Summer of Science (SoS)
Introduction to Econometrics

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Econometrics: An Overview

Econometrics is the science of using mathematical and statistical methods to analyze economic data. It plays a crucial role in understanding economic phenomena, making predictions, and guiding policy decisions. Let's take a journey through the key components of econometrics and its fascinating applications.

Week 1: Simple Regression Model

- Introduction to econometrics and regression analysis.
- Simple regression model: $Y = \beta_0 + \beta_1 X + \varepsilon$.
- Estimation of coefficients using OLS.
- Interpretation of coefficients and hypothesis testing.

Week 2: Multiple Regression Model

- Extension of simple regression to multiple independent variables.
- Multiple regression model:
  $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k + \varepsilon.$
- Assumptions of the multiple regression model.
- Interpreting coefficients and conducting hypothesis tests.

Week 3: Model Specification

- Selecting the appropriate functional form for the model.
- Handling categorical variables and interaction terms.
- Model selection techniques: stepwise regression, AIC, BIC.
- Out-of-sample prediction and model evaluation.

Week 4: Endogeneity

- Understanding endogeneity and its impact on regression results.
- Instrumental Variable (IV) approach to address endogeneity.
- Two-Stage Least Squares (2SLS) method.
- Tests for endogeneity: Sargan test, Hausman test.

Week 5: Binary Dependent Variables

- Introduction to models with binary outcomes.
- Logit model: $P(Y = 1) = \dfrac{1}{1 + e^{-(\beta_0 + \beta_1 X)}}$.
- Odds ratio and interpreting logit model coefficients.
- Marginal effects and their calculation.

Week 6: Time Series Analysis

- Understanding time series data and its properties.
- Auto-Regressive (AR) model for time series forecasting.
- Augmented Dickey-Fuller (ADF) test for unit root.
- Error Correction Model (ECM) for cointegrated time series.

Auto-Regression Model: An Interesting Topic in Econometrics

The Auto-Regression (AR) model is a powerful time series model used to predict future values based on past observations. It assumes that a variable is linearly related to its own lagged values and random error terms. The AR(1) model is a simple example:

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \varepsilon_t \tag{1}$$

where:

- Y_t is the variable of interest at time t.
- Y_{t-1} is the lagged value of the variable at time $t-1$.
- β_0 and β_1 are the parameters to be estimated.
- ε_t is the error term, representing the deviation of the actual value from the predicted value.

AR Model: Estimation

To estimate the parameters β_0 and β_1 in the AR(1) model, we use the method of Ordinary Least Squares (OLS). The OLS estimates minimize the sum of squared residuals (errors) given by:

$$\text{Minimize } \sum_{t=1}^{n} \varepsilon_t^2 = \sum_{t=1}^{n} (Y_t - \beta_0 - \beta_1 Y_{t-1})^2 \tag{2}$$

The OLS estimates $\hat{\beta}_0$ and $\hat{\beta}_1$ are obtained by differentiating the sum of squared residuals with respect to the parameters and setting the derivatives to zero.

AR Model: Forecasting

Once we have estimated the parameters $\hat{\beta}_0$ and $\hat{\beta}_1$, we can use the AR(1) model to forecast future values of the variable Y. Given the observed value Y_t at time t, the forecasted value $\hat{Y}_{t+1}$ for the next period is given by:

$$\hat{Y}_{t+1} = \hat{\beta}_0 + \hat{\beta}_1 Y_t \tag{3}$$

We can continue this process to forecast values for multiple future periods.

Simpler Research on Auto-Regression Model

- **Research Question:** Can an AR(1) model accurately predict the next day's temperature based on historical weather data?

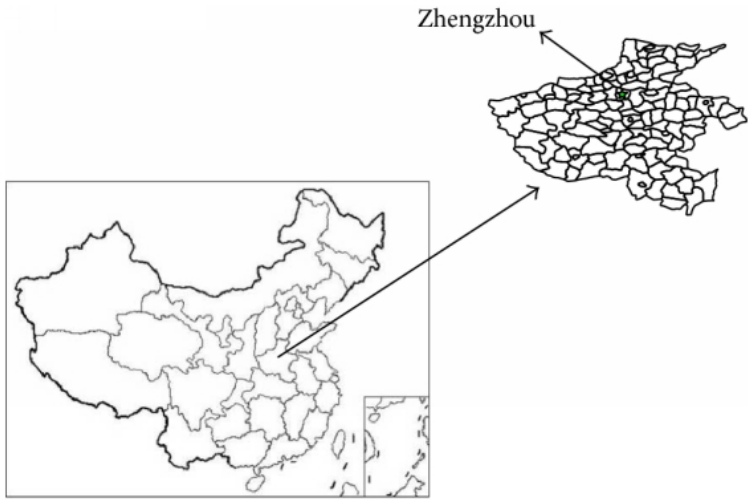

Figure: A village in China for our model

Data Collection

- Historical weather data from a local weather station.
- Daily temperature records for the past year.

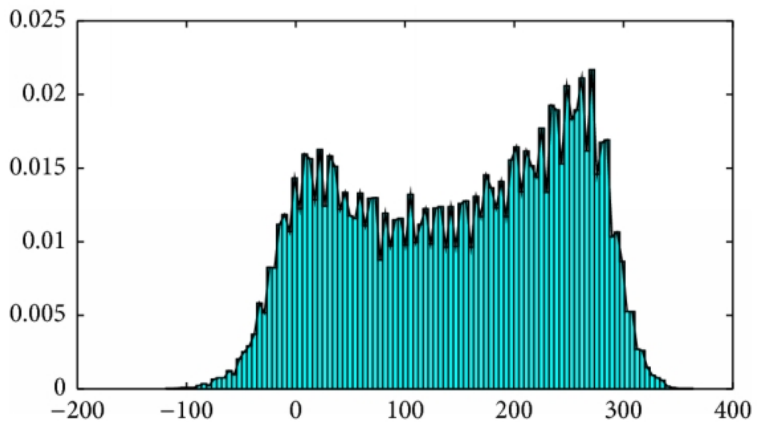

Figure: Distribution of daily average temperature (1951-2013)

Model Estimation

- Fit an AR(1) model to the temperature time series.
- Estimate the parameters $\hat{\beta}_0$ and $\hat{\beta}_1$ using OLS.

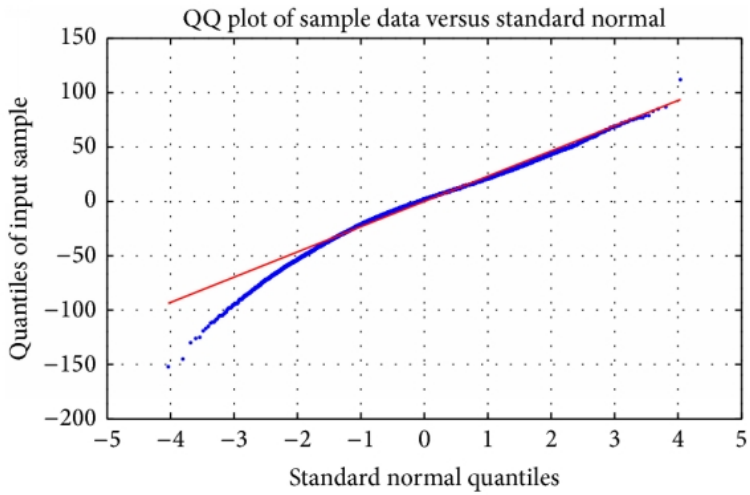

Figure: Plot of daily temperature difference

Model Evaluation

- Use the AR(1) model to forecast the temperature for the next day.
- Compare the forecasted temperature with the actual temperature recorded on the next day.
- Calculate the forecast error and assess the accuracy of the model.

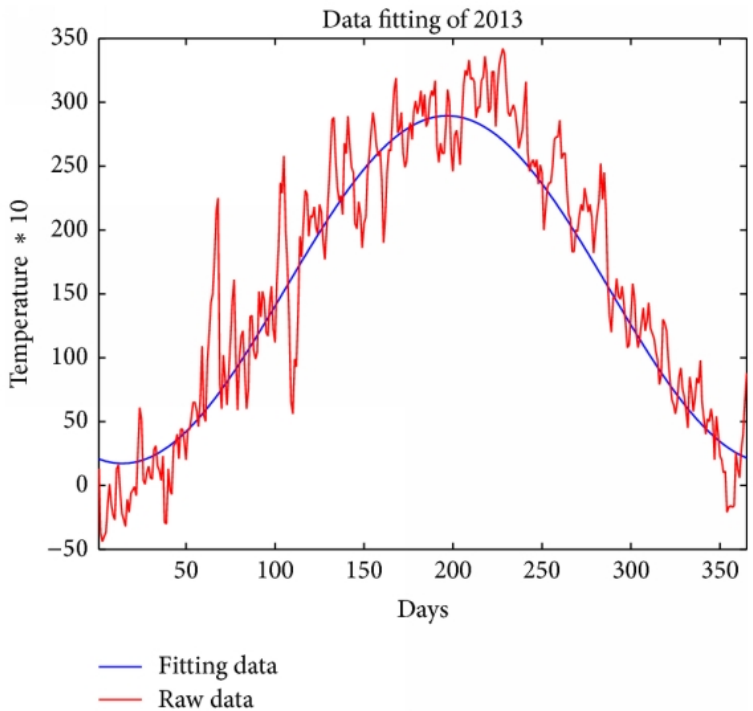

Figure: Data fitting of temperature

Results

- The AR(1) model provides reasonably accurate temperature forecasts for the next day.
- Forecast errors are within an acceptable range, indicating the model's effectiveness in short-term temperature prediction.

Conclusion

The Auto-Regression Model, particularly the AR(1) model, shows promising potential in short-term temperature prediction based on historical weather data. While this research focuses on weather forecasting, the AR model's applications extend to various fields, including finance, economics, and climate science. The simplicity and effectiveness of the AR model make it a valuable tool in time series analysis and prediction.

Conclusion

Econometrics is a powerful and versatile tool for analyzing economic data and making informed decisions. It allows us to model complex economic relationships, evaluate policy options, and predict future outcomes. From simple regression to advanced time series analysis, econometrics equips us with the tools to understand and shape the economic world around us.