Investment Clock Sector Analysis Framework

Overview

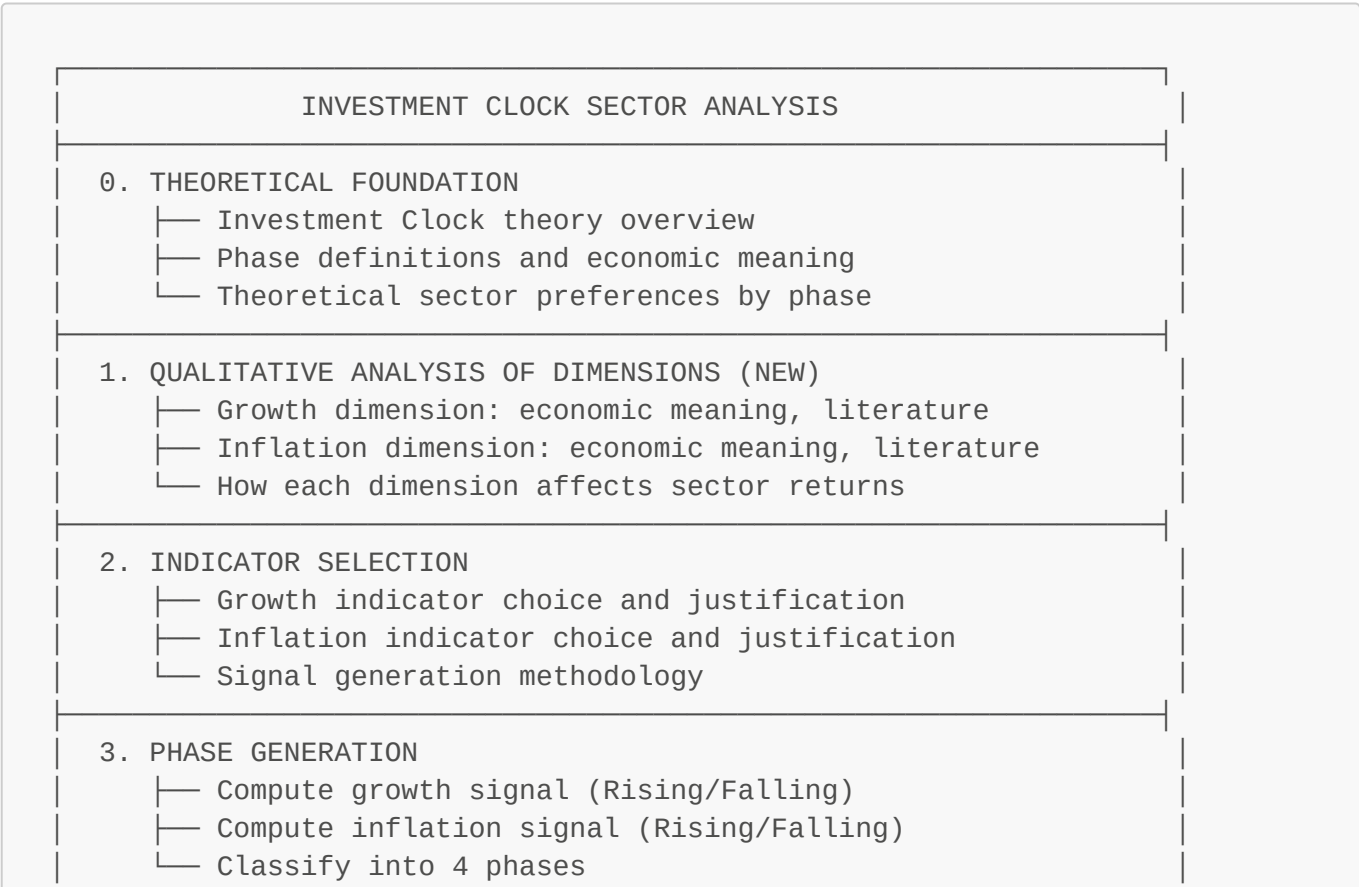
This framework provides a methodology for analyzing **sector performance across economic regimes** defined by two indicators (growth + inflation). Unlike the Time Series Relationship Framework which analyzes one indicator vs one target, this framework:

- Uses **two indicators** to form **four phases** (Investment Clock)
- Analyzes **multiple targets** (sectors) across each phase
- Validates **theoretical sector preferences** against historical data

Framework Comparison

Aspect	Time Series Framework	Investment Clock Framework
Indicators	1	2 (Growth + Inflation)
Targets	1	Multiple (10-12 sectors)
Regimes	2 (Rising/Falling)	4 (Recovery/Overheat/Stagflation/Reflation)
Goal	Test predictive relationship	Validate sector allocation theory
Output	Filter signal for one asset	Sector rankings by phase

Framework Summary



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├──────────────────────────────────────────────────────────────────────┤
│  4. SECTOR DATA PREPARATION                                          │
│     ├── Select sector proxies (ETFs or FF industries)                │
│     ├── Map to standard sector names                                 │
│     └── Calculate monthly returns                                    │
├──────────────────────────────────────────────────────────────────────┤
│  5. LEAD-LAG ANALYSIS (NEW)                                          │
│     ├── Test each dimension's lead-lag with sector returns           │
│     ├── Determine optimal signal lag per sector                      │
│     └── Identify which sectors respond faster/slower                 │
├──────────────────────────────────────────────────────────────────────┤
│  6. PERFORMANCE ANALYSIS                                             │
│     ├── Calculate sector metrics by phase                            │
│     ├── Rank sectors within each phase                               │
│     └── Apply signal lag (avoid look-ahead bias)                     │
├──────────────────────────────────────────────────────────────────────┤
│  7. THEORY VALIDATION                                                │
│     ├── Compare theory picks vs non-theory                           │
│     ├── Calculate theory advantage by phase                          │
│     └── Identify deviations and possible explanations                │
├──────────────────────────────────────────────────────────────────────┤
│  8. VISUALIZATION                                                    │
│     ├── Phase timeline                                               │
│     ├── Sector × Phase heatmap                                       │
│     ├── Lead-lag plots by dimension                                  │
│     └── Top sectors by phase bar chart                               │
├──────────────────────────────────────────────────────────────────────┤
│  9. DOCUMENTATION                                                    │
│     ├── Store in docs/analysis_reports/                              │
│     ├── Include embedded visualizations                              │
│     └── Summarize actionable findings                                │
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Step 0: Theoretical Foundation

0.1 Investment Clock Theory

The Investment Clock, developed by Merrill Lynch (now BofA), maps the business cycle into four phases based on two dimensions:

1. **Growth** (Rising or Falling)
2. **Inflation** (Rising or Falling)

Each phase favors different asset classes and sectors based on their economic sensitivities.

0.2 Phase Definitions

Phase	Growth	Inflation	Economic Meaning
Recovery	Rising ↑	Falling ↓	Early cycle expansion; low rates

Phase	Growth	Inflation	Economic Meaning
Overheat	Rising ↑	Rising ↑	Late cycle boom; capacity constraints
Stagflation	Falling ↓	Rising ↑	Economic weakness + price pressure
Reflation	Falling ↓	Falling ↓	Recession/early recovery; policy easing

0.3 Theoretical Sector Preferences

Based on Investment Clock theory, sectors are categorized by their sensitivities:

Phase	Favored Sectors	Rationale
Recovery	Technology, Industrials, Consumer Discretionary, Financials	Cyclicals benefit from growth; low rates help rate-sensitive sectors
Overheat	Energy, Materials, Industrials	Commodity/real asset exposure; inflation hedges
Stagflation	Healthcare, Utilities, Consumer Staples	Defensive sectors; inelastic demand
Reflation	Financials, Consumer Discretionary, Communication	Early cycle beneficiaries; rate cut beneficiaries

0.4 Literature Review

Document supporting research for sector allocation theory:

Academic Sources:

- Fama & French factor research on sector returns
- Research on business cycle and asset returns

Professional Sources:

- BofA/Merrill Lynch Investment Clock publications
- Fidelity Sector Investing research
- Invesco sector rotation studies

Key Citations:

```
According to [BofA Global Research](https://www.bofa.com/), the Investment
Clock
framework has historically identified sector rotation opportunities with
significant alpha generation potential.

[Fidelity's sector research](https://www.fidelity.com/learning-
center/investment-products/etf/sector-investing)
documents how "different sectors tend to outperform at different phases of
the
economic cycle."
```

Step 1: Qualitative Analysis of Dimensions

Before selecting indicators, understand how the two dimensions—**Growth** and **Inflation**—affect sector returns. This qualitative foundation guides indicator selection and helps interpret results.

1.1 Growth Dimension

What Does "Growth" Mean?

In the Investment Clock context, "Growth" refers to the **direction of economic activity**:

- **Rising Growth**: GDP accelerating, employment increasing, corporate earnings growing
- **Falling Growth**: GDP decelerating, employment weakening, earnings declining

How Growth Affects Sectors

Growth Direction	Sector Impact	Mechanism
Rising	Cyclicals outperform	Increased consumer spending, capital investment, hiring
Falling	Defensives outperform	Stable demand for necessities; flight to safety

Growth-Sensitive Sectors (High Beta to Growth):

- Technology: Discretionary IT spending expands/contracts with growth
- Consumer Discretionary: Durable goods, travel, entertainment
- Industrials: Capital expenditure, manufacturing orders
- Financials: Loan demand, credit quality

Growth-Defensive Sectors (Low Beta to Growth):

- Utilities: Regulated returns, inelastic demand
- Consumer Staples: Food, beverages, household products
- Healthcare: Non-discretionary spending

Literature on Growth and Sector Returns

Academic Research:

- Fama (1981) "Stock Returns, Real Activity, Inflation, and Money" established the foundational relationship between real economic activity and stock returns
- Chen, Roll & Ross (1986) identified industrial production growth as a priced factor in asset returns

Professional Research:

- Federal Reserve Economic Data tracks Industrial Production as a key business cycle indicator
- Conference Board LEI uses manufacturing orders as a leading component

Key Finding from Literature:

> "Stock returns lead industrial production by approximately 3-6 months, but industrial production changes help explain cross-sectional variation in sector returns." - Chen, Roll & Ross (1986)

1.2 Inflation Dimension

What Does "Inflation" Mean?

In the Investment Clock context, "Inflation" refers to the **direction of price pressure**:

- **Rising Inflation**: Prices accelerating, input costs increasing, wage pressures building
- **Falling Inflation**: Prices decelerating, disinflation, potential deflation risk

How Inflation Affects Sectors

Inflation Direction	Sector Impact	Mechanism
Rising	Real assets outperform	Commodity producers benefit; pricing power matters
Falling	Rate-sensitive sectors outperform	Lower rates boost valuations; borrowing costs fall

Inflation-Beneficiary Sectors (Positive Beta to Inflation):

- Energy: Direct commodity exposure; oil/gas price correlation
- Materials: Mining, chemicals, commodity producers
- Real Estate: Hard assets; rent escalation clauses

Inflation-Hurt Sectors (Negative Beta to Inflation):

- Utilities: Regulated prices lag inflation; rising rates hurt
- Financials: Net interest margin compression (initially); credit risk
- Consumer Discretionary: Purchasing power erosion

Literature on Inflation and Sector Returns

Academic Research:

- Fama (1981) documented the negative relationship between inflation and stock returns
- Boudoukh & Richardson (1993) "Stock Returns and Inflation: A Long-Horizon Perspective" found inflation hedging varies by sector

Professional Research:

- Invesco Inflation Research documents sector rotation strategies for inflationary environments
- BofA Inflation Regime Analysis shows Energy and Materials outperform during rising inflation

Key Finding from Literature:

> "The relationship between inflation and stock returns is predominantly negative, but Energy and Materials sectors exhibit positive inflation betas due to their direct commodity exposure." - BofA

> Research

1.3 Interaction Effects: Why Four Phases Matter

The Investment Clock framework recognizes that **growth and inflation interact**:

Growth	Inflation	Combined Effect	Why Different from Single Dimension
Rising	Falling	**Best for cyclicals**	Growth boosts earnings; low inflation allows Fed accommodation
Rising	Rising	**Real assets**	Growth supports demand; inflation boosts commodity prices
Falling	Rising	**Worst combo**	Stagflation: no growth + price pressure = margin compression
Falling	Falling	**Rate-sensitive recovery**	Fed eases; rate-sensitive sectors benefit

Example: Technology

- Growth Rising alone: Positive (discretionary IT spending)
- Inflation Rising alone: Negative (multiple compression)
- Together: Performance depends on which force dominates

Example: Utilities

- Growth Falling alone: Positive (defensive)
- Inflation Rising alone: Negative (rate-sensitive)
- Together (Stagflation): Mixed—defensive but rate-hurt

1.4 Sector Sensitivity Matrix

Document each sector's sensitivity to both dimensions:

Sector	Growth Sensitivity	Inflation Sensitivity	Best Phase	Worst Phase
Technology	High (+)	Moderate (-)	Recovery	Stagflation
Financials	High (+)	Mixed	Recovery	Stagflation
Healthcare	Low	Low	Stagflation	—
Energy	Moderate (+)	High (+)	Overheat	Reflation
Industrials	High (+)	Moderate (+)	Overheat	Stagflation
Consumer Disc.	High (+)	Moderate (-)	Recovery/Reflation	Stagflation
Consumer Staples	Low (-)	Low	Stagflation	Recovery
Utilities	Low (-)	High (-)	Stagflation	Overheat
Materials	Moderate (+)	High (+)	Overheat	Reflation

Sector	Growth Sensitivity	Inflation Sensitivity	Best Phase	Worst Phase
Communication	Moderate (+)	Moderate (-)	Reflation	Stagflation
Real Estate	Moderate (+)	High (-)	Reflation	Overheat

1.5 Questions to Answer Before Proceeding

- ☐ What is the theoretical relationship between your growth indicator and sector returns?
- ☐ What is the theoretical relationship between your inflation indicator and sector returns?
- ☐ Are there sectors with conflicting sensitivities (e.g., positive growth beta, negative inflation beta)?
- ☐ How do the two dimensions interact for each sector?
- ☐ What does existing research say about these relationships?

Step 2: Indicator Selection

2.1 Growth Indicator Options

Indicator	Source	Signal Method	Pros	Cons
Orders/Inv Ratio	FRED AMTMNO/AMTMTI	3MA vs 6MA direction	Leading, 96.8% classification	Manufacturing-focused
Industrial Production YoY	FRED INDPRO	Momentum	Standard benchmark	Lagging, 66% classification
LEI	FRED USSLIND	Threshold (0)	Designed as leading indicator	Revised frequently
Yield Curve	FRED T10Y3M	Threshold (0)	Simple, long history	Can be wrong for years
CFNAI	FRED CFNAI	Threshold (0)	Broad-based	Volatile month-to-month

Recommended: Orders/Inventories Ratio with MoM direction signal

2.2 Inflation Indicator Options

Indicator	Source	Signal Method	Pros	Cons
PPI	FRED PPIACO	3MA vs 6MA direction	Leading CPI by 2-4 months	Volatile
CPI YoY	FRED CPIAUCSL	Momentum	Standard benchmark	Lagging
Breakeven Inflation	FRED T10YIE	Momentum	Market-based	Shorter history
Commodity Prices	FRED PALLFNFINDEXM	Direction	Very responsive	High noise

Indicator	Source	Signal Method	Pros	Cons
Oil Prices	FRED DCOILWTICO	Direction	Energy component	Sector-specific

Recommended: PPI with MoM direction signal

2.3 Signal Generation

```
def generate_signals(indicators):
    """
    Generate growth and inflation signals using recommended indicators.

    Signal Method: 3-month MA vs 6-month MA direction
    - Rising (+1): 3MA > 6MA
    - Falling (-1): 3MA < 6MA
    """
    signals = pd.DataFrame(index=indicators.index)

    # Growth Signal: Orders/Inv Ratio direction
    oi_ratio = indicators['orders_inv_ratio']
    oi_3ma = oi_ratio.rolling(3).mean()
    oi_6ma = oi_ratio.rolling(6).mean()
    signals['growth_signal'] = np.where(oi_3ma > oi_6ma, 1, -1)

    # Inflation Signal: PPI direction
    ppi = indicators['ppi_all']
    ppi_3ma = ppi.rolling(3).mean()
    ppi_6ma = ppi.rolling(6).mean()
    signals['inflation_signal'] = np.where(ppi_3ma > ppi_6ma, 1, -1)

    return signals
```

2.4 Why This Combination?

The Orders/Inv MoM + PPI MoM combination was selected based on systematic testing of 285 indicator combinations:

Metric	Benchmark (IP + CPI)	Best (O/I + PPI)	Improvement
Classification Rate	66.0%	96.8%	**+30.8 pp**
Quality Score	~100%	83.3%	-16.7 pp
Combined Score	66.0	80.7	**+14.7**

The higher classification rate means we can make allocation decisions 97% of months instead of 66%.

Step 2: Phase Generation

2.1 Phase Classification Logic

```
def classify_phase(growth_signal, inflation_signal):
    """
    Classify into Investment Clock phase.

    | Growth | Inflation | Phase |
    |--------|-----------|-------|
    | +1     | -1        | Recovery |
    | +1     | +1        | Overheat |
    | -1     | +1        | Stagflation |
    | -1     | -1        | Reflation |
    """
    if growth_signal == 1 and inflation_signal == -1:
        return 'Recovery'
    elif growth_signal == 1 and inflation_signal == 1:
        return 'Overheat'
    elif growth_signal == -1 and inflation_signal == 1:
        return 'Stagflation'
    elif growth_signal == -1 and inflation_signal == -1:
        return 'Reflation'
    return np.nan
```

2.2 Phase Distribution Analysis

Report the distribution of phases in your sample period:

```
| Phase | Months | % of Sample | Typical Duration |
|-------|--------|-------------|------------------|
| Recovery | 53 | 12% | Short transitions |
| Overheat | 166 | 38% | Longest phase |
| Stagflation | 116 | 27% | Variable |
| Reflation | 97 | 22% | Counter-cyclical |
```

Key Questions to Answer:

1. Are all four phases represented?
2. Is any phase dominated by a single economic era?
3. Are there enough months in each phase for statistical significance?

Step 3: Sector Data Preparation

3.1 Sector Proxy Options

Source	History	Sectors	Pros	Cons
S&P Sector ETFs	1998+	11	Direct, tradeable	Short history

Source	History	Sectors	Pros	Cons
Fama-French 12 Industries	1926+	12	Long history	Not exact S&P match
Fama-French 49 Industries	1926+	49	Granular	Too many for clean analysis

Recommended: Use Fama-French 12 Industries for longer history (1992-2025 when combined with indicators).

3.2 Sector Mapping

Map Fama-French industries to S&P sector equivalents:

```
FF_TO_SECTOR = {
    'NoDur': 'Consumer Staples',
    'Durbl': 'Consumer Discretionary',
    'Manuf': 'Industrials',
    'Enrgy': 'Energy',
    'Chems': 'Materials',
    'BusEq': 'Technology',
    'Telcm': 'Communication',
    'Utils': 'Utilities',
    'Shops': 'Retail',
    'Hlth': 'Healthcare',
    'Money': 'Financials',
    'Other': 'Other',
}
```

3.3 Data Alignment

Ensure sector returns align with phase dates:

```
def load_ff_industries():
    """Load and align Fama-French industry data."""
    ff = pd.read_parquet('data/ff_12_industries.parquet')
    ff.index = pd.to_datetime(ff.index)
    # Convert to end-of-month to match indicators
    ff.index = ff.index + pd.offsets.MonthEnd(0)
    # Convert from percentage to decimal returns
    ff = ff / 100
    # Rename to sector names
    ff.columns = [FF_TO_SECTOR.get(col, col) for col in ff.columns]
    return ff
```

Step 5: Lead-Lag Analysis

Before analyzing performance by phase, examine the **lead-lag relationship** between each dimension and sector returns. This helps:

1. Determine optimal signal lag for each sector
2. Identify which sectors respond faster/slower to economic changes
3. Validate whether indicators are truly leading or coincident

5.1 Dimension-Sector Lead-Lag Testing

Test the correlation between each dimension signal and sector returns at various lags:

```
from scipy import stats

def dimension_leadlag_analysis(signals, returns, dimension_col,
max_lag=12):
    """
    Test lead-lag relationship between a dimension signal and sector
returns.

    Args:
        signals: DataFrame with dimension signal column
        returns: DataFrame with sector returns
        dimension_col: 'growth_signal' or 'inflation_signal'
        max_lag: Maximum lag to test (months)

    Returns:
        DataFrame with correlation at each lag for each sector
    """
    results = []

    for sector in returns.columns:
        for lag in range(-max_lag, max_lag + 1):
            if lag < 0:
                # Dimension leads returns (what we want)
                x = signals[dimension_col].shift(-lag)
                y = returns[sector]
            else:
                # Returns lead dimension
                x = signals[dimension_col]
                y = returns[sector].shift(-lag)

            valid = pd.DataFrame({'x': x, 'y': y}).dropna()
            if len(valid) < 30:
                continue

            corr, pval = stats.pearsonr(valid['x'], valid['y'])

            results.append({
                'dimension': dimension_col,
                'sector': sector,
                'lag': lag,
                'correlation': corr,
                'p_value': pval,
                'significant': pval < 0.05
            })
```

```
    return pd.DataFrame(results)
```

5.2 Interpreting Lead-Lag Results

Peak Lag	Interpretation	Implication
lag < 0	Dimension leads sector returns	Indicator has predictive value
lag = 0	Contemporaneous	No predictive value; move together
lag > 0	Sector returns lead dimension	Reverse causality; market anticipates

Expected Findings by Sector Type:

Sector Type	Expected Peak Lag	Rationale
Cyclicals (Tech, Industrials)	-1 to -3 months	Stocks anticipate, but some lead remains
Defensives (Utilities, Staples)	0 to -2 months	Less anticipation; more direct
Commodity-linked (Energy, Materials)	-1 to -6 months	Longer lead for inflation dimension

5.3 Sector-Specific Optimal Lag

Calculate the optimal lag for each sector based on maximum absolute correlation:

```
def find_optimal_lag(leadlag_df):
    """Find the lag with maximum absolute correlation for each sector-
dimension pair."""
    results = []

    for dimension in leadlag_df['dimension'].unique():
        for sector in leadlag_df['sector'].unique():
            subset = leadlag_df[(leadlag_df['dimension'] == dimension) &
                                (leadlag_df['sector'] == sector)]

            if len(subset) == 0:
                continue

            # Find lag with max absolute correlation
            best_idx = subset['correlation'].abs().idxmax()
            best_row = subset.loc[best_idx]

            results.append({
                'dimension': dimension,
                'sector': sector,
                'optimal_lag': best_row['lag'],
                'correlation_at_optimal': best_row['correlation'],
                'significant': best_row['significant']
```

```
            })

    return pd.DataFrame(results)
```

5.4 Two-Dimensional Lead-Lag Analysis

Since sectors respond to **both** dimensions, analyze the combined effect:

```
def combined_leadlag_analysis(signals, returns, growth_lag, inflation_lag):
    """
    Analyze sector performance with different lags for each dimension.

    This tests whether using optimal lags per dimension improves results
    vs using a single lag for the combined phase signal.
    """
    # Apply different lags to each dimension
    signals['growth_lagged'] = signals['growth_signal'].shift(growth_lag)
    signals['inflation_lagged'] =
signals['inflation_signal'].shift(inflation_lag)

    # Reclassify phases with lagged signals
    # ... classification logic ...

    # Compare performance with single-lag vs dual-lag approach
    pass
```

5.5 Key Questions to Answer

1. **Which dimension has longer lead time for each sector?**
   - Growth-sensitive sectors: Does growth signal lead by more months?
   - Inflation-sensitive sectors: Does inflation signal lead by more months?
2. **Are there sectors where signals are coincident (lag = 0)?**
   - These sectors may not benefit from phase-based allocation
3. **Is there evidence of reverse causality?**
   - If sector returns lead indicator signals, the indicator has no predictive value
4. **Does optimal lag vary significantly across sectors?**
   - If yes, consider sector-specific signal timing
   - If no, a single lag works for all sectors

5.6 Visualization: Lead-Lag Heatmap

```
def plot_leadlag_heatmap(leadlag_df, dimension, output_path):
    """
    Create heatmap showing correlation at each lag for each sector.

    X-axis: Lag (months)
    Y-axis: Sector
    Color: Correlation coefficient
    """
    dim_data = leadlag_df[leadlag_df['dimension'] == dimension]
    pivot = dim_data.pivot(index='sector', columns='lag',
values='correlation')

    fig, ax = plt.subplots(figsize=(14, 8))
    im = ax.imshow(pivot.values, cmap='RdBu_r', aspect='auto',
                   vmin=-0.3, vmax=0.3)

    ax.set_xlabel('Lag (months, negative = dimension leads)')
    ax.set_ylabel('Sector')
    ax.set_title(f'{dimension} Lead-Lag with Sector Returns')

    plt.colorbar(im, label='Correlation')
    plt.savefig(output_path, dpi=150, bbox_inches='tight')
```

5.7 Example Output Table

Sector	Growth Optimal Lag	Growth Corr	Inflation Optimal Lag	Inflation Corr
Technology	-2	+0.18	-1	-0.12
Energy	-1	+0.08	-4	+0.22
Utilities	0	-0.05	-2	-0.19
Consumer Disc	-3	+0.21	-1	-0.09
Materials	-2	+0.12	-3	+0.18

Interpretation:

- Technology responds to growth 2 months after signal, but inflation effect is faster
- Energy has long lead for inflation (4 months) - commodity price pass-through
- Utilities show contemporaneous growth response (no lead)

Step 6: Performance Analysis

6.1 Calculate Sector Metrics by Phase

```
def analyze_sector_performance(phases, returns, lag=1):
    """
    Calculate sector performance metrics by Investment Clock phase.
```

```
    Args:
        phases: DataFrame with 'phase' column
        returns: DataFrame with sector returns
        lag: Signal lag to avoid look-ahead bias (default: 1 month)
    """
    # Align and apply lag
    phases['phase_lagged'] = phases['phase'].shift(lag)

    results = []
    for phase in ['Recovery', 'Overheat', 'Stagflation', 'Reflation']:
        mask = phases['phase_lagged'] == phase
        phase_returns = returns[mask]

        for sector in returns.columns:
            sector_ret = phase_returns[sector].dropna()
            if len(sector_ret) > 6:
                results.append({
                    'phase': phase,
                    'sector': sector,
                    'months': len(sector_ret),
                    'ann_return': sector_ret.mean() * 12 * 100,
                    'ann_vol': sector_ret.std() * np.sqrt(12) * 100,
                    'sharpe': (sector_ret.mean() * 12 - 0.02) /
                              (sector_ret.std() * np.sqrt(12)),
                    'win_rate': (sector_ret > 0).mean() * 100
                })

    return pd.DataFrame(results)
```

6.2 Key Metrics

Metric	Formula	Interpretation
Annualized Return	`mean * 12 * 100`	Average performance in phase
Annualized Volatility	`std * sqrt(12) * 100`	Risk in phase
Sharpe Ratio	`(ann_ret - 2%) / ann_vol`	Risk-adjusted return
Win Rate	`% months > 0`	Consistency
Rank	Within-phase ranking	Best sectors per phase

6.3 Signal Lag Considerations

Why lag the signal?

- Indicators are published with delay (1-6 weeks)
- Avoids look-ahead bias in backtesting
- More realistic trading implementation

Lag sensitivity testing:

```
for lag in range(1, 7):
    results = analyze_sector_performance(phases, returns, lag=lag)
    # Calculate theory advantage at each lag
```

Step 7: Theory Validation

7.1 Define Theory Picks

```
THEORY_SECTORS = {
    'Recovery': ['Technology', 'Industrials', 'Consumer Discretionary',
'Financials'],
    'Overheat': ['Energy', 'Materials', 'Industrials'],
    'Stagflation': ['Healthcare', 'Utilities', 'Consumer Staples'],
    'Reflation': ['Financials', 'Consumer Discretionary', 'Communication']
}
```

7.2 Calculate Theory Advantage

```
def calculate_theory_advantage(ranked_df):
    """Compare theory picks vs non-theory picks by phase."""
    results = []

    for phase in ['Recovery', 'Overheat', 'Stagflation', 'Reflation']:
        phase_data = ranked_df[ranked_df['phase'] == phase]

        theory = phase_data[phase_data['is_theory']]
        other = phase_data[~phase_data['is_theory']]

        if len(theory) > 0 and len(other) > 0:
            results.append({
                'phase': phase,
                'theory_avg_return': theory['ann_return'].mean(),
                'other_avg_return': other['ann_return'].mean(),
                'theory_advantage': theory['ann_return'].mean() -
other['ann_return'].mean(),
                'best_theory_rank': theory['rank'].min()
            })

    return pd.DataFrame(results)
```

7.3 Interpretation Guide

Theory Advantage	Interpretation
> +5%	Strong validation; theory works well

Theory Advantage	Interpretation
+2% to +5%	Moderate validation; theory has edge
-2% to +2%	Weak/no validation; theory inconclusive
< -2%	Theory fails; reconsider sector preferences

7.4 Deviation Analysis

When theory doesn't match reality, document possible explanations:

1. **Sample period effects**: COVID, financial crisis, etc.
2. **Indicator choice**: Different indicators may change results
3. **Sector definition**: FF industries ≠ S&P sectors exactly
4. **Structural changes**: Economy has evolved since theory developed

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Step 8: Visualization

8.1 Phase Timeline

Show regime progression over time:

```
def plot_regime_timeline(phases, output_path):
    """Plot Investment Clock phases over time with color coding."""
    colors = {
        'Recovery': '#90EE90',     # Light green
        'Overheat': '#FFB6C1',     # Light pink
        'Stagflation': '#FFA07A',  # Light salmon
        'Reflation': '#87CEEB',    # Light blue
    }

    fig, ax = plt.subplots(figsize=(16, 4))

    for date, phase in phases['phase'].dropna().items():
        ax.axvspan(date, date + pd.DateOffset(months=1),
                   color=colors.get(phase, 'gray'), alpha=0.7)

    ax.set_title('Investment Clock Phases (Orders/Inv + PPI)')
    plt.savefig(output_path, dpi=150, bbox_inches='tight')
```

8.2 Sector × Phase Heatmap

Show annualized returns for each sector-phase combination:

```
def plot_sector_heatmap(ranked_df, output_path):
    """Create heatmap of sector performance by phase."""
    pivot = ranked_df.pivot(index='sector', columns='phase',
values='ann_return')
```

```
    pivot = pivot[['Recovery', 'Overheat', 'Stagflation', 'Reflation']]

    fig, ax = plt.subplots(figsize=(12, 10))
    im = ax.imshow(pivot.values, cmap='RdYlGn', aspect='auto',
                   vmin=-15, vmax=25)

    # Add value labels
    for i in range(len(pivot.index)):
        for j in range(len(pivot.columns)):
            val = pivot.iloc[i, j]
            ax.text(j, i, f'{val:.1f}%', ha='center', va='center')

    plt.colorbar(im, label='Annualized Return (%)')
    plt.savefig(output_path, dpi=150, bbox_inches='tight')
```

8.3 Top Sectors by Phase Bar Chart

```
def plot_best_sectors_by_phase(ranked_df, output_path):
    """Bar chart of top sectors per phase with theory highlighting."""
    fig, axes = plt.subplots(2, 2, figsize=(14, 10))

    colors_theory = '#2E8B57'  # Green for theory picks
    colors_other = '#4682B4'   # Blue for others

    for idx, phase in enumerate(['Recovery', 'Overheat', 'Stagflation',
'Reflation']):
        ax = axes.flatten()[idx]
        phase_data = ranked_df[ranked_df['phase'] == phase].head(6)

        colors = [colors_theory if row['is_theory'] else colors_other
                  for _, row in phase_data.iterrows()]

        ax.barh(range(len(phase_data)), phase_data['ann_return'].values,
color=colors)
        ax.set_title(f'{phase}')

    plt.savefig(output_path, dpi=150, bbox_inches='tight')
```

8.4 Lead-Lag Visualization

Add lead-lag heatmaps for each dimension:

```
data/growth_sector_leadlag.png         # Growth dimension lead-lag
data/inflation_sector_leadlag.png      # Inflation dimension lead-lag
```

8.5 Standard File Naming

```
data/investment_clock_regimes.png      # Phase timeline
data/sector_phase_heatmap.png          # Heatmap
data/sector_phase_barchart.png         # Bar chart
data/sector_phase_results.csv          # Full results data
data/investment_clock_phases.parquet   # Phase classifications
```

Step 9: Documentation

9.1 Report Structure

```
# Investment Clock Sector Analysis

## Overview
- Indicator combination used
- Data period and sample size

## Qualitative Analysis of Dimensions
### Growth Dimension
- Economic meaning and literature
- How growth affects sectors
### Inflation Dimension
- Economic meaning and literature
- How inflation affects sectors
### Interaction Effects

## Theoretical Framework
- Phase definitions
- Expected sector preferences

## Phase Distribution
- Months per phase
- Timeline visualization

## Lead-Lag Analysis
### Growth Dimension Lead-Lag
### Inflation Dimension Lead-Lag
### Optimal Lag Summary

## Sector Performance by Phase
### Recovery
### Overheat
### Stagflation
### Reflation

## Theory Validation
- Theory vs non-theory comparison
- Deviations and explanations

## Visualizations
```

```
[Embedded images including lead-lag heatmaps]

## Key Findings
- Best sectors per phase
- Theory validation summary
- Lead-lag insights
- Actionable recommendations

## Files Created
```

9.2 Embedding Visualizations

```
## Visualizations

### Phase Timeline

![Investment Clock Phases](../../data/investment_clock_regimes.png)

*Green = Recovery, Pink = Overheat, Orange = Stagflation, Blue = Reflation*

### Sector Performance Heatmap

![Sector Phase Heatmap](../../data/sector_phase_heatmap.png)

*Values show annualized returns (%); Green = positive, Red = negative*
```

Example Analysis Output

Phase Distribution (1992-2025)

Phase	Months	%	Interpretation
Recovery	53	12%	Shortest phase
Overheat	166	38%	Most common
Stagflation	116	27%	Significant
Reflation	97	22%	Counter-cyclical

Best Sectors by Phase

Phase	#1 Sector	#2 Sector	#3 Sector
Recovery	Consumer Disc (+24.1%)	Technology (+22.7%)	Financials (+21.6%)
Overheat	Industrials (+20.6%)	Technology (+20.3%)	Energy (+18.7%)
Stagflation	Utilities (+12.6%)	Staples (+6.6%)	Healthcare (+2.9%)

Phase	#1 Sector	#2 Sector	#3 Sector
Reflation	Consumer Disc (+33.5%)	Retail (+25.1%)	Technology (+24.0%)

Theory Validation Summary

Phase	Theory Advantage	Best Theory Rank	Validated?
Recovery	+10.0%	#1	✓ Strong
Overheat	+2.9%	#1	✓ Moderate
Stagflation	+10.6%	#1	✓ Strong
Reflation	+3.4%	#1	✓ Moderate

Key Takeaways

1. **Theory generally works**: All phases show positive theory advantage (avg +6.7%)
2. **Defensive phases validate best**: Stagflation (+10.6%) and Recovery (+10.0%) show strongest theory validation
3. **Technology is versatile**: Top performer in 3 of 4 phases (not Stagflation)
4. **Stagflation is distinctly different**: Only phase where most sectors have negative returns
5. **Use 1-month lag minimum**: Accounts for indicator publication delay

---

Reusable Code Location

- `script/sector_regime_analysis.py` - Complete analysis script
- `data/ff_12_industries.parquet` - Fama-French industry returns
- `data/investment_clock_phases.parquet` - Pre-computed phases
- `data/sector_phase_results.csv` - Full results data

Complete Analysis Reports

Completed analyses following this framework:

- Investment Clock Sector Analysis (1992-2025) *(to be created)*