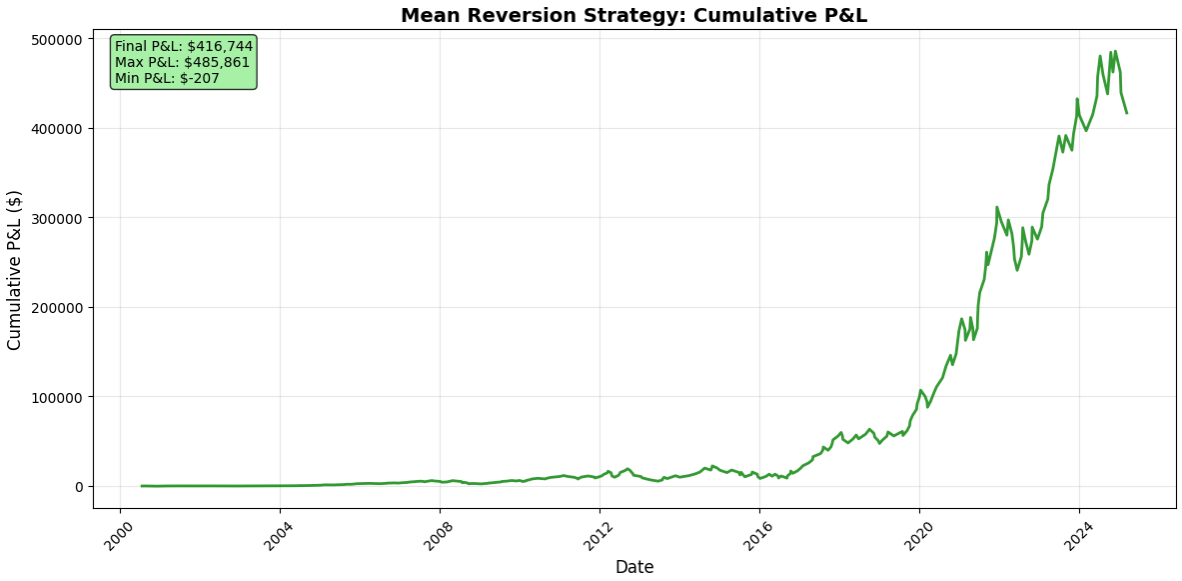
```
# Run mean reversion backtest
# Now you can specify which stock to trade!
mr_signals, mr_trades, mr_metrics = mr_backtest(
    hist,
    symbol="AAPL",  #  Choose your stock here: "AAPL", "MSFT", "GOOGL", etc.
    bollinger_win=20,
    num_std=2.0,
```

```
    risk_params={"max_pos":100}
)

print(f"  Mean Reversion Results (AAPL):")
print(f"Generated {len(mr_signals)} signals")
print(f"Executed {len(mr_trades)} trades")
print(f"Total Return: {mr_metrics['total_return']:.2%}")
print(f"Max Drawdown: {mr_metrics['max_drawdown']:.2%}")
print(f"Sharpe Ratio: {mr_metrics['sharpe_ratio']:.2f}")

# Process trades through tracker for visualization
mr_tracker = PositionTracker(starting_cash=100000)
for trade in mr_trades:
    mr_tracker.update(trade)

print(f"\nSample signals:")
print(mr_signals.head())
```

```
  Mean Reversion Results (AAPL):
Generated 333 signals
Executed 333 trades
Total Return: -828.39%
Max Drawdown: -17.18%
Sharpe Ratio: -11.10

Sample signals:
Price                      last_price      high       low      open  \
Date
2000-07-24 00:00:00+00:00    0.731632  0.794557  0.713787  0.789862
2000-08-23 00:00:00+00:00    0.816159  0.822734  0.767321  0.773426
2000-09-22 00:00:00+00:00    0.784227  0.787983  0.751355  0.756051
2000-09-26 00:00:00+00:00    0.772956  0.822734  0.772017  0.801132
2000-09-29 00:00:00+00:00    0.386947  0.435786  0.381313  0.423576

Price                         volume     upper     lower       mid  signal
Date
2000-07-24 00:00:00+00:00   412171200  0.900700  0.734059  0.817380       1
2000-08-23 00:00:00+00:00   236863200  0.800693  0.672995  0.736844      -1
2000-09-22 00:00:00+00:00   726700800  0.962914  0.805000  0.883957       1
2000-09-26 00:00:00+00:00   290936800  0.975086  0.777895  0.876491       1
2000-09-29 00:00:00+00:00  7421640800  1.080247  0.595438  0.837843       1
```

Mean Reversion Equity Curve

```
# Get mean reversion blotter and create equity curve
mr_blotter = mr_tracker.get_blotter()

if not mr_blotter.empty:
    mr_blotter["cum_pnl"] = mr_blotter["cash_flow"].cumsum()

    plt.figure(figsize=(12, 6))
    plt.plot(mr_blotter["timestamp"], mr_blotter["cum_pnl"],
             color='green', linewidth=2, alpha=0.8)
    plt.title("Mean Reversion Strategy: Cumulative P&L", fontsize=14, fontweight='bold')
    plt.xlabel("Date", fontsize=12)
    plt.ylabel("Cumulative P&L ($)", fontsize=12)
    plt.grid(True, alpha=0.3)
    plt.xticks(rotation=45)

    # Add performance metrics as text
    final_pnl = mr_blotter["cum_pnl"].iloc[-1]
    max_pnl = mr_blotter["cum_pnl"].max()
    min_pnl = mr_blotter["cum_pnl"].min()

    plt.text(0.02, 0.98, f'Final P&L: ${final_pnl:,.0f}\nMax P&L: ${max_pnl:,.0f}\nMin P&L: $
             transform=plt.gca().transAxes, fontsize=10, verticalalignment='top',
             bbox=dict(boxstyle='round', facecolor='lightgreen', alpha=0.8))

    plt.tight_layout()
    plt.show()

    print(f"  Mean Reversion Summary:")
    print(f"  Final P&L: ${final_pnl:,.2f}")
    print(f"  Number of trades: {len(mr_blotter)}")
else:
    print("  No trades executed for mean reversion strategy")
```




```
Mean Reversion Summary:
 Final P&L: $416,743.93
 Number of trades: 333
```

Strategy 3: Cross-Asset Arbitrage

Strategy Description: True cross-asset arbitrage strategy using Apple (AAPL) and Amazon (AMZN). Trades the spread between these two highly correlated tech stocks when it diverges beyond a threshold.

Method: - Estimates hedge ratio (beta) between AAPL and AMZN using linear regression - Calculates spread: AAPL - beta × AMZN
- Generates signals when z-score of spread exceeds threshold - Executes both legs simultaneously (long one asset, short the other)

Parameters: - Spread threshold: 2.0 (z-score) - Max position: 100 shares per leg

```
# Run arbitrage backtest
# Now you can specify which two stocks to pair!
try:
    arb_signals, arb_trades, arb_metrics = arb_backtest(
        hist,
        symbol1="AAPL",  #  Choose your first stock: "AAPL", "MSFT", "GOOGL", etc.
        symbol2="AMZN",  #  Choose your second stock: "AMZN", "META", "NFLX", etc.
```

```
        threshold=2.0,
        risk_params={"max_pos":100}
    )

    print(f"  Arbitrage Results (AAPL-AMZN):")
    print(f"Generated {len(arb_signals)} signals")
    print(f"Executed {len(arb_trades)} trades")
    print(f"Total Return: {arb_metrics['total_return']:.2%}")
    print(f"Max Drawdown: {arb_metrics['max_drawdown']:.2%}")
    print(f"Sharpe Ratio: {arb_metrics['sharpe_ratio']:.2f}")

    # Process trades through tracker for visualization
    arb_tracker = PositionTracker(starting_cash=100000)
    for trade in arb_trades:
        arb_tracker.update(trade)

    print(f"\nSample signals:")
    print(arb_signals.head())

except Exception as e:
    print(f"  Arbitrage strategy error: {e}")
    print("Creating placeholder results for comparison...")
    # Create dummy results so comparison works
    arb_signals = pd.DataFrame()
    arb_trades = []
    arb_metrics = {"total_return": 0.0, "max_drawdown": 0.0, "sharpe_ratio": 0.0}
    arb_tracker = PositionTracker(starting_cash=100000)
```

```
[**********************100%**********************]  1 of 1 completed

Downloading data for AMZN from 2000-06-01 to 2025-06-30 with interval 1d
Loaded AMZN data for arbitrage pair AAPL-AMZN
Loaded 6306 aligned data points for AAPL-AMZN arbitrage
Estimated hedge ratio (beta): 0.9833
Generated 681 arbitrage signals
AAPL-AMZN arbitrage backtest complete: 682 total trades executed
  Arbitrage Results (AAPL-AMZN):
Generated 341 signals
Executed 682 trades
Total Return: 213.14%
Max Drawdown: -22.98%
```

```
Sharpe Ratio: -21.40

Sample signals:
                                 p1        p2    spread  signal  signal_change
Date
2000-06-23 00:00:00+00:00  0.776713  1.693750 -0.888790      -1           True
2000-09-06 00:00:00+00:00  0.878146  2.293750 -1.377350       1           True
2000-09-20 00:00:00+00:00  0.917358  1.875000 -0.926373      -1           True
2000-09-29 00:00:00+00:00  0.386947  1.921875 -1.502876       1           True
2000-10-17 00:00:00+00:00  0.302420  1.096875 -0.776162      -1           True
```

Arbitrage Equity Curve

```python
# Get arbitrage blotter and create equity curve
arb_blotter = arb_tracker.get_blotter()

if not arb_blotter.empty:
    arb_blotter["cum_pnl"] = arb_blotter["cash_flow"].cumsum()

    plt.figure(figsize=(12, 6))
    plt.plot(arb_blotter["timestamp"], arb_blotter["cum_pnl"],
             color='red', linewidth=2, alpha=0.8)
    plt.title("Arbitrage Strategy: Cumulative P&L", fontsize=14, fontweight='bold')
    plt.xlabel("Date", fontsize=12)
    plt.ylabel("Cumulative P&L ($)", fontsize=12)
    plt.grid(True, alpha=0.3)
    plt.xticks(rotation=45)

    # Add performance metrics as text
    final_pnl = arb_blotter["cum_pnl"].iloc[-1]
    max_pnl = arb_blotter["cum_pnl"].max()
    min_pnl = arb_blotter["cum_pnl"].min()

    plt.text(0.02, 0.98, f'Final P&L: ${final_pnl:,.0f}\nMax P&L: ${max_pnl:,.0f}\nMin P&L: $
             transform=plt.gca().transAxes, fontsize=10, verticalalignment='top',
             bbox=dict(boxstyle='round', facecolor='lightcoral', alpha=0.8))

    plt.tight_layout()
    plt.show()
```

```
    print(f"  Arbitrage Summary:")
    print(f"   Final P&L: ${final_pnl:,.2f}")
    print(f"   Number of trades: {len(arb_blotter)}")
else:
    print("  No trades executed for arbitrage strategy")
```


```
  Arbitrage Summary:
   Final P&L: $107,458.26
   Number of trades: 682
```

Strategy Comparison & Analysis

Now let's compare all three strategies side by side to evaluate their relative performance.

```
# Performance comparison table
performance_data = {
    'Strategy': ['Trend Following', 'Mean Reversion', 'Arbitrage'],
    'Total Return': [
        f"{tf_metrics['total_return']:.2%}",
        f"{mr_metrics['total_return']:.2%}",
        f"{arb_metrics['total_return']:.2%}"
    ],
```

```
    'Max Drawdown': [
        f"{tf_metrics['max_drawdown']:.2%}",
        f"{mr_metrics['max_drawdown']:.2%}",
        f"{arb_metrics['max_drawdown']:.2%}"
    ],
    'Sharpe Ratio': [
        f"{tf_metrics['sharpe_ratio']:.2f}",
        f"{mr_metrics['sharpe_ratio']:.2f}",
        f"{arb_metrics['sharpe_ratio']:.2f}"
    ],
    'Number of Trades': [len(tf_trades), len(mr_trades), len(arb_trades)]
}

performance_df = pd.DataFrame(performance_data)
print("  STRATEGY PERFORMANCE COMPARISON")
print("=" * 60)
print(performance_df.to_string(index=False))
print("=" * 60)
```

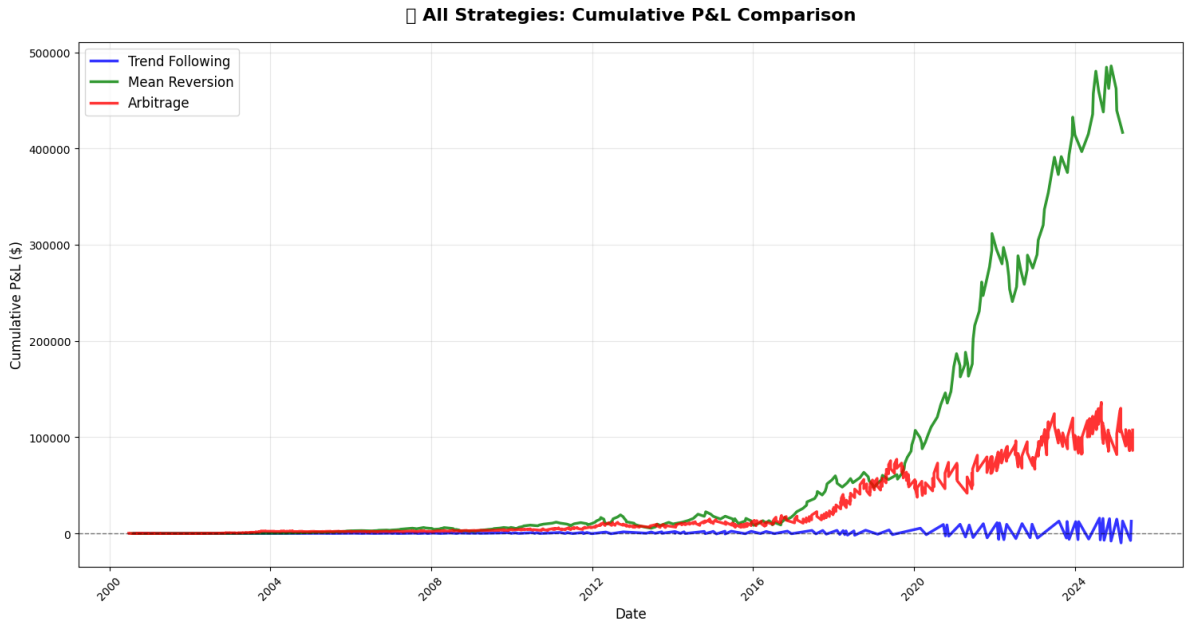
```
  STRATEGY PERFORMANCE COMPARISON
============================================================
       Strategy Total Return Max Drawdown Sharpe Ratio  Number of Trades
Trend Following        4.78%      -22.18%      -131.22               161
 Mean Reversion     -828.39%      -17.18%       -11.10               333
      Arbitrage      213.14%      -22.98%       -21.40               682
============================================================
```

```
# Combined equity curves comparison
plt.figure(figsize=(15, 8))

# Get blotters for each strategy using the correct tracker variables
tf_blotter = tf_tracker.get_blotter()
mr_blotter = mr_tracker.get_blotter()
arb_blotter = arb_tracker.get_blotter()

# Plot trend following
if not tf_blotter.empty:
    tf_blotter["cum_pnl"] = tf_blotter["cash_flow"].cumsum()
    plt.plot(tf_blotter["timestamp"], tf_blotter["cum_pnl"],
             label="Trend Following", linewidth=2.5, color='blue', alpha=0.8)
```

```
# Plot mean reversion
if not mr_blotter.empty:
    mr_blotter["cum_pnl"] = mr_blotter["cash_flow"].cumsum()
    plt.plot(mr_blotter["timestamp"], mr_blotter["cum_pnl"],
             label="Mean Reversion", linewidth=2.5, color='green', alpha=0.8)

# Plot arbitrage
if not arb_blotter.empty:
    arb_blotter["cum_pnl"] = arb_blotter["cash_flow"].cumsum()
    plt.plot(arb_blotter["timestamp"], arb_blotter["cum_pnl"],
             label="Arbitrage", linewidth=2.5, color='red', alpha=0.8)

plt.title("  All Strategies: Cumulative P&L Comparison", fontsize=16, fontweight='bold', pad=
plt.xlabel("Date", fontsize=12)
plt.ylabel("Cumulative P&L ($)", fontsize=12)
plt.legend(fontsize=12, loc='upper left')
plt.grid(True, alpha=0.3)
plt.xticks(rotation=45)

# Add zero line for reference
plt.axhline(y=0, color='black', linestyle='--', alpha=0.5, linewidth=1)

plt.tight_layout()
plt.show()

# Print detailed summary statistics
print("\n  DETAILED STRATEGY SUMMARY")
print("=" * 70)
for name, blotter, tracker in [
    ("Trend Following", tf_blotter, tf_tracker),
    ("Mean Reversion", mr_blotter, mr_tracker),
    ("Arbitrage", arb_blotter, arb_tracker)
]:
    if not blotter.empty:
        final_pnl = blotter["cum_pnl"].iloc[-1]
        max_pnl = blotter["cum_pnl"].max()
        min_pnl = blotter["cum_pnl"].min()
        max_dd = max_pnl - blotter["cum_pnl"].min()

        print(f"\n  {name}:")
        print(f"  Final P&L: ${final_pnl:,.2f}")
        print(f"  Max P&L: ${max_pnl:,.2f}")
```

```
        print(f"  Min P&L: ${min_pnl:,.2f}")
        print(f"  Max Drawdown: ${max_dd:,.2f}")
        print(f"  Number of trades: {len(blotter)}")

        # Get position summary
        summary = tracker.get_pnl_summary()
        print(f"  Current cash: ${summary['current_cash']:,.2f}")
        print(f"  Current positions: {summary['positions']}")
    else:
        print(f"\n {name}: No trades executed")

print("\n" + "=" * 70)
```

```
/var/folders/5y/9gbrlsgx0sn17yw7ydqrny4h0000gn/T/ipykernel_52033/2515814227.py:37: UserWarnin
  plt.tight_layout()
/Library/Frameworks/Python.framework/Versions/3.11/lib/python3.11/site-packages/IPython/core/
  fig.canvas.print_figure(bytes_io, **kw)
```




```
 DETAILED STRATEGY SUMMARY
======================================================================
```

```
 Trend Following:
  Final P&L: $12,646.06
  Max P&L: $15,768.83
  Min P&L: $-9,905.15
  Max Drawdown: $25,673.97
  Number of trades: 161
  Current cash: $112,646.06
  Current positions: {'AAPL': -100}

 Mean Reversion:
  Final P&L: $416,743.93
  Max P&L: $485,861.21
  Min P&L: $-207.47
  Max Drawdown: $486,068.68
  Number of trades: 333
  Current cash: $516,743.93
  Current positions: {'AAPL': -8100}

 Arbitrage:
  Final P&L: $107,458.26
  Max P&L: $136,149.02
  Min P&L: $-192.81
  Max Drawdown: $136,341.82
  Number of trades: 682
  Current cash: $207,458.26
  Current positions: {'AAPL': 100, 'AMZN': -98}

======================================================================
```