Polynomial Regression

Simple Linear Regression

$$y = b_0 + b_1 x_1$$

Multiple Linear Regression

$$y = b_0 + b_1 x_1 + b_2 x_2 + \ldots + b_n x_n$$

Polynomial Linear Regression

$$y = b_0 + b_1 x_1 + b_2 x_1^2 + \ldots + b_n x_1^n$$

Polynomial Regression

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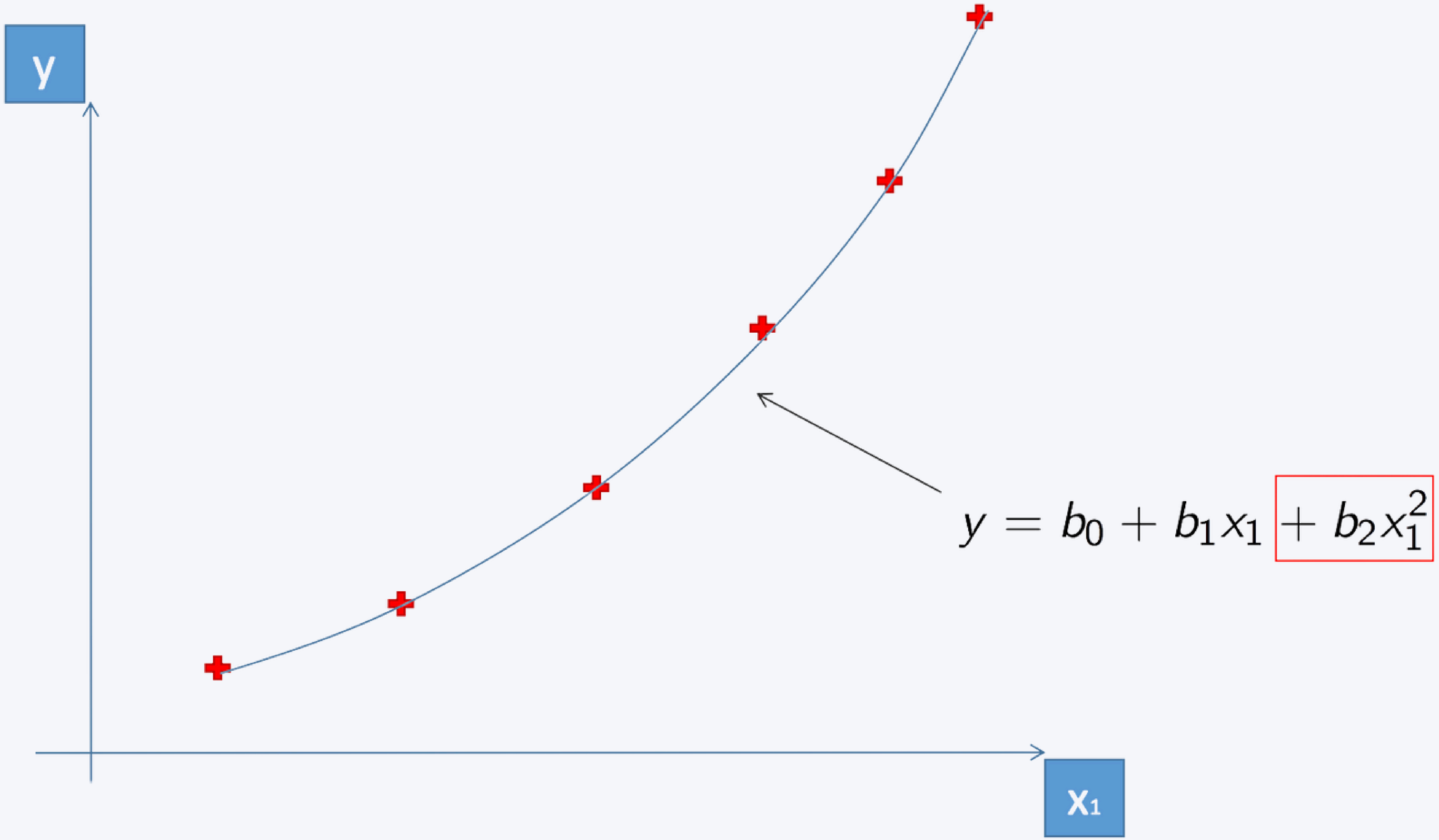

Polynomial Linear Regression is an extension of linear regression that **models non-linear relationships by transforming the input variables into polynomial terms.** Even though the relationship between the variables may **not** be linear, the regression itself is still considered "**linear**" because the model is linear in terms of the coefficients.

Polynomial Regression

Key Features of Polynomial Regression

Transformation of Variables:

- In regular linear regression, the model is: **$y=b0+b1x$**
- In polynomial regression, higher-order terms are added:**$y=b0+b1x+b2x2+b3x3+...$**

These polynomial terms allow the model to **capture curves or more complex relationships.**

Fitting Curves:

- Useful when the data shows a **non-linear relationshi**p, such as U-shaped, S-shaped, or exponential patterns.

Still a **"Linear Model":**

- Even though the relationship is non-linear, it is called "linear" because the equation remains linear in terms of the coefficients **(b0,b1,b2).**

- This is why it's called **Polynomial Linear Regression.**

Polynomial Regression

When to Use Polynomial Regression?

- When the data shows **clear non-linear patterns** that cannot be captured by regular linear regression.
- When adding **flexibility** is needed for better accuracy but without overfitting (important to choose the right degree of the polynomial).

Polynomial Linear Regression

$$y = b_0 + b_1 x_1 + b_2 x_1^2 + \dots + b_n x_1^n$$

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Why Do We Need Polynomial Regression?

- Linear regression works only **for straight-line relationships.**
- Many real-world relationships are non-linear, such as:
    - Population growth.
    - Disease progression.
    - Economic data (e.g., sales trends).

Example: Stock price data that linear regression cannot capture.

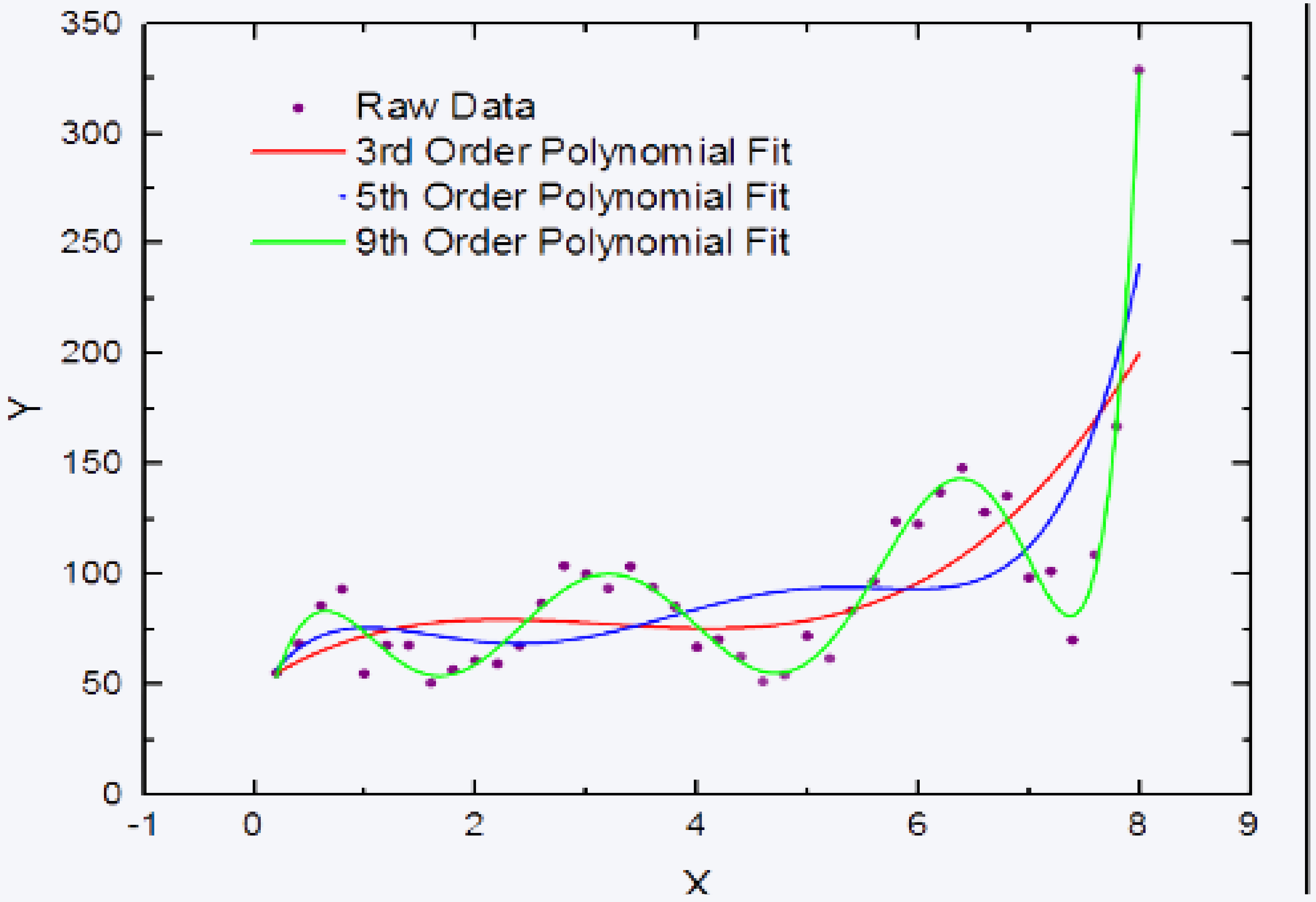
https://www.investopedia.com/terms/p/polynomial_trending.asp

Polynomial Regression

How Polynomial Regression Works

- **Convert** the input variable (x) into polynomial terms (x^2,x^3).
- **Apply** linear regression to estimate coefficients ($\beta0$,$\beta1$).

- ***<u>Higher-order terms allow the model to capture curves.</u>***



Polynomial Regression

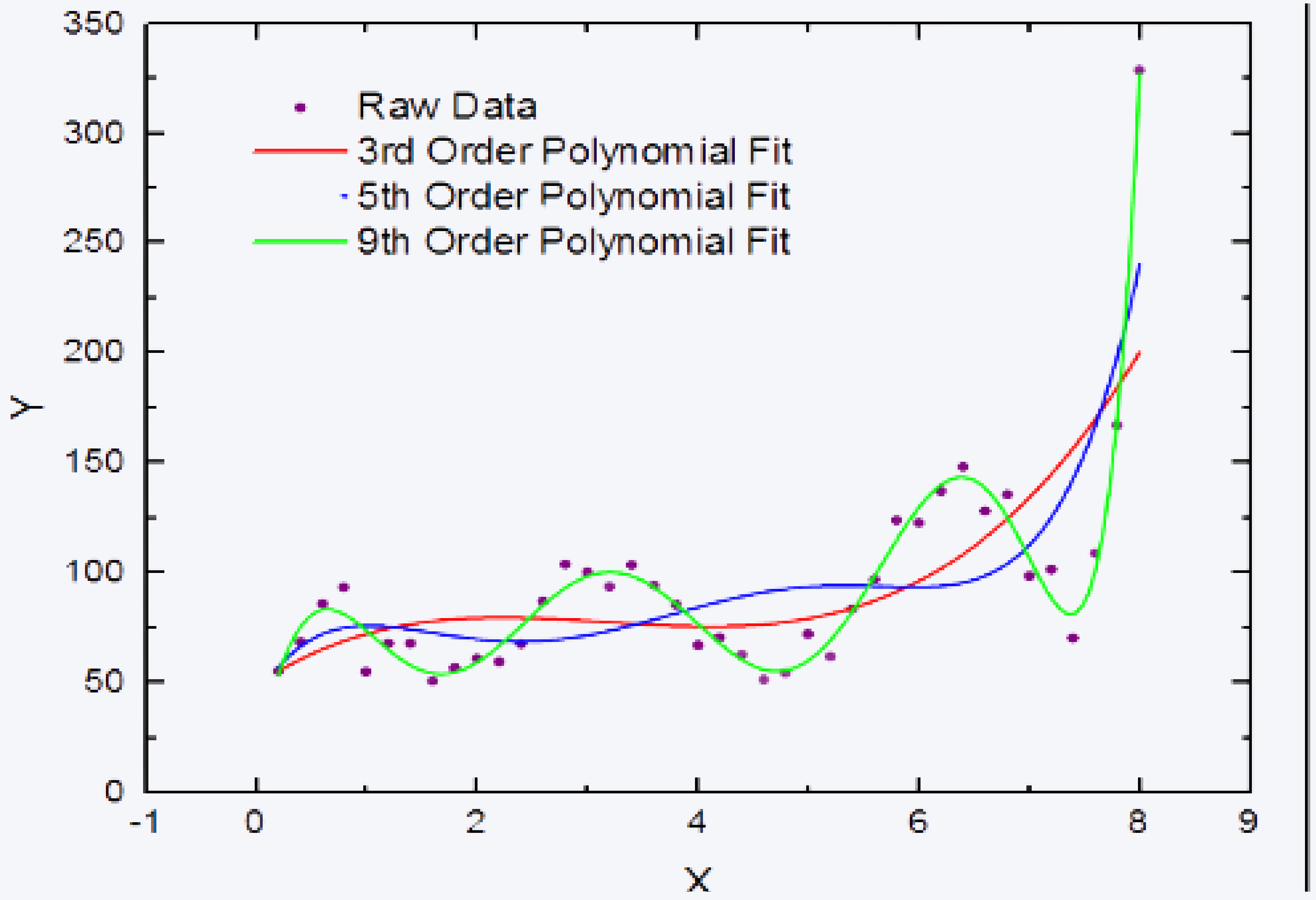
Choosing the Polynomial Degree

The degree of the polynomial affects the model's complexity:

- **Low degree:** Underfitting (model too simple).
- **High degree:** Overfitting (model too complex, fits noise).

Use tools like:

- Cross-validation.
- Adjusted R2.



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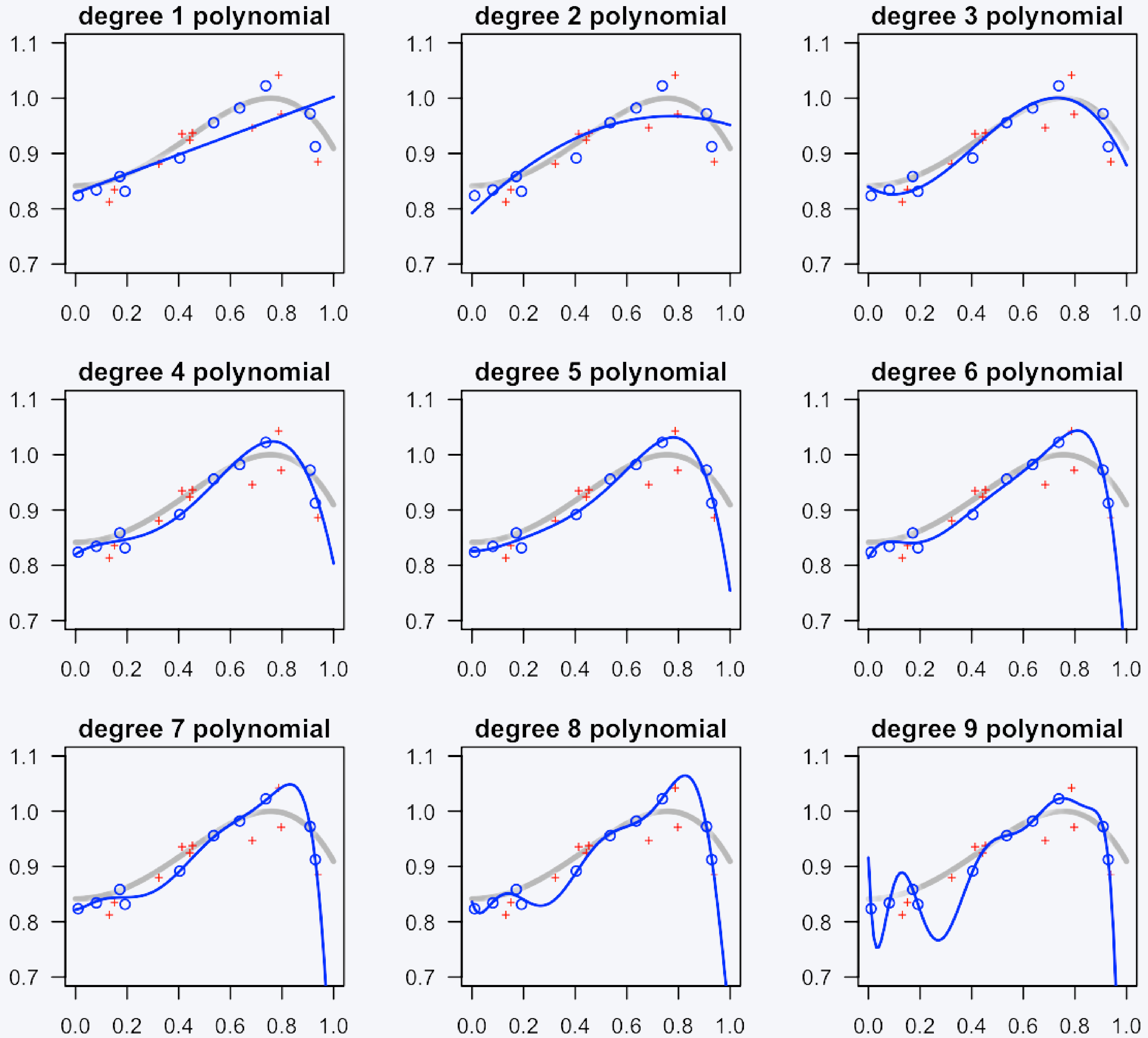
Choosing the Polynomial Degree



https://allmodelsarewrong.github.io/overfit.html

Polynomial Regression

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Practical Applications

Use cases for polynomial regression:

- Forecasting trends in sales or demand.
- Modeling natural phenomena (e.g., rainfall vs. crop yield).
- Predicting disease progression.
- Engineering data (e.g., stress-strain curves).

Limitations of Polynomial Regression

- Overfitting when the degree is too high.
- Sensitive to outliers.
- May not generalize well to unseen data.
- Not suitable for truly complex, non-linear relationships (consider other models like decision trees or neural networks).

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Hands-On Code

Polynomial Linear Regression