

cointegration for the applied economist

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Cointegration for the Applied Economist: A Practical Guide

In the world of applied economics, the ability to uncover long run relationships between variables can make the difference between a superficial analysis and a truly insightful study. **Cointegration for the applied economist** is a statistical concept that allows researchers to identify stable, equilibrium relationships among non stationary time series. Whether you're working on macroeconomic policy, financial markets, or regional development, understanding cointegration can help you build models that capture both short term dynamics and long term equilibrium forces.

Why Cointegration Matters in Applied Research

Economic data are often non stationary—think of GDP, inflation, or commodity prices that trend upward over time. Traditional regression techniques can produce spurious relationships when applied to such data. Cointegration offers a way to:

- Detect genuine economic linkages that persist over time.
- Construct error correction models that describe how variables adjust toward equilibrium.
- Improve forecasting accuracy by incorporating long run dynamics.
- Provide policy relevance by identifying which variables drive long term outcomes.

In essence, cointegration allows the applied economist to move beyond short term fluctuations and answer questions about the underlying forces that shape the economy.

Foundations: What Is Cointegration?

Cointegration arises when two or more integrated (non stationary) time series share a common stochastic trend. When such a relationship exists, a linear combination of the series is stationary, meaning it has a constant mean and variance over time.

Key Concepts

1. Integrated Series ($I(1)$): A series that becomes stationary after differencing once. Most macroeconomic variables fall into this category.
2. Stationarity: A property of a time series where statistical properties (mean, variance) do not change over time.
3. Cointegrating Vector: Coefficients that define the linear combination of variables that yields a stationary series.
4. Error Correction Mechanism: A dynamic representation that captures how deviations from long run equilibrium are corrected over time.

Cointegration is often illustrated using the classic example of a supply and demand relationship in a commodity market. Prices and quantities traded may each trend upward, but their difference—representing the market surplus or deficit—tends to fluctuate around a stable mean.

Testing for Cointegration: A Step by Step Roadmap

Applied economists typically follow a systematic procedure to test for and estimate cointegrating relationships. Below is a comprehensive guide that blends theory with practical tips.

1. Preliminary Data Analysis

Before diving into unit root tests, perform basic descriptive statistics and visual inspections:

- Plot the series to identify obvious trends or structural breaks.
- Check for seasonality, outliers, or missing observations.
- Compute summary statistics (mean, variance, skewness) to get a feel for the data.

Clean data is the foundation of any reliable econometric analysis.

2. Unit Root Tests

Cointegration analysis begins with establishing that each series is integrated of the same order, usually $I(1)$. Common unit root tests include:

- Augmented Dickey–Fuller (ADF) Test: Tests for a unit root in a univariate time series.
- Phillips–Perron (PP) Test: A non-parametric alternative to ADF.
- Kwiatkowski–Phillips–Schmidt–Shin (KPSS) Test: Tests the null hypothesis of stationarity, useful for cross-checking.

When applying these tests:

- Include deterministic components (trend, intercept) based on visual inspection.
- Use appropriate lag lengths—too many lags inflate variance; too few may leave autocorrelation.
- Consider structural breaks by employing tests like the Zivot–Andrews or Perron tests if the data show regime shifts.

3. Engle–Granger Two Step Procedure

The Engle–Granger method is a classic approach for testing cointegration between two variables. It involves two steps:

1. Estimate the Long-Run Relationship:

Run an OLS regression of one variable on the other(s). For example, $Y_t = \alpha + \beta X_t + u_t$.

2. Store the residuals ($\hat{u}_t$).

- Apply an ADF test to the residuals.
- If the residuals are stationary (reject unit root), the variables are cointegrated.

While straightforward, the Engle–Granger approach is limited to two variables and may suffer from endogeneity issues.

4. Johansen's Multivariate Cointegration Test

For systems with three or more variables, the Johansen procedure is the gold standard. It uses a vector autoregression (VAR) framework and provides:

- Rank tests (trace and maximum eigenvalue) to determine the number of cointegrating vectors.
- Estimation of cointegrating relationships via the generalized eigenvalue problem.

Key steps include:

1. Specify a VAR in differences ($\Delta Y_t = \alpha + \beta_1 \Delta Y_{t-1} + \dots + \beta_p \Delta Y_{t-p} + \epsilon_t$).
2. Select appropriate lag length based on information criteria (AIC, BIC).

3. Run the Johansen test to identify cointegrating rank.
4. Estimate the cointegrating vectors and construct an error correction model.

5. Diagnostic Checks

After estimating cointegrating relationships, validate the model:

- Check residuals for autocorrelation using the Ljung–Box test.
- Assess heteroskedasticity with tests like White's or Breusch–Pagan.
- Verify model stability via the CUSUM and CUSUMSQ tests.
- Test for over identifying restrictions if you use instrumental variables.

Robust diagnostics ensure that your conclusions are trustworthy.

Building an Error Correction Model (ECM)

Once cointegration is confirmed, an ECM captures both short run dynamics and the speed of adjustment toward equilibrium.

Structure of an ECM

An ECM typically takes the form:

$$\Delta Y_t = \alpha + \beta_1 \Delta X_t + \beta_2 \Delta X_{t-1} + \dots + \beta_p \Delta X_{t-p+1} + \gamma_1 EC_{t-1} + \gamma_2 EC_{t-2} + \dots + \gamma_q EC_{t-q+1} + \mu_t$$

Where:

- ΔY_t and ΔX_t are first differences of the dependent and independent variables.
- $\beta_1, \beta_2, \dots, \beta_p$ represent the short-run effects of changes in X on Y .
- $\gamma_1, \gamma_2, \dots, \gamma_q$ represent the speed of adjustment toward long-run equilibrium.
- EC_{t-1} is the lagged error correction term, derived from the cointegrating vector.

Interpretation of Coefficients

- Short Run Effect (β): Indicates the immediate impact of changes in X on Y .
- Speed of Adjustment (γ): A negative γ indicates that deviations from the long-run equilibrium are corrected in the next period; the magnitude reflects how fast the adjustment occurs.
- Large absolute values of γ indicate a strong restoring force toward equilibrium.

Practical Tips for Applied Economists

- Use lagged error correction terms up to the lag length suggested by the VAR.
- Incorporate exogenous variables (e.g., policy shocks) as additional regressors.
- Test for structural breaks in the error correction term.
- Compare ECM performance with a purely differenced model to highlight the benefits of long-run information.

Common Pitfalls and How to Avoid Them

1. Misidentifying the Order of Integration

Incorrectly assuming that a series is $I(1)$ when it is actually $I(0)$ or $I(2)$ can lead to spurious cointegration tests. Always corroborate unit root results with multiple tests and consider structural breaks.

2. Overlooking Deterministic Components

Failing to include intercepts or trends can bias cointegration estimates. Visual inspection of plots often reveals whether a deterministic trend is present.

3. Ignoring Endogeneity

In the Engle–Granger approach, endogeneity can inflate the significance of cointegration. The Johansen method mitigates this by estimating the system jointly.

4. Neglecting Diagnostic Checks

Even if the cointegration test passes, residual autocorrelation or heteroskedasticity can invalidate inference. Always perform thorough diagnostics.

Case Studies: Cointegration in Action

1. Monetary Policy and Inflation

Applied economists often investigate the relationship between money supply growth and inflation. A typical study might:

- Collect monthly data on M2 growth and CPI inflation.
- Test both series for unit roots.
- Apply Johansen's test to determine if a stable long run relationship exists.
- Estimate an ECM to capture how inflation adjusts to changes in money supply.

Results can inform central banks about the persistence of monetary shocks.

2. Housing Prices and Income

Real estate analysts examine whether housing prices and household income are cointegrated. A successful cointegration test suggests that housing markets are anchored to income levels over the long term. The ECM can then quantify how quickly prices respond to income shocks.

3. Commodity Prices and Global Demand

In commodity markets, price dynamics are influenced by global demand and supply shocks. By testing for cointegration between commodity prices and global demand indices, analysts can identify whether prices revert to equilibrium after short run shocks.

Software and Implementation

Most applied economists rely on statistical software to perform cointegration tests and estimate ECMs. Below are common tools and their key functions:

- Stata:

Commands: `dfuller` (ADF), `xtunitroot`, `coint_johansen`, `var`, `ecm`.

- User-friendly syntax and built in diagnostic tests.
- Packages: `urca` (unit root and cointegration), `VAR`, `tsDyn` (ECM).
- Highly customizable and open source.
- Interactive interface, ideal for time series analysis.
- Commands: `cointegration`, `ecm`.

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