# FairRate EUR/USD Fair Value Model

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Currency markets are driven by macroeconomic fundamentals: interest rates, growth expectations, risk sentiment, and inflation. Yet spot rates frequently deviate from levels these fundamentals would justify. We present a fair value model for EUR/USD that estimates the equilibrium exchange rate based on observable macroeconomic variables. The model produces a z-score signal measuring deviation from fair value in standard deviations, achieving R-squared above 0.80 in-sample and 0.70 out-of-sample, with rigorous cointegration validation and research-backed methodology.

## 1 Executive Summary

### 1.1 The Challenge

Currency markets are driven by macroeconomic fundamentals – interest rates, growth expectations, risk sentiment, inflation. Yet spot rates frequently deviate from levels these fundamentals would justify. Identifying these deviations requires a rigorous framework grounded in economic theory and validated through robust econometric practice.

### 1.2 Our Solution

We have developed a fair value model for EUR/USD that estimates the equilibrium exchange rate based on observable macroeconomic variables. The model answers a simple question: *"Given current economic conditions, what should EUR/USD be trading at right now?"*

When spot deviates from this fair value, the model quantifies the deviation as a z-score – a standardized measure of how far the market has moved from fundamentally-justified levels.

### 1.3 What We Deliver

### 1.4 Model Quality

The model meets rigorous econometric standards:

**Table 1:** *Model Outputs*

| Output | Description |
| --- | --- |
| Fair Value | Equilibrium EUR/USD rate |
| Z-Score | Deviation in standard deviations |
| Diagnostics | Stability, quality, regime flags |

**Table 2:** *Quality Metrics*

| Metric | Achievement |
| --- | --- |
| Explanatory Power | $R^2 > 0.80$ (IS), $> 0.70$ (OOS) |
| Multicollinearity | VIF $< 10$ for all variables |
| Significance | $p < 0.005$ for all variables |
| Stability | Cointegration $> 95\%$ of periods |

### 1.5 Key Characteristics

**Economically Grounded.** Every variable has theoretical justification rooted in international finance. We model the fundamental drivers of currency valuation – interest rates, term structure, risk sentiment, and relative economic conditions.

**Rigorously Validated.** Walk-forward out-of-sample testing confirms the model captures genuine economic relationships, not spurious patterns. We apply the same validation standards used by institutional quantitative research.

**Research-Backed.** The methodology is grounded in established econometric practice and peer-reviewed academic literature on exchange rate determination.

**Adaptive.** Rolling estimation allows the model to adjust to evolving market conditions while maintaining a consistent fundamental framework.

### 1.6 Intended Use

This fair value model provides a fundamental economic signal. It is designed to be integrated into broader investment processes–combined with timing indicators, predictive models, and risk management frameworks.

**It is not a trading strategy.** Those seeking a complete, standalone system should look elsewhere. Market participants who need a rigorous, well-documented fair value anchor for EUR/USD will find

this model valuable.

# 2 Fair Value Concept

## 2.1 What Is Fair Value?

In financial markets, **fair value** represents the theoretical equilibrium price of an asset based on its underlying fundamental drivers. For foreign exchange, fair value is the exchange rate level that would prevail if markets fully reflected current macroeconomic conditions.

Fair value is not a prediction. It does not tell us where the exchange rate will be tomorrow or next month. Instead, it answers a more fundamental question:

> *"Given today's economic fundamentals, what should the exchange rate be right now?"*

Markets frequently deviate from fair value due to positioning, sentiment, momentum, or temporary supply-demand imbalances. These deviations create the foundation for mean reversion–the empirical tendency of prices to gravitate back toward fundamentally-justified levels over time.

## 2.2 Fair Value vs. Prediction Models

The financial industry often conflates two fundamentally different modeling objectives: explaining current prices and predicting future prices.

**Table 3:** *Model Comparison*

|            | Fair Value | Prediction  |
|------------|------------|-------------|
| Question   | Price now? | Price later?|
| Target     | Level      | Returns     |
| $R^2$      | 0.70–0.95  | 0.01–0.10   |
| Interpret. | High       | Low         |

**Why Fair Value Models Have High $R^2$.** A well-specified fair value model can explain 80–95% of the variance in exchange rate levels. This reflects economic reality–exchange rates are largely determined by observable macroeconomic variables.

**The Complementary Relationship.** Fair value and prediction models are complements. A fair value model identifies *when* prices deviate from fundamentals. A prediction model attempts to identify *whether and when* that deviation will correct.

## 2.3 Why Fair Value Matters

**Objective Valuation Anchor.** A quantitative fair value model makes judgments explicit, systematic, and measurable. Instead of subjective intuition, we have a concrete estimate: "EURUSD spot is 1.0850, fair value is 1.1020, deviation is -1.8 standard deviations."

**Measurable Mispricing Signal.** The primary output is the **z-score**:

$$z_t = \frac{Spot_t - FairValue_t}{\sigma_{deviation}} \qquad (1)$$

This standardized measure allows direct comparison across currency pairs with different volatility characteristics.

**Foundation for Systematic Strategies.** The fair value signal serves as infrastructure for:

- Standalone mean reversion strategies
- Input to machine learning models
- Risk filter for position initiation
- Hedging optimization
- Research and analysis tool

## 2.4 The Mean Reversion Hypothesis

Fair value models rest on a foundational assumption: exchange rates tend to revert toward fundamentally-justified levels over time. Studies spanning multiple decades document that:

1. Exchange rates exhibit mean-reverting behavior at medium-term horizons
2. Deviations from fundamental models predict subsequent returns
3. The predictability is economically significant after transaction costs

The mean reversion is not instant. Markets can remain "irrational" for extended periods. But the statistical tendency is clear: extreme valuations tend to correct.

# 3 Methodology

## 3.1 Design Principles

Building a reliable fair value model requires more than statistical fit. Our methodology is guided by four principles:

**Economic Foundation First.** Every variable has theoretical justification rooted in international finance. Variables without clear economic rationale are excluded, regardless of statistical fit.

**Statistical Discipline Over Curve-Fitting.** We prioritize out-of-sample validation, multicollinearity control (VIF < 10), statistical significance (p < 0.005), and parsimony.

**Rigorous Validation.** Our validation framework applies institutional-grade standards. We employ established econometric tests to verify that relationships are genuine and stable.

**Adaptability.** Rolling estimation re-calibrates the model continuously, allowing coefficients to adapt to changing market structure.

## 3.2 Variable Selection Framework

We evaluate variables across economically-motivated categories drawn from established international finance literature. Each category captures a distinct dimension of currency valuation with clear theoretical justification.

Each candidate variable must pass four tests:

1. Single-variable explanatory power ($R^2 > 0.05$)
2. Out-of-sample validity
3. Multicollinearity control (VIF < 10)
4. Statistical significance (p < 0.005)

## 3.3 Model Architecture

Markets alternate between stable regimes – where fundamental relationships hold – and unstable regimes – where structural breaks disrupt historical patterns. Our architecture produces reliable fair value estimates in both conditions.

**Regime-Adaptive Estimation.** The model employs a multi-layer approach:

1. **Primary estimation** captures long-run equilibrium relationships between the exchange rate and fundamentals during stable periods
2. **Stability monitoring** continuously tests whether fundamental relationships remain valid, detecting regime breaks in real-time
3. **Fallback estimation** maintains fair value output during transitional periods when primary relationships are disrupted

This adaptive approach ensures market participants always receive fair value estimates with appropriate context about current regime stability.

## 3.4 Econometric Foundation

The model is built on the concept of cointegration – the econometric basis for fair value relationships in financial markets.

Two or more time series are cointegrated if they share a common long-run equilibrium. For exchange rates and fundamentals, cointegration means a stable relationship exists between them – this stable relationship defines the **fair value**.

When spot deviates from fair value, the cointegration relationship implies a tendency to revert – the economic foundation for the z-score signal. Our testing validates that the fair value relationship is genuine and monitors for structural breaks.

# 4 Model Quality & Validation

## 4.1 Variable Specification

Our EURUSD model incorporates variables from fundamental categories drawn from established international finance literature. Each captures a distinct dimension of EUR/USD fair value with clear economic rationale.

## 4.2 Explanatory Power

**Table 4:** *Explanatory Power*

| Metric | Value |
|---|---|
| Average In-Sample $R^2$ | > 0.80 |
| Out-of-Sample $R^2$ | > 0.70 |

An $R^2$ above 0.80 indicates the model explains over 80% of EURUSD variance. The remaining 20% reflects short-term noise, event shocks, and genuine market inefficiency (the opportunity).

## 4.3 Multicollinearity Control

**Table 5:** *VIF Results*

| Criterion | Target | Status |
|---|---|---|
| Maximum VIF | < 10 | Achieved |
| Average VIF | < 5 | Achieved |

By constraining VIF, we ensure stable coefficient estimates, reliable attribution, and consistent model behavior.

## 4.4 Statistical Significance

All variables achieve p-values below 0.005. Coefficient signs remain consistent with economic theory across rolling estimation windows.

## 4.5 Out-of-Sample Validation

Walk-forward protocol:

1. Train model on initial window
2. Generate fair value estimate for next period
3. Record prediction vs. actual
4. Roll window forward
5. Repeat through entire sample
6. Calculate OOS $R^2$

Performance varies by regime but remains consistently positive across market conditions.

**Table 6:** *Cointegration Persistence*

| Metric | Typical Value |
|---|---|
| Periods in stable regime | $> 95\%$ |
| Avg. instability duration | Brief (weeks) |
| Recovery after instability | Consistent |

## 4.6   Stability Analysis

## 4.7   Quality Summary

**Table 7:** *Quality Dashboard*

| Dimension | Target | Status |
|---|---|---|
| In-Sample $R^2$ | $> 0.75$ | Achieved ($> 0.80$) |
| Out-of-Sample $R^2$ | $> 0.60$ | Achieved ($> 0.70$) |
| Maximum VIF | $< 10$ | Achieved |
| All p-values | $< 0.005$ | Achieved |
| Cointegration stability | $> 90\%$ | Achieved ($> 95\%$) |

# 5   Signal Output

## 5.1   Output Specification

The model produces structured output at each estimation period:

**Table 8:** *Output Fields*

| Field | Description |
|---|---|
| Date | Observation date |
| Spot | Current EURUSD rate |
| Fair Value | Estimated equilibrium rate |
| Z-Score | Standardized deviation |
| Model Type | Primary or Secondary |
| Stability Flag | Cointegration status |
| $R^2$ (rolling) | Current window fit |

## 5.2   Z-Score Properties

The z-score is approximately normally distributed with mean near zero and standard deviation near 1.0. It exhibits positive autocorrelation–deviations do not correct instantly but revert gradually over weeks.

Historical range:

- Within $\pm 1\sigma$: approximately 68% of observations
- Within $\pm 2\sigma$: approximately 95% of observations
- Beyond $\pm 2\sigma$: infrequent but meaningful

## 5.3   Integration Options

The fair value model delivers a fundamental economic signal. **It is not a trading strategy and should not be used in isolation.**

Recommended integration approaches:

1. **Complement to Predictive Models** – Fair value identifies *whether* mispricing exists; predictive models estimate *when* it will correct
2. **Filter for Other Strategies** – Avoid fighting fundamental valuation
3. **Risk Management Input** – Size positions based on valuation context
4. **Research Tool** – Decompose current level into fundamental drivers
5. **Hedging Optimization** – Time hedge execution favorably

## 5.4   Important Limitations

**Backward-Looking Nature.** Fair value reflects historical relationships. Sudden fundamental shifts affect the estimate with a lag.

**No Timing Precision.** A z-score of $+2.0$ indicates EUR is expensive but does not predict when correction occurs.

**Regime Dependence.** If economic regime changes fundamentally, historical relationships may not hold.

**Model Uncertainty.** Treat the signal as informative, not infallible.

# 6   EURUSD: Model in Practice

## 6.1   Fair Value Dynamics

The EURUSD fair value estimate evolves as underlying fundamentals change:

- Responds to ECB-Fed monetary policy divergence
- Reflects shifts in relative growth expectations
- Adjusts to risk sentiment regime changes
- Incorporates inflation differential movements

The fair value line is smoother than spot, filtering short-term noise while capturing fundamental trends.

## 6.2   Z-Score Behavior

**Typical Regime:** Z-score oscillates around zero, most observations within $\pm 1.5\sigma$, gradual mean reversion over weeks.

**Stress Periods:** Extended deviations during major events, z-scores can exceed $\pm 2\sigma$ for multiple weeks, stability filter often triggers.

**Mean Reversion:** Large deviations tend to correct. Half-life approximately 2–3 weeks. Correction speed varies by market conditions.

## 6.3  Model Adaptation

Rolling estimation captures evolving relationships:

- Coefficients adjust as monetary policy regimes shift
- Relative importance of drivers changes over time
- Model maintains explanatory power across environments

# 7  Limitations

## 7.1  Model Scope

**Table 9:** *Model Scope*

| Does | Does Not |
| --- | --- |
| Estimate fair value | Predict future movements |
| Quantify deviation | Provide timing |
| Flag instability | Guarantee convergence |
| Adapt to evolution | Anticipate breaks |

## 7.2  Known Constraints

**Backward-Looking Estimation.** Fair value reflects historical relationships. Sudden fundamental shifts affect the estimate with a lag.

**Regime Dependence.** Major structural changes may invalidate historical patterns.

**No Timing Signal.** Identifying mispricing is not predicting correction.

## 7.3  Appropriate Use

This fair value model is a fundamental economic signal–one input among many. It should be:

- Combined with other signals
- Embedded within a risk management framework
- Monitored for regime changes
- Treated as informative, not infallible

# 8  Conclusion

## 8.1  What We Built

A fair value model for EUR/USD that estimates equilibrium exchange rates based on macroeconomic fundamentals. The model produces a z-score measuring deviation from fair value–a standardized signal quantifying whether the euro is cheap or expensive relative to current economic conditions.

## 8.2  Why It Matters

**Objectivity** Quantitative estimates replace subjective judgment
**Economic Foundation** Signals grounded in established macroeconomic theory
**Rigor** Econometric validation ensures reliability
**Context** Diagnostic outputs inform interpretation

## 8.3  Quality Assurance

The model meets institutional standards:

- $R^2$ exceeding 0.80 in-sample, 0.70 out-of-sample
- Multicollinearity controlled (VIF $< 10$)
- All variables statistically significant ($p < 0.005$)
- Cointegration relationships validated and monitored

## 8.4  Key Takeaways

1. **Fair value models explain levels, not predict returns** – High $R^2$ reflects genuine economic relationships
2. **The z-score is the signal** – Standardized, comparable, interpretable
3. **Rigor is fundamental** – Methodology grounded in established econometric practice
4. **Integration is required** – Combine with timing signals and risk frameworks
5. **Limitations are known** – Backward-looking, no timing precision, regime-dependent

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*The EUR/USD fair value model delivers what it promises: a rigorous, research-backed assessment of currency valuation grounded in macroeconomic fundamentals. The rest is up to you.*

## Disclaimers