Case Study: Optimizing Product Prices Using Machine Learning

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Overview

Price elasticity of demand

Case Study: Price Optimization in Fashion E-commerce

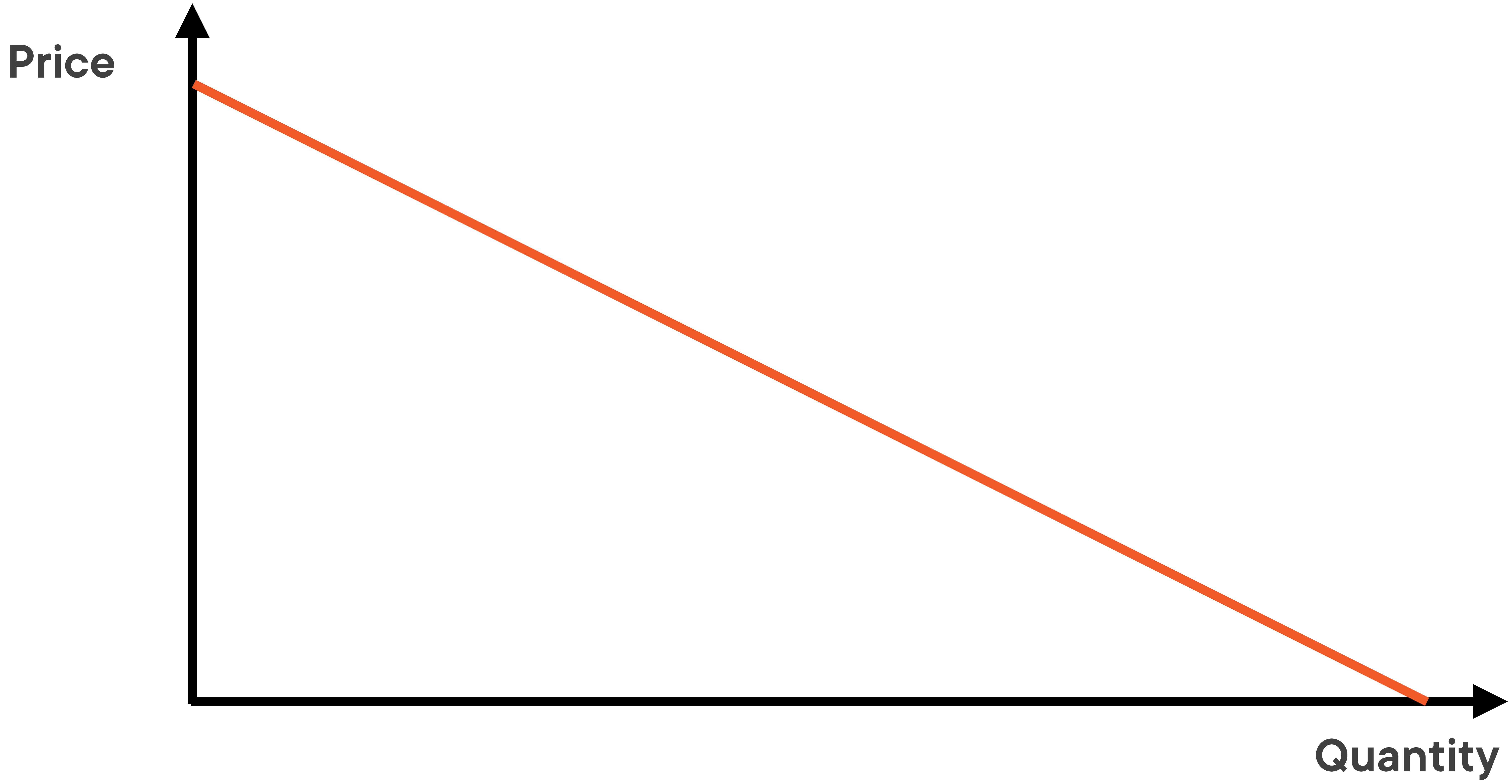
Price Elasticity of Demand

Law of Demand

If all other factors remain equal, the higher the price of a good, fewer people will demand that good.

Demand Curve

Demand Curve

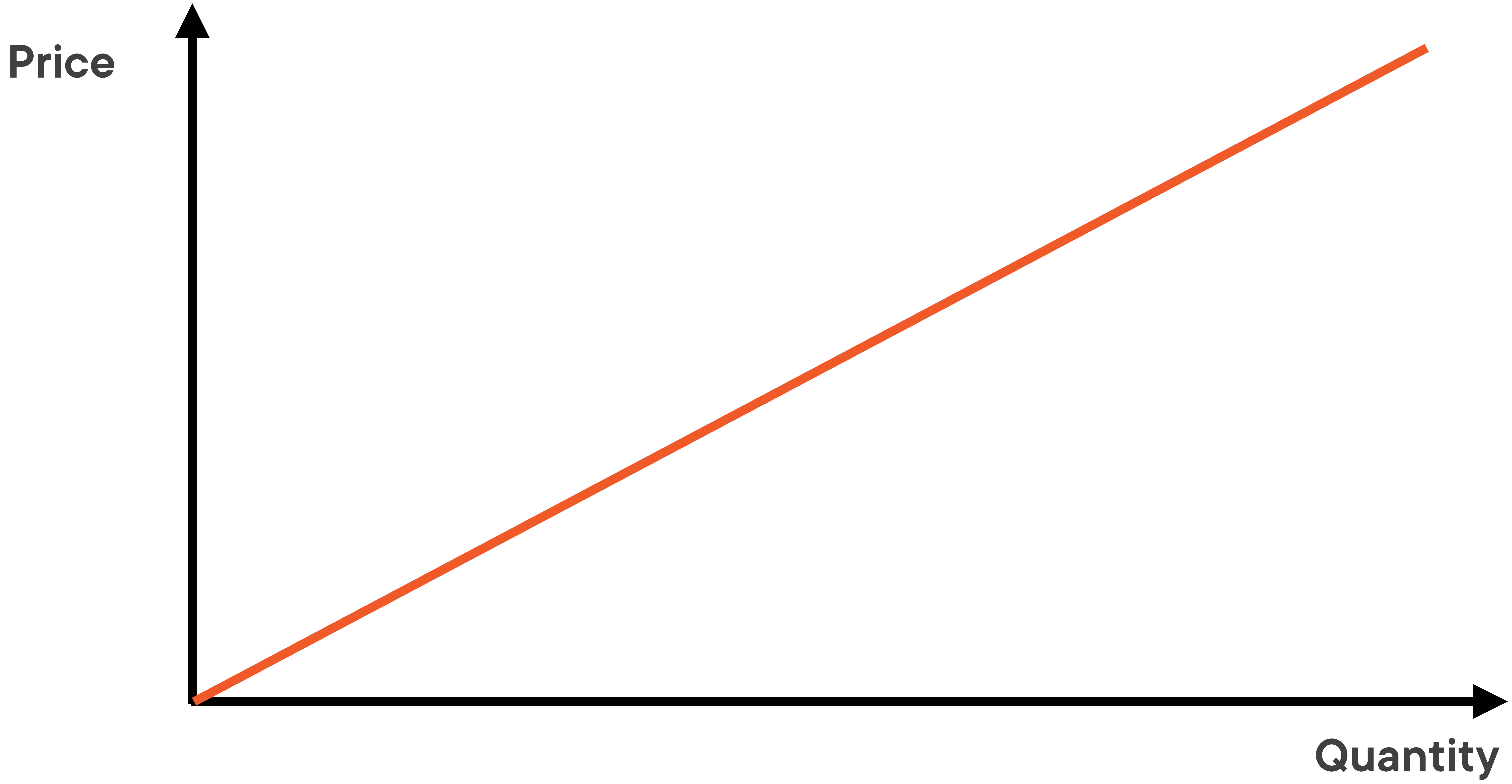


Law of Supply

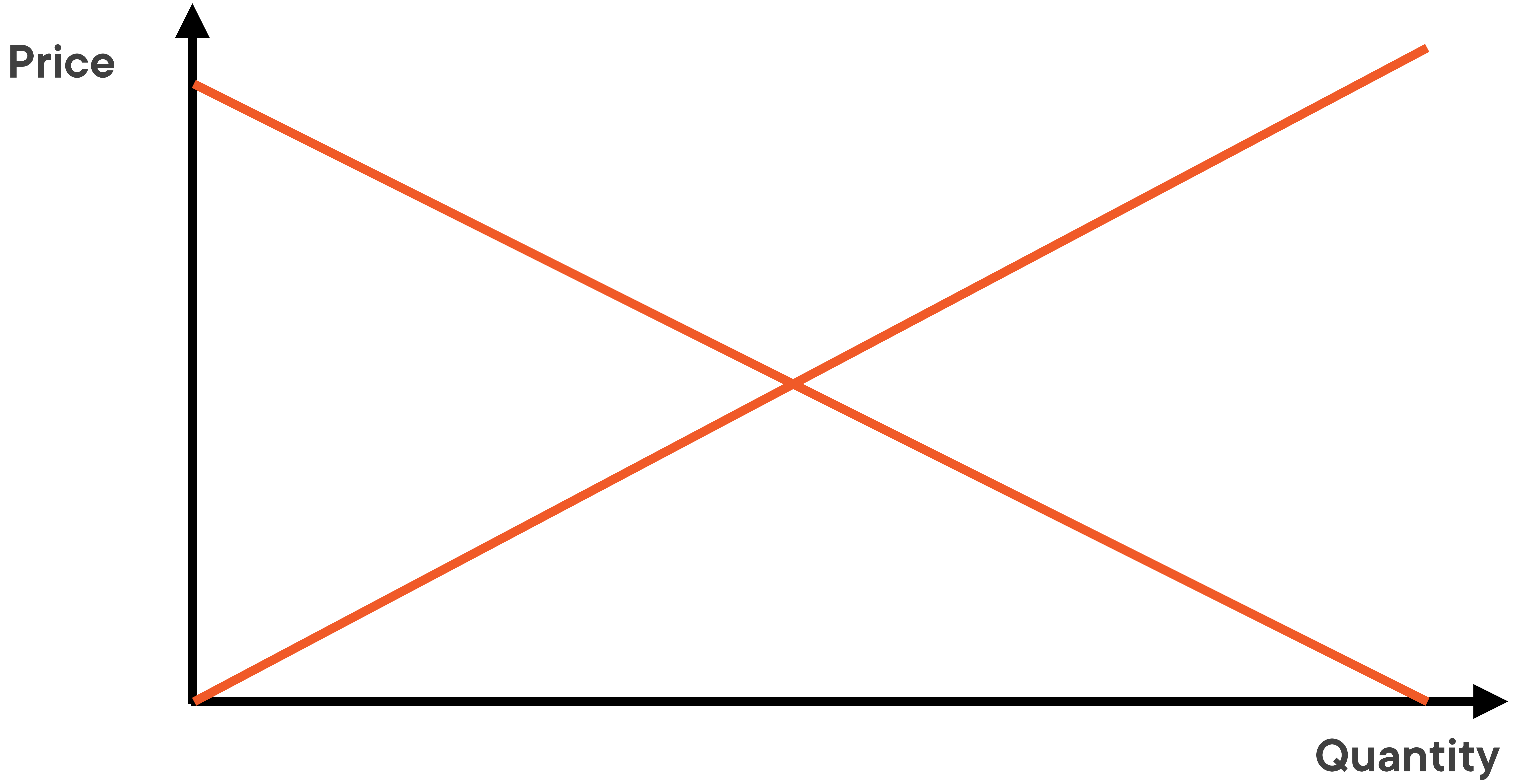
If all other factors remain equal, the higher the price of a good, higher the quantity supplied

Supply Curve

Supply Curve



Law of Supply and Demand



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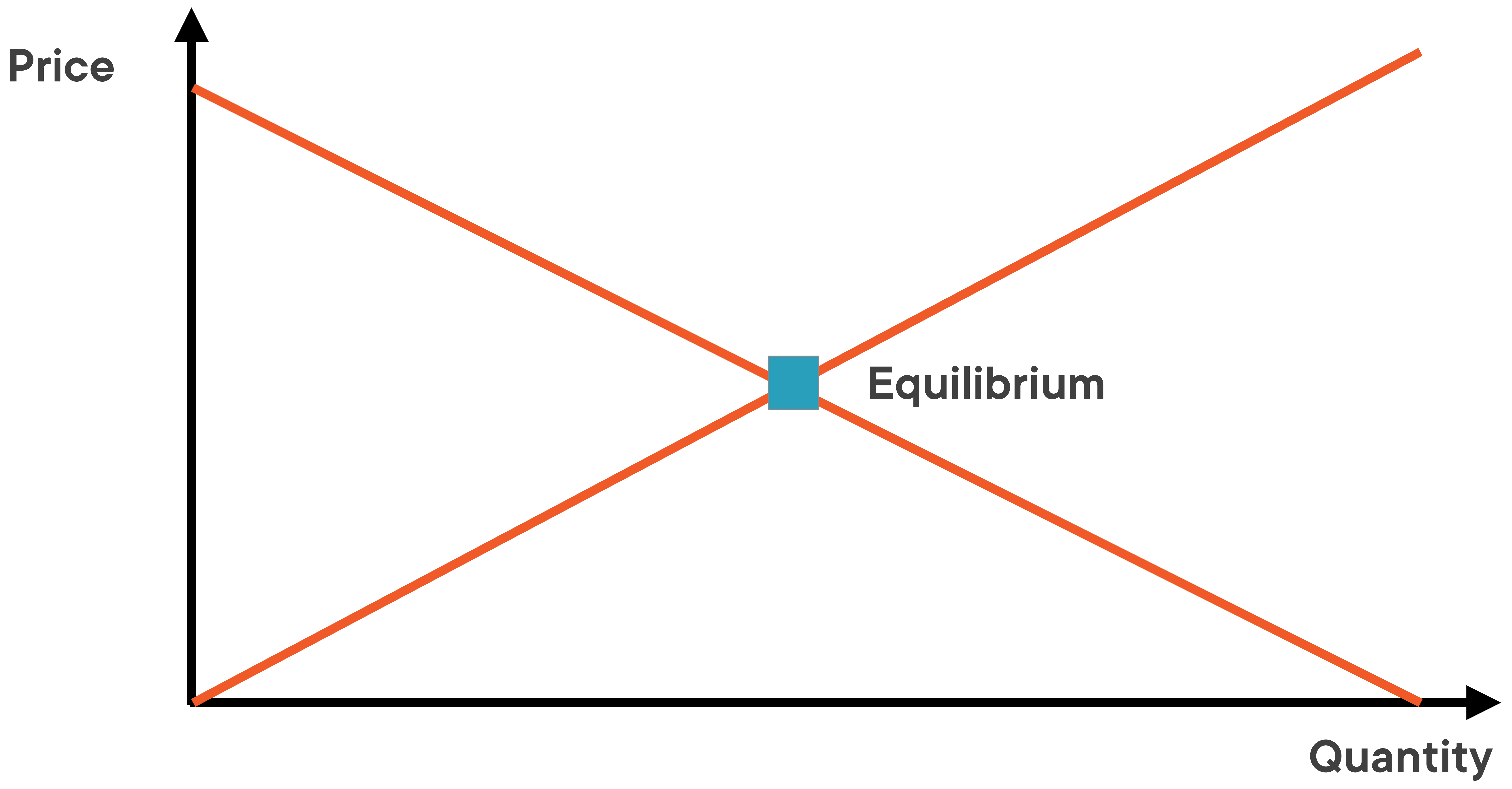

Elasticity of Demand

Refers to how sensitive demand for a good is compared to changes in other economic factors such as price or income

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Refers to how **sensitive** demand for a good is compared to changes in other economic factors such as price or income

Elasticity of Demand

Price elasticity of demand

Income elasticity of demand

Substitute elasticity of demand

Elasticity of Demand

Price elasticity of demand

Income elasticity of demand

Substitute elasticity of demand

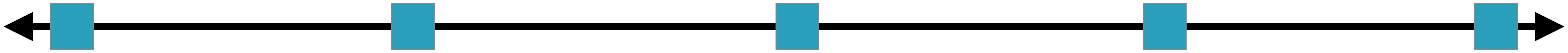
Price Elasticity of Demand

Price elasticity of demand is a measure of the change in the quantity purchased of a product in relation to a change in its price.

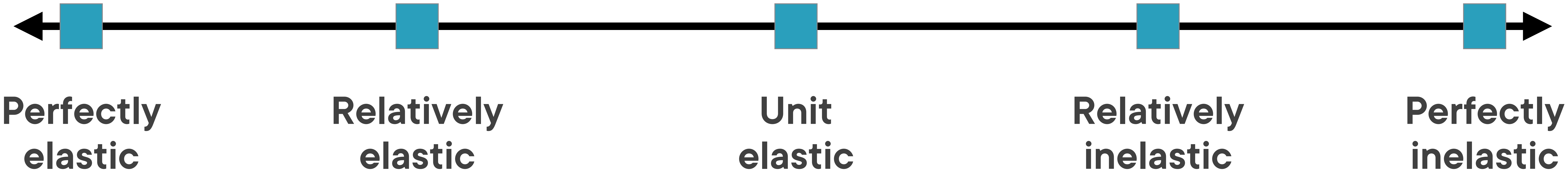
Price Elasticity of Demand

$$\text{Price elasticity of demand} = \frac{\text{Percentage change in quantity demanded}}{\text{Percentage change in price}}$$

Price Elasticity of Demand



Price Elasticity of Demand



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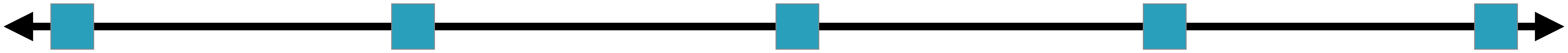
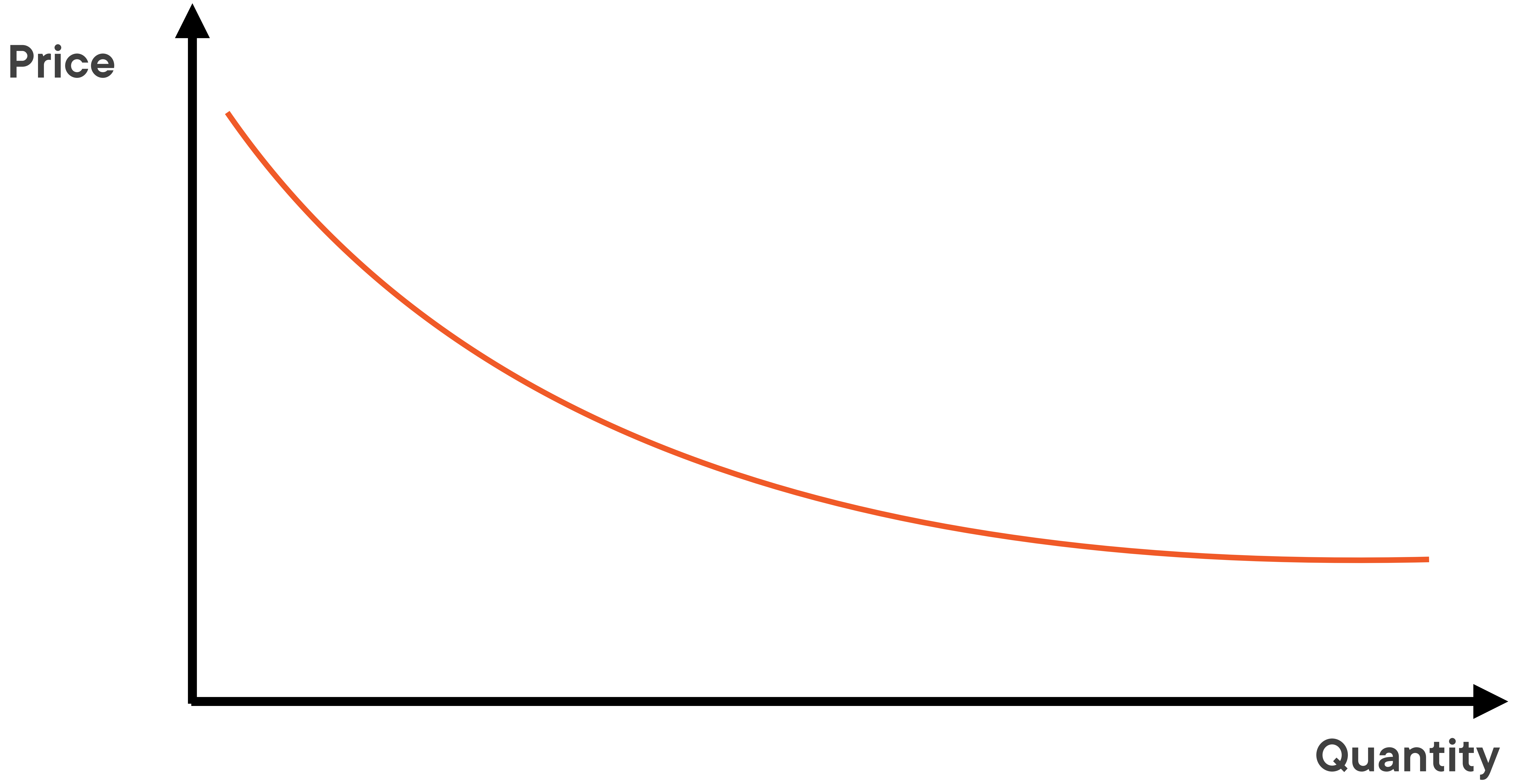


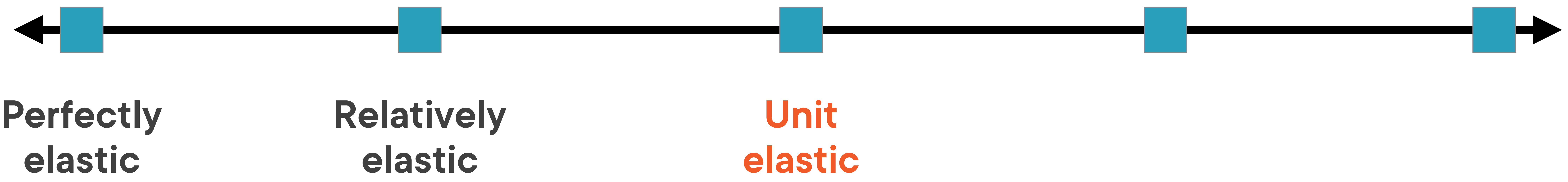
Perfectly elastic

Price Elasticity of Demand

Elastic Demand: Mobile Phones



Price Elasticity of Demand



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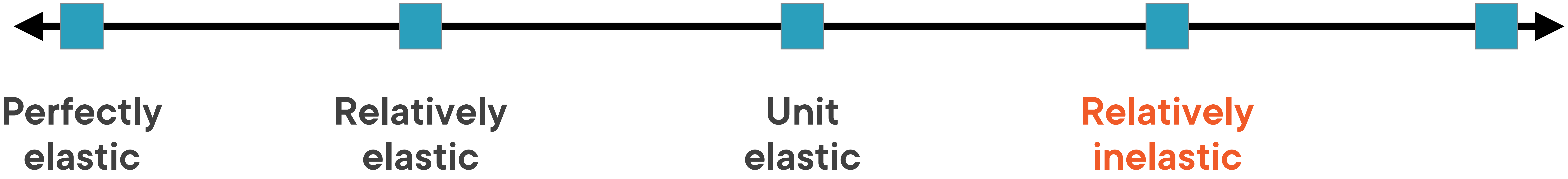

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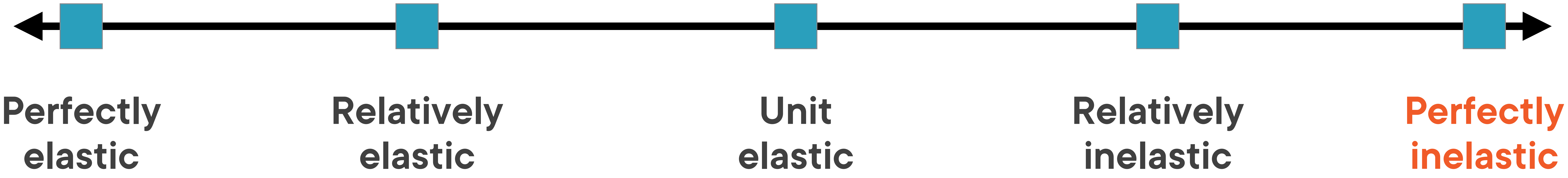
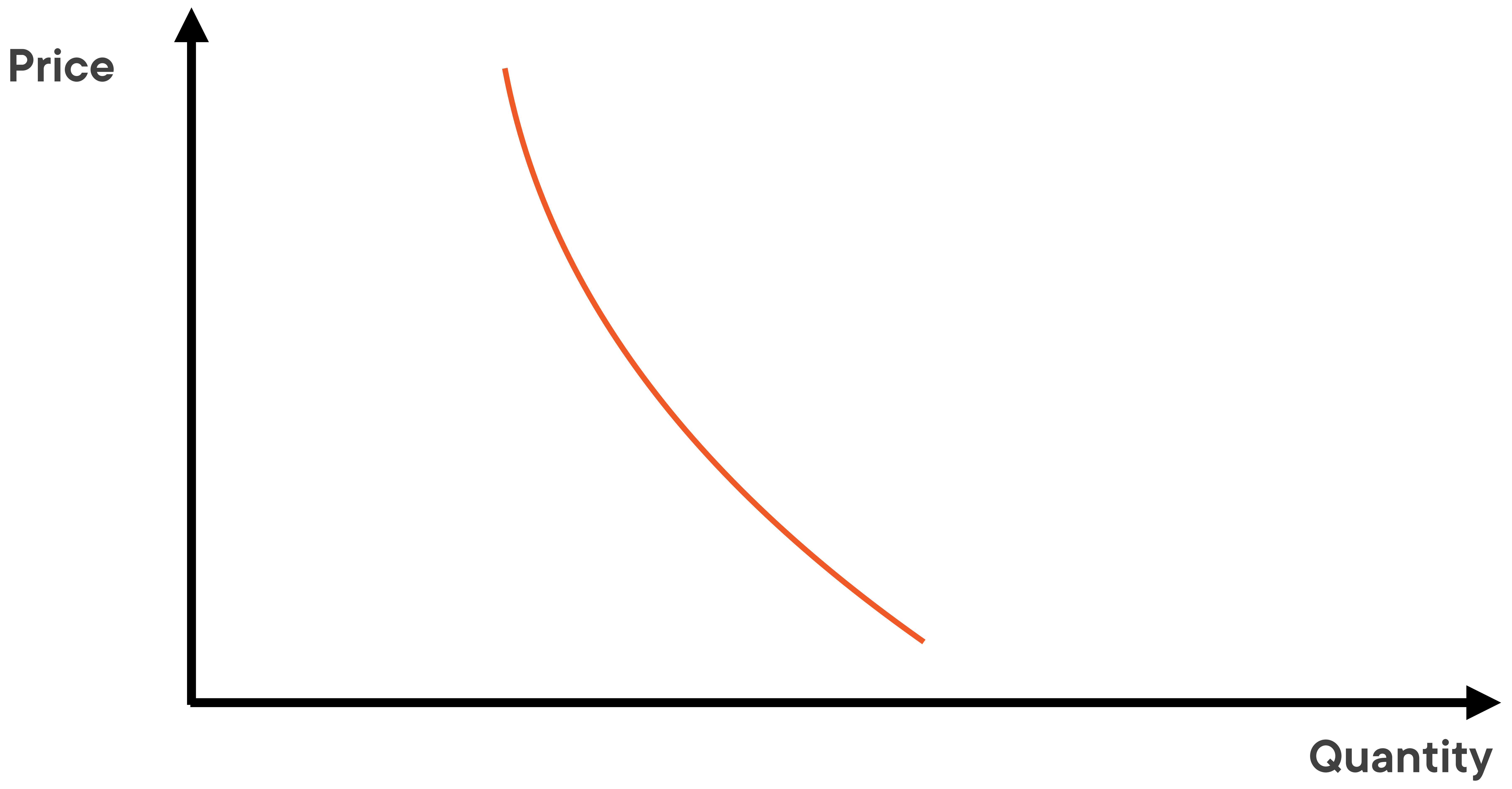


Inelastic Demand: Bread



Any firm’s goal would be to move their products **from relatively elastic to relatively inelastic**

Optimal Price Point

The price point of a product at which the total profit of the seller is maximized

https://www.accountingtools.com/articles/2017/5/13/optimal-price

Case Study: Price Optimization in Fashion E-commerce

Background and Context

Background and context of research paper and,
overview of steps and challenges faced

Fashion E-commerce: Optimal Price Point

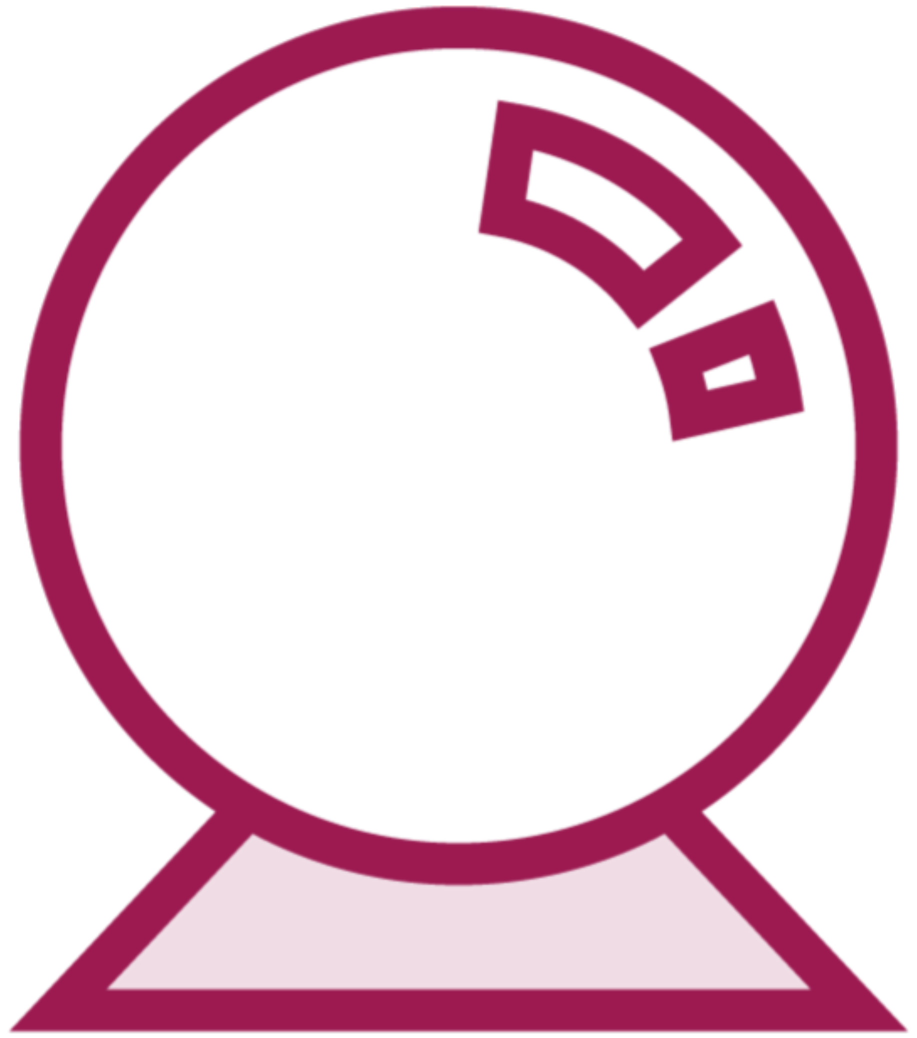
Optimal price point maximizes revenue and profit for the company

Use machine learning and optimization techniques to find optimal price points across products in many categories

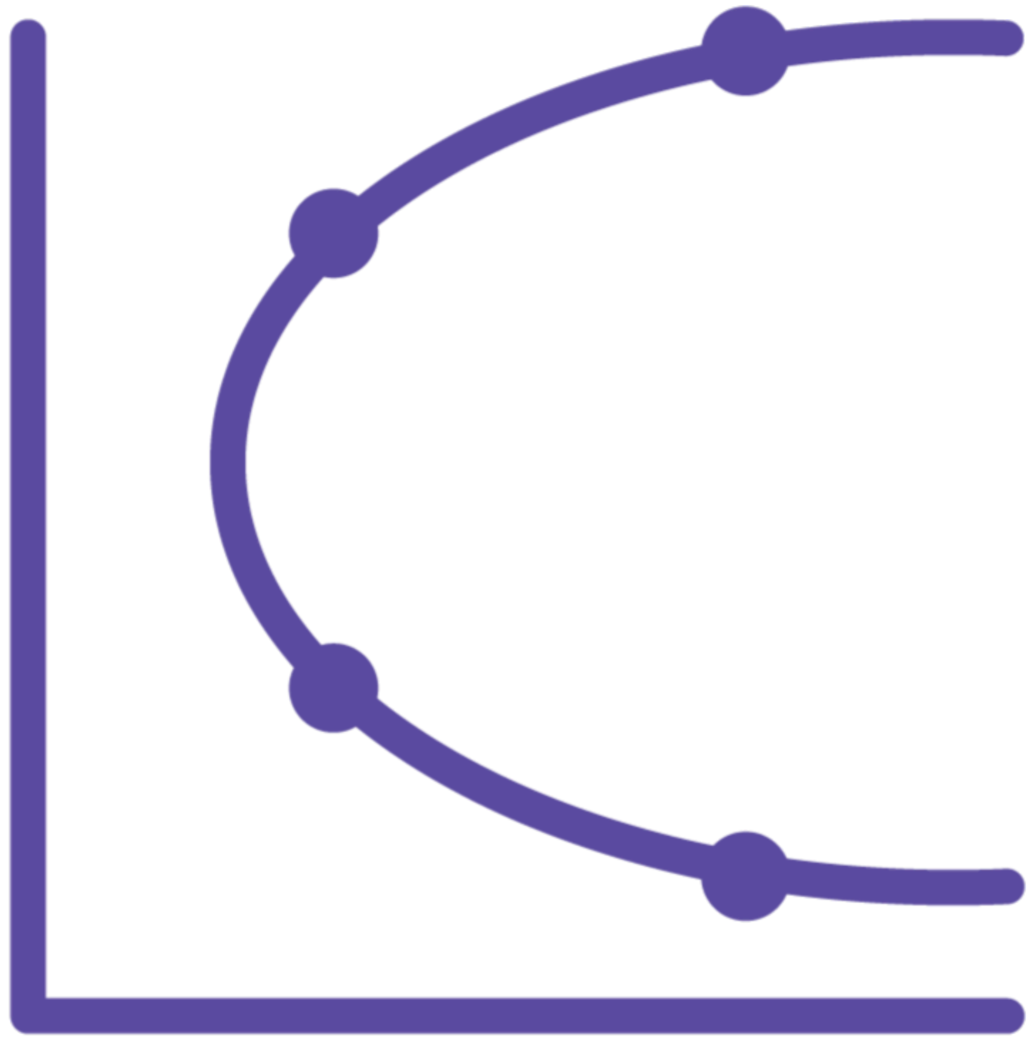
Myntra: Leading Indian fashion e-commerce company

https://arxiv.org/pdf/2007.05216v2.pdf

Three Main Components



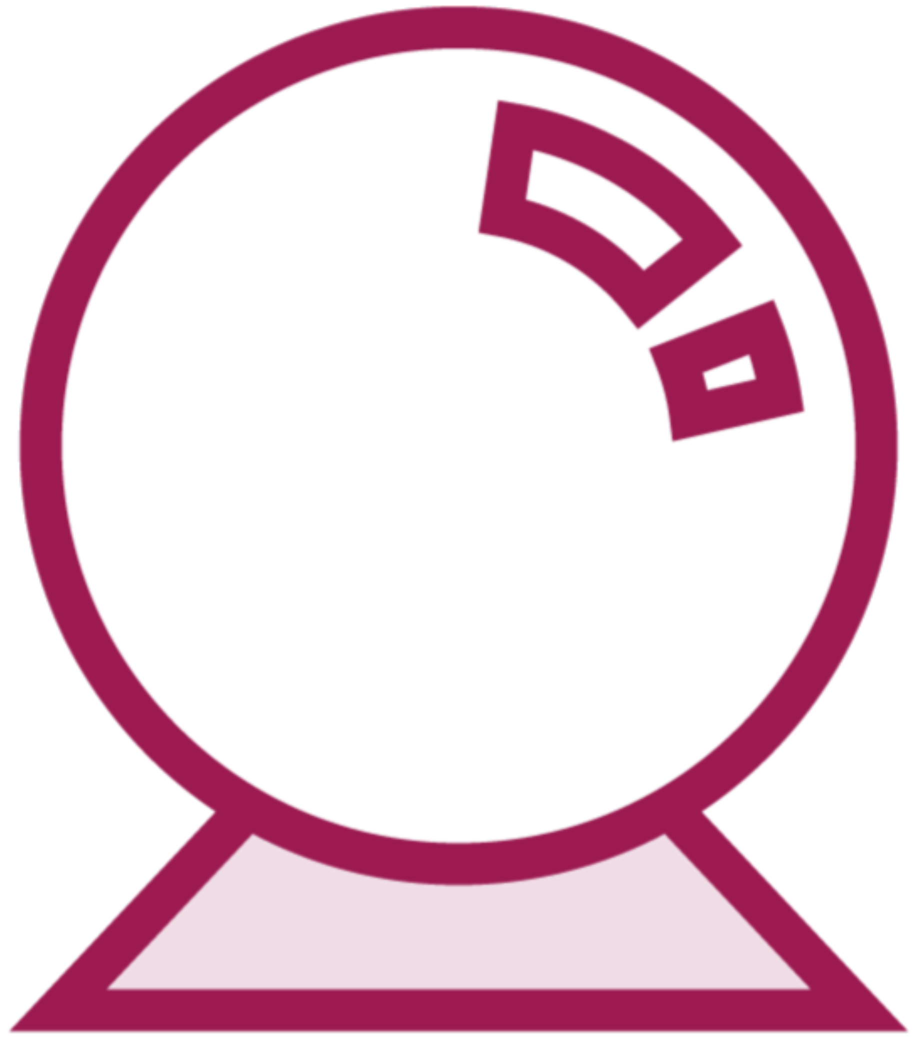
Demand prediction model



Compute price elasticity of demand

Linear programming optimization

Three Main Components



Demand prediction model

Compute price elasticity of demand

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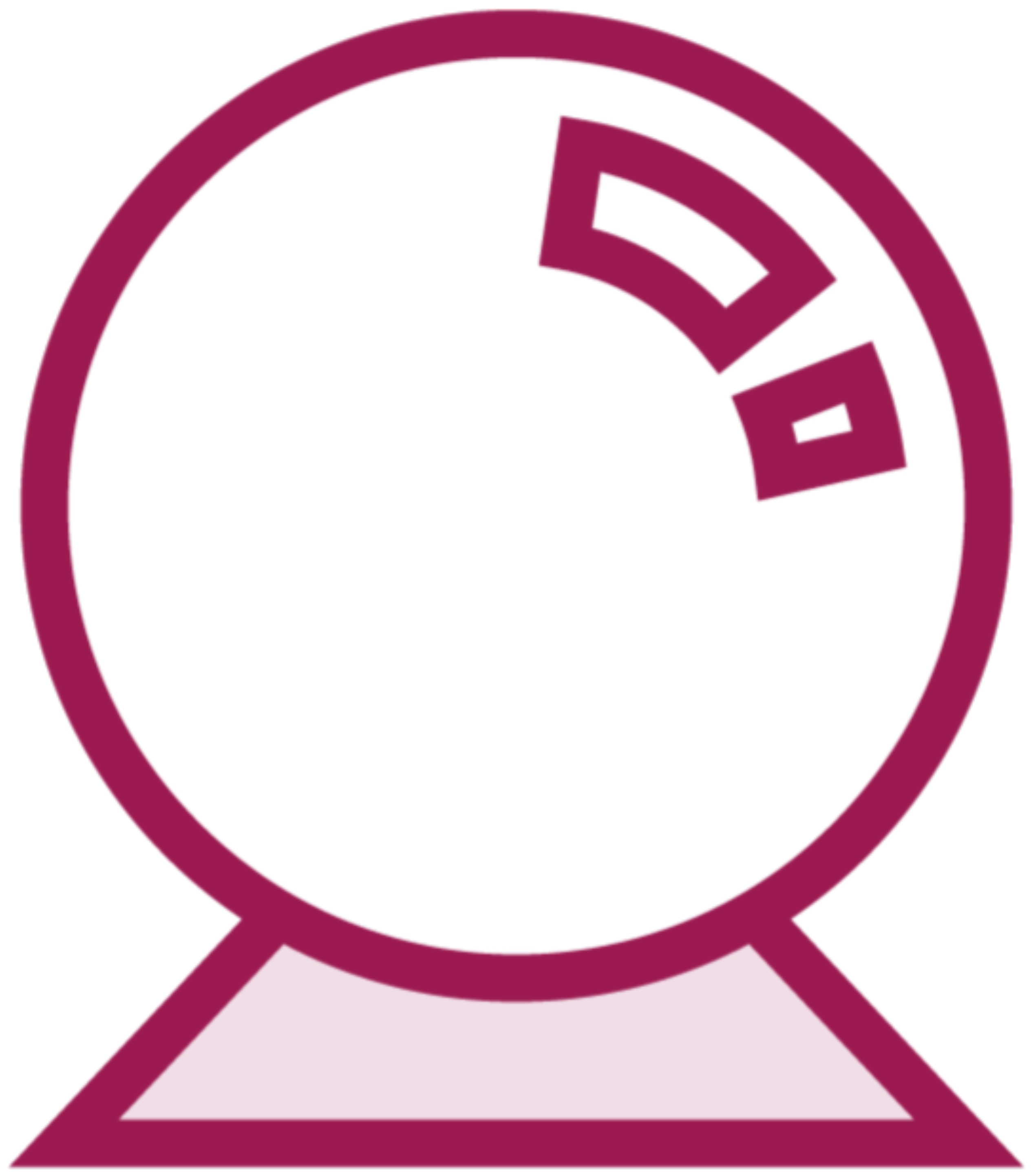
Demand Prediction Model

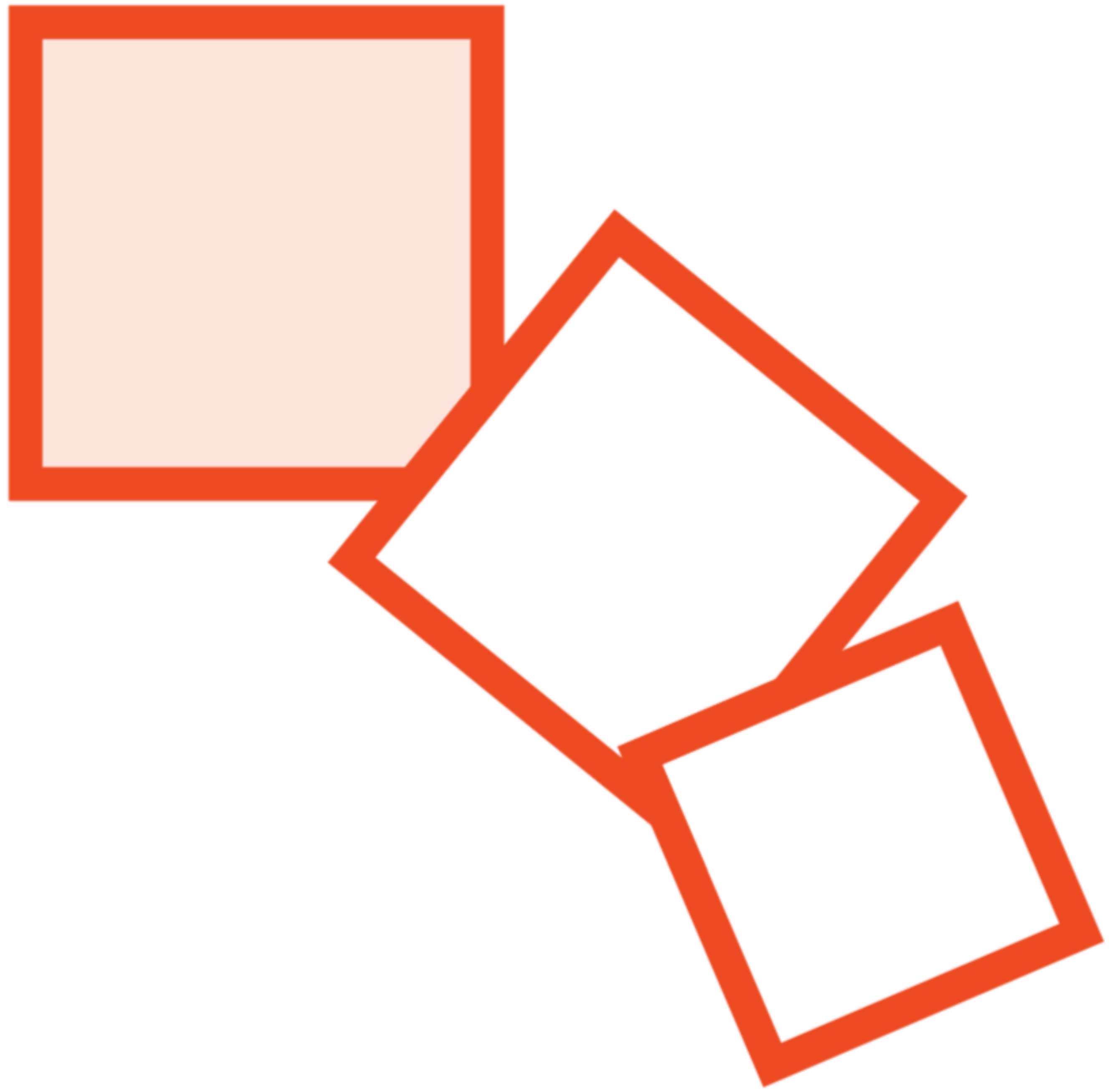


Predict the next day's demand for each product at a certain discount

Discounted prices have better click-through and conversion rates

Model trained on historical sales and browsing clickstream data

Cannibalization Across Brands



Can lead to cannibalization among products on the platform

Increasing the discount on a product might reduce sales of a competing product

To overcome this:

- Model run at a category level
- Created features at a brand level

Cold-start Problem

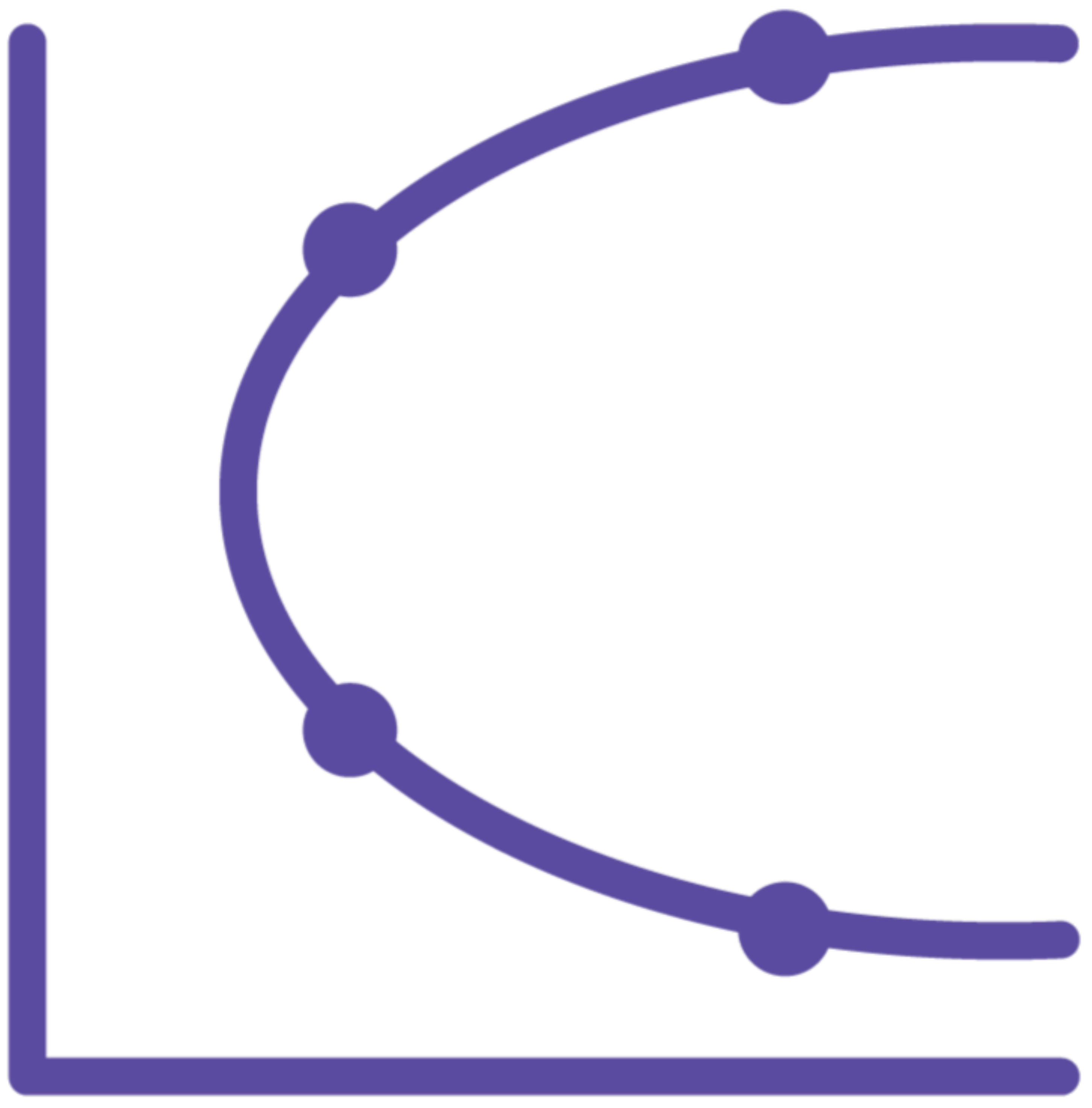
Predicting demand for new products with no browsing or sales history

Used deep-learning models to learn product embeddings

Embeddings used as features in the demand prediction model

Generates demand for all products for the next day at the base discount value

Price Elasticity of Demand



Use price elasticity of demand to get demand at different discount values

Gives multiple price-demand pairs for each product

Select a single price point for every product to maximize revenue

Linear Programming

Use linear programming to find the right optimal price for every product

Objective function to maximize revenue

Deployed solution and ran A/B tests on regular vs. optimized prices

Methodology and Results

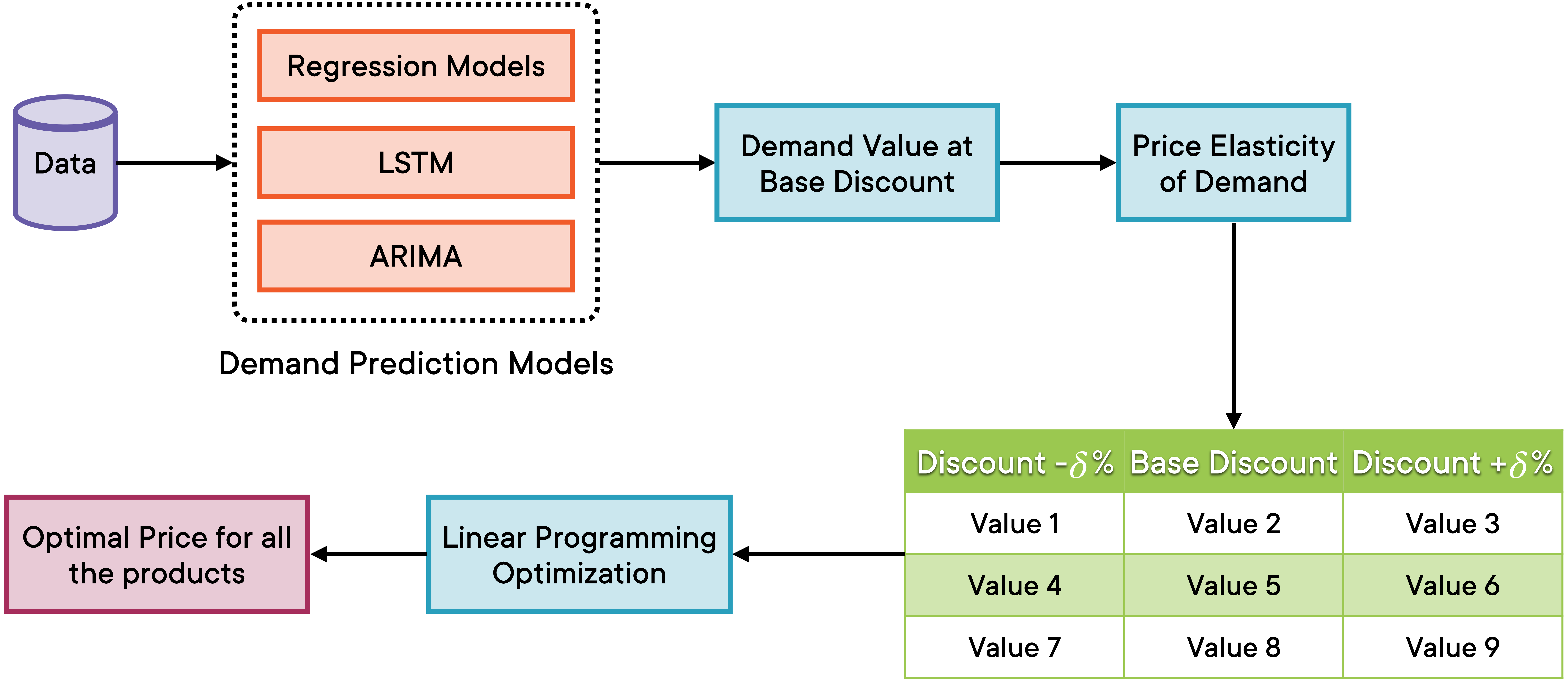
Data sources, feature engineering,
models used, and results

Optimal Price Points for all Products

$$R = \sum_{i=1}^{n} p_i, q_i$$

p_i is the price assigned to the i^{th} product
and q_i is the quantity sold of the i^{th} product

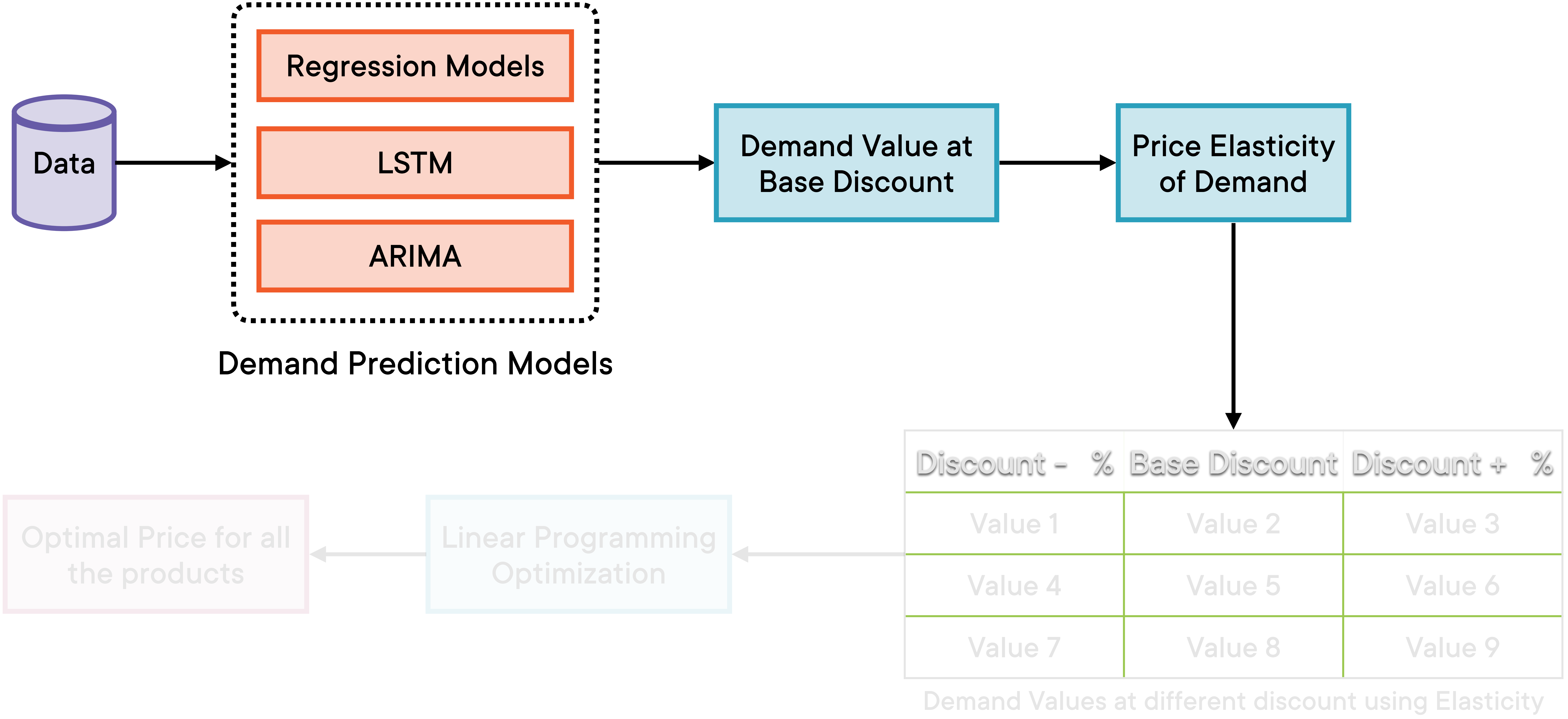
Price Optimization Workflow



Discount -δ%	Base Discount	Discount +δ%
Value 1	Value 2	Value 3
Value 4	Value 5	Value 6
Value 7	Value 8	Value 9

Demand Values at different discount using Elasticity

Price Optimization Workflow



Data Sources

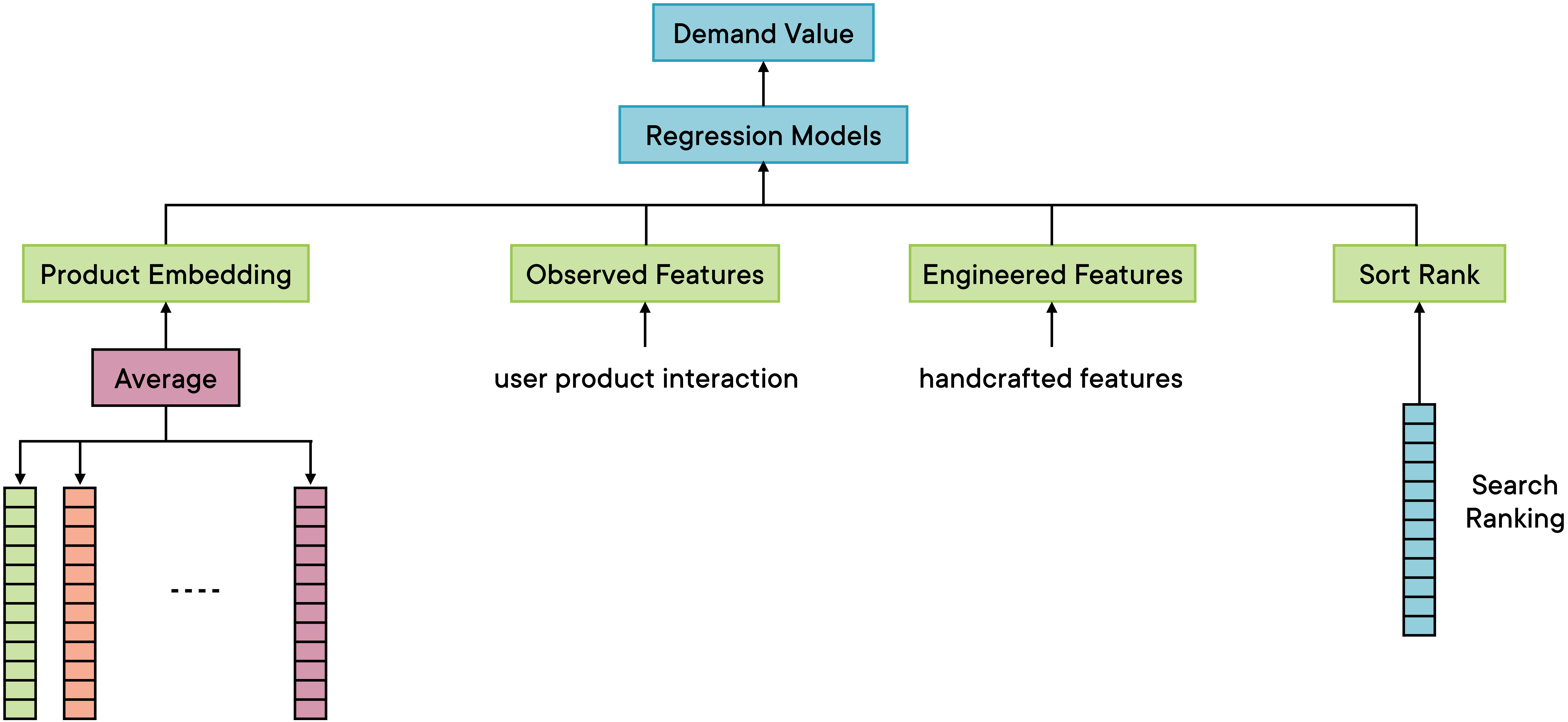
Clickstream data: User activity such as clicks, carts, orders etc.

Product catalog: Details of a product like brand, color, price, and other attributes

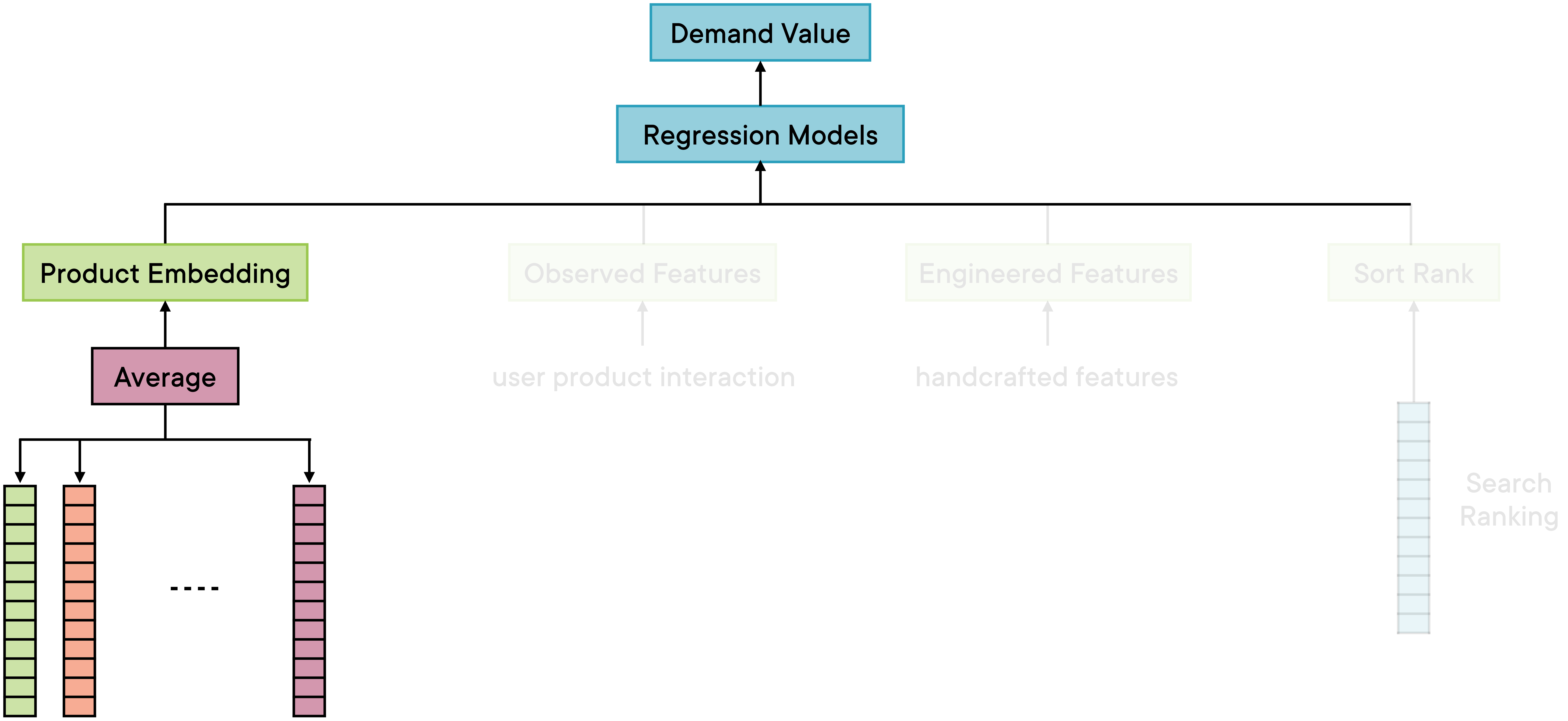
Price data: Price and quantity of product sold at hour-level granularity

Sort rank: Search rank and corresponding scores for all live products on the platform

Feature Engineering



Feature Engineering



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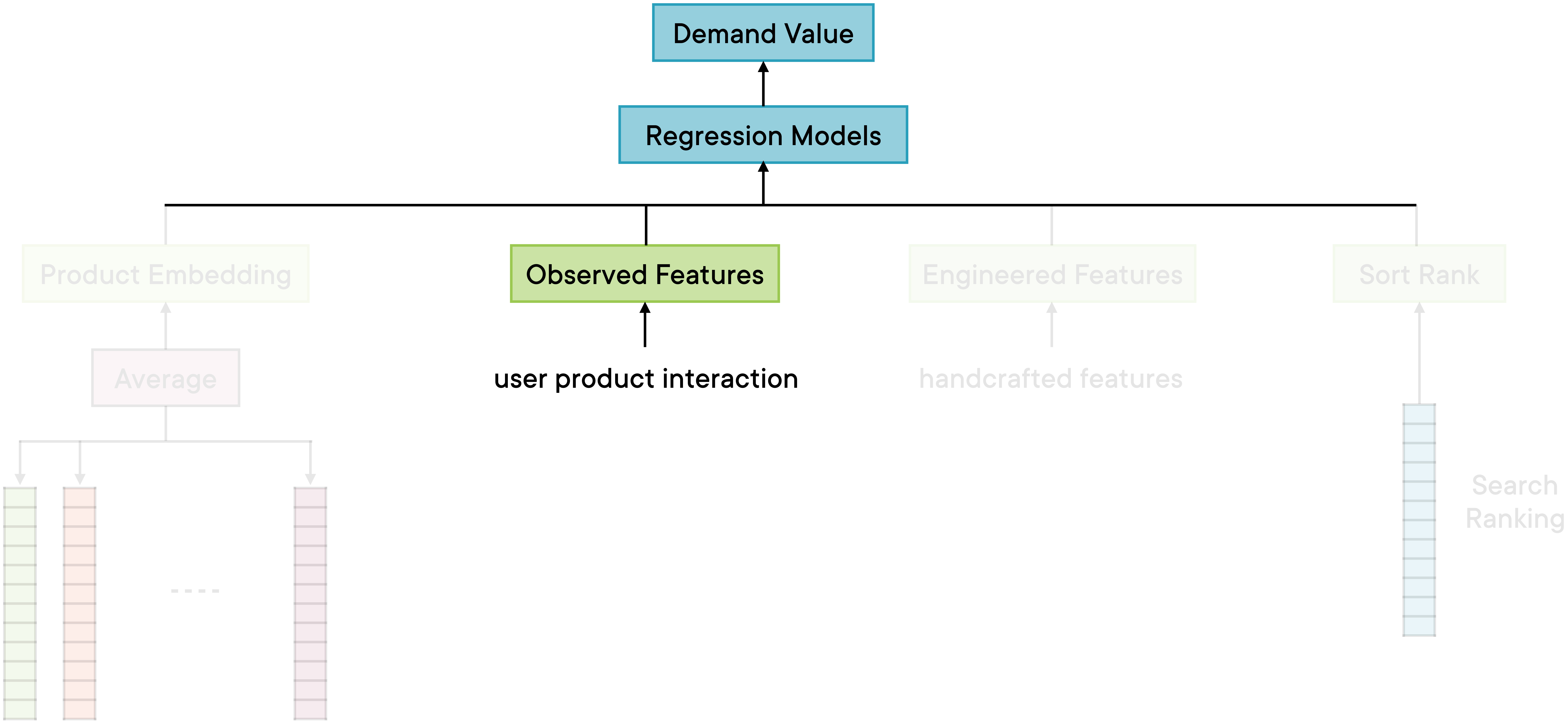

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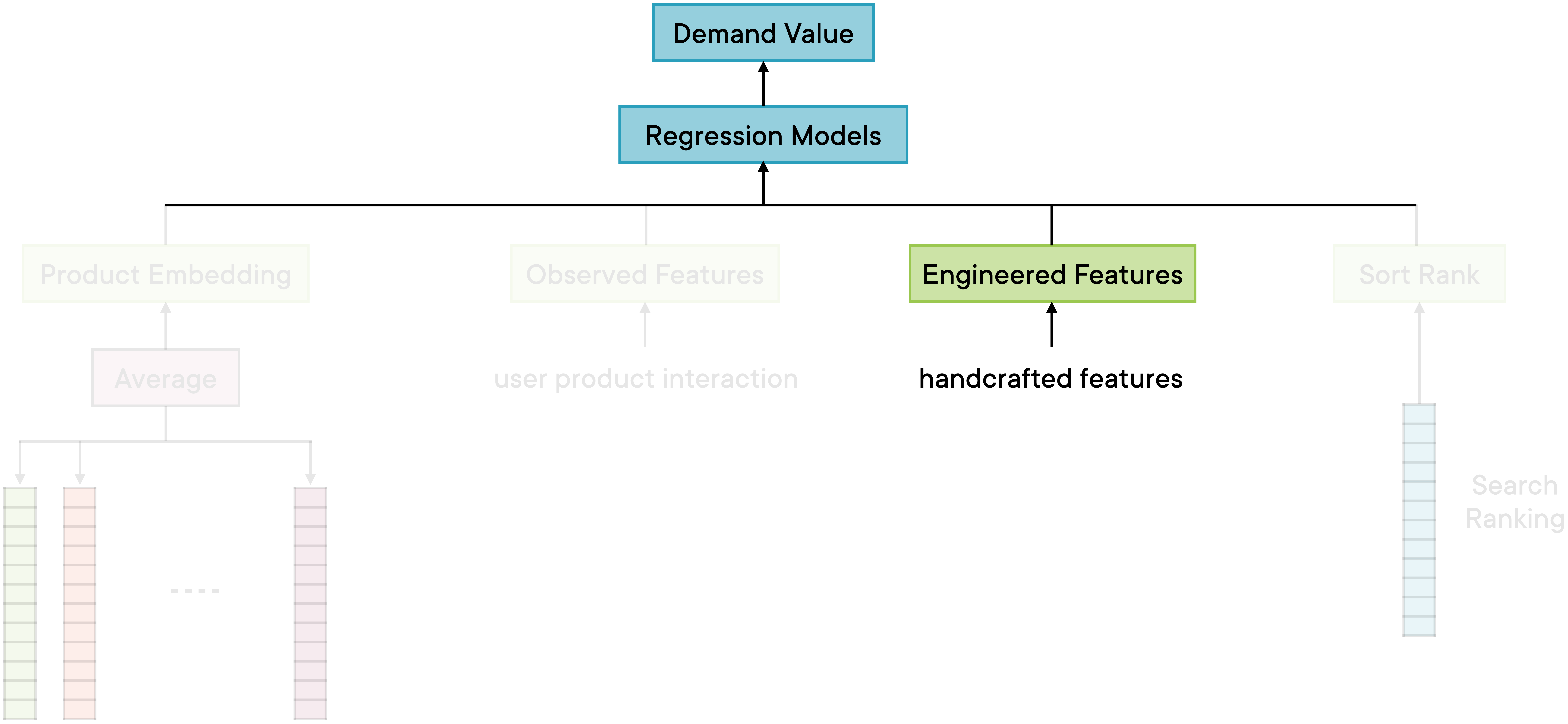

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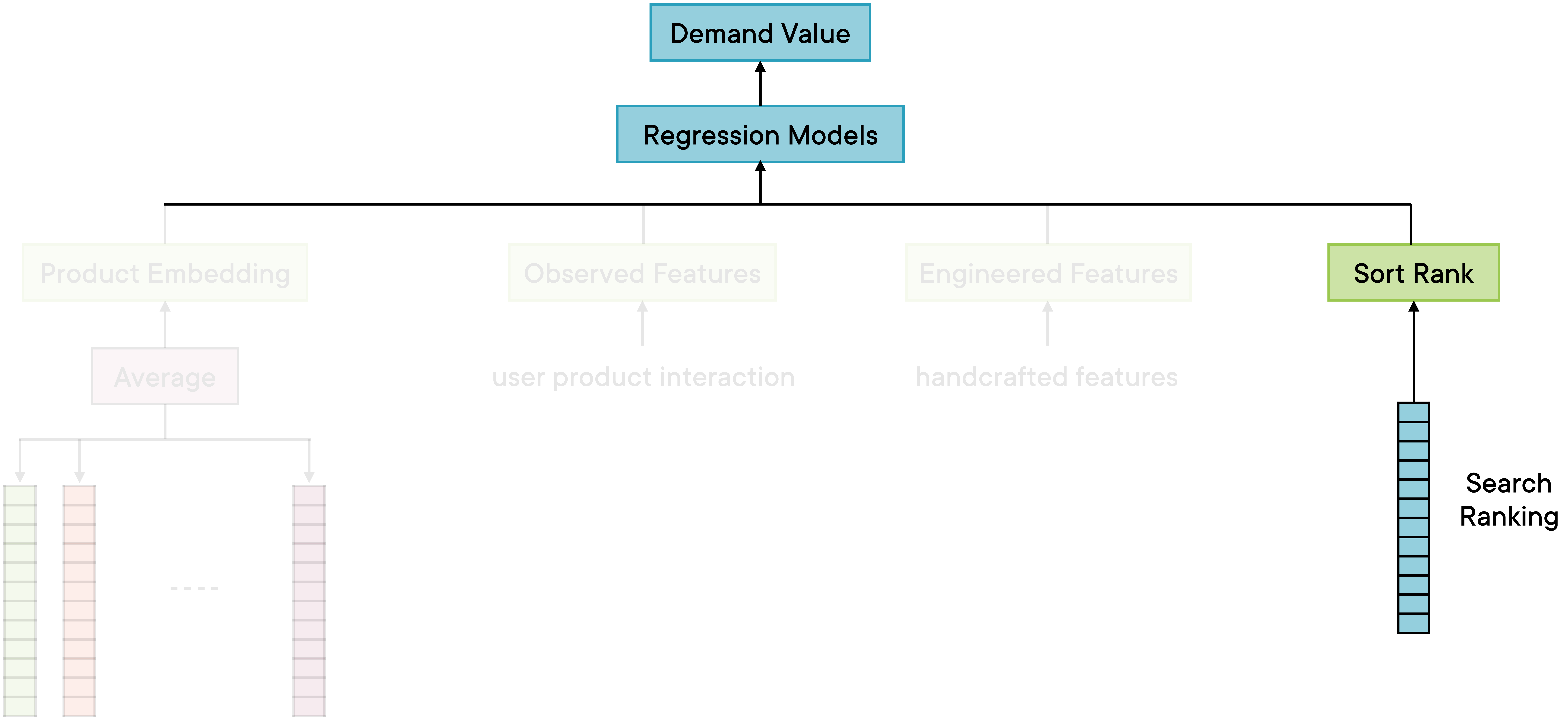
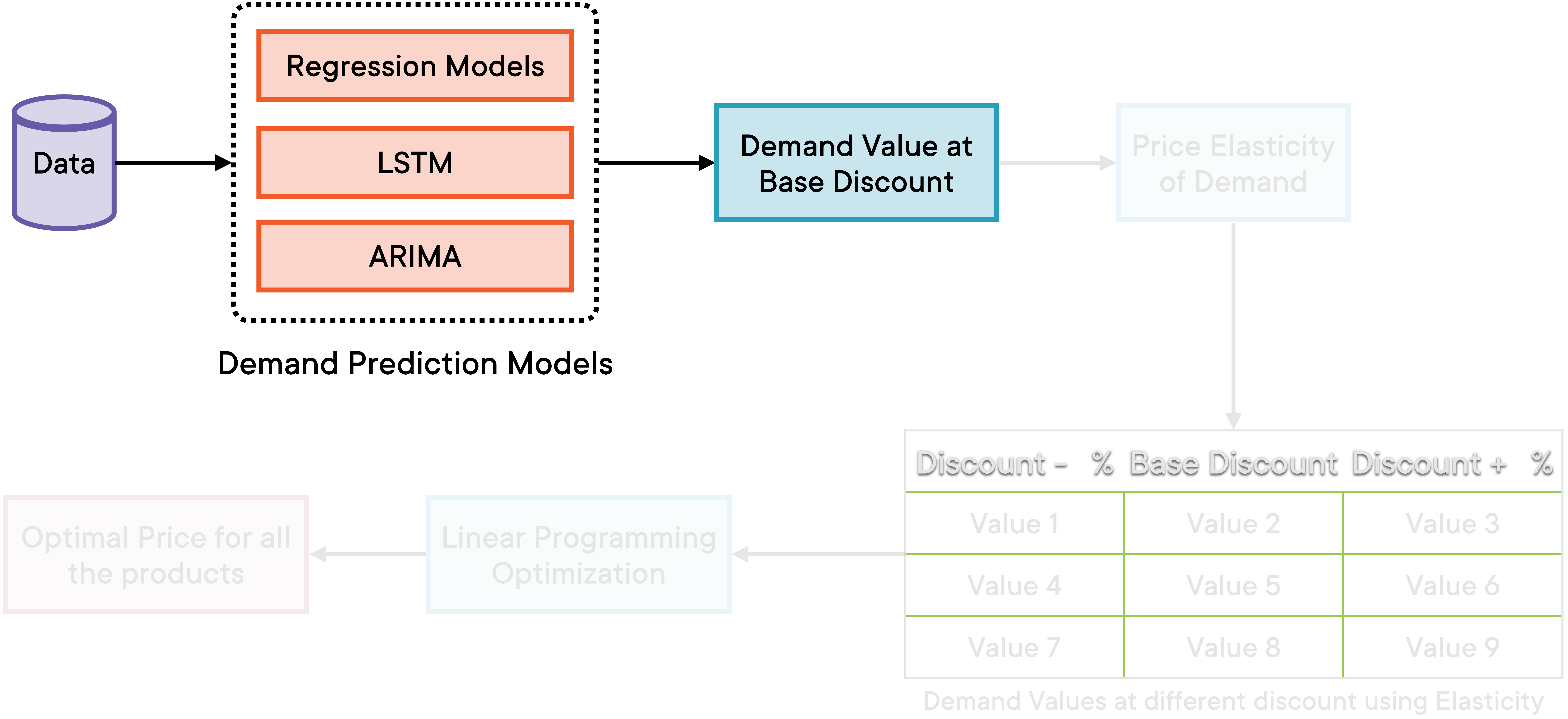
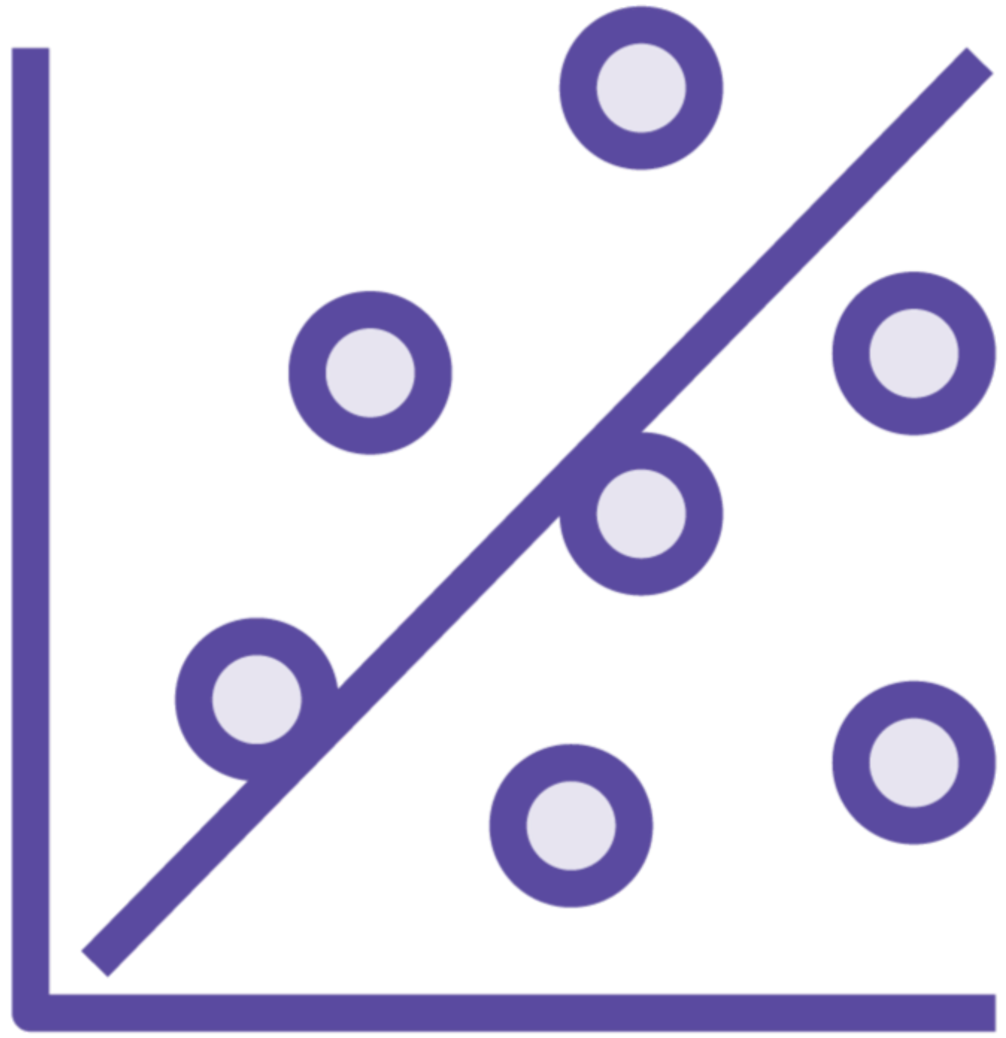


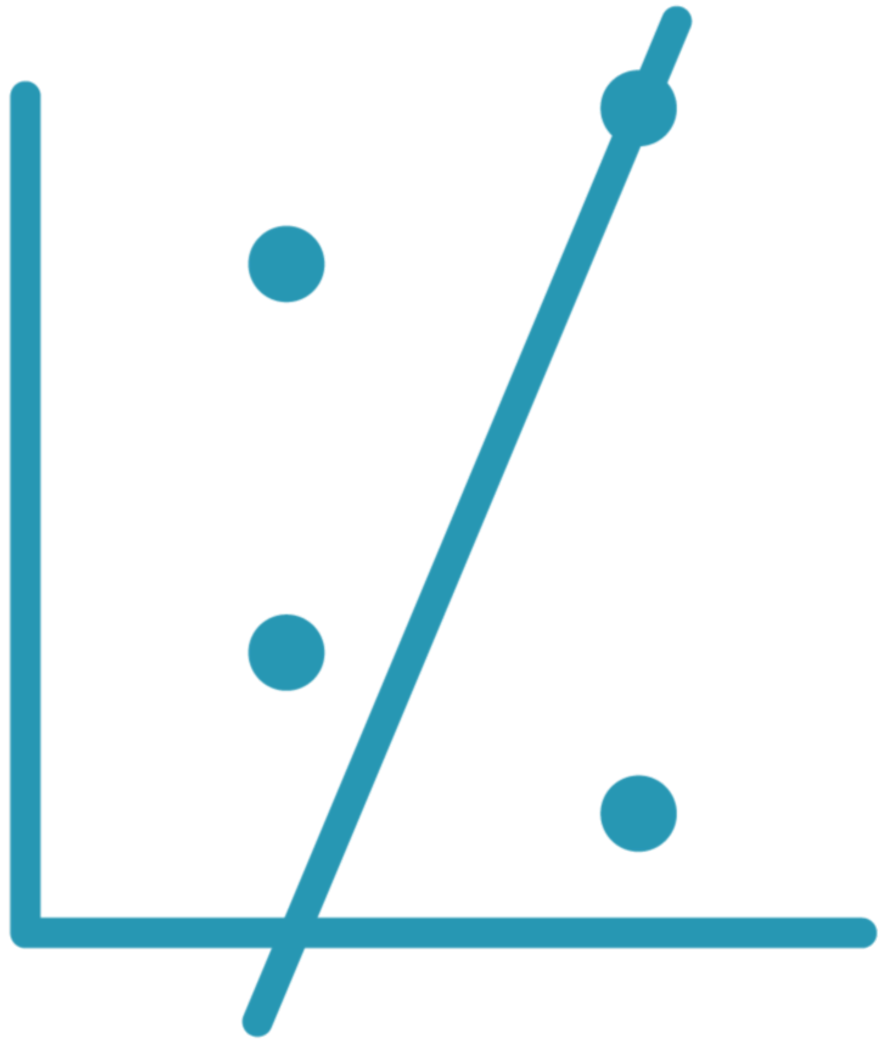
Price Optimization Workflow



Demand Prediction Model



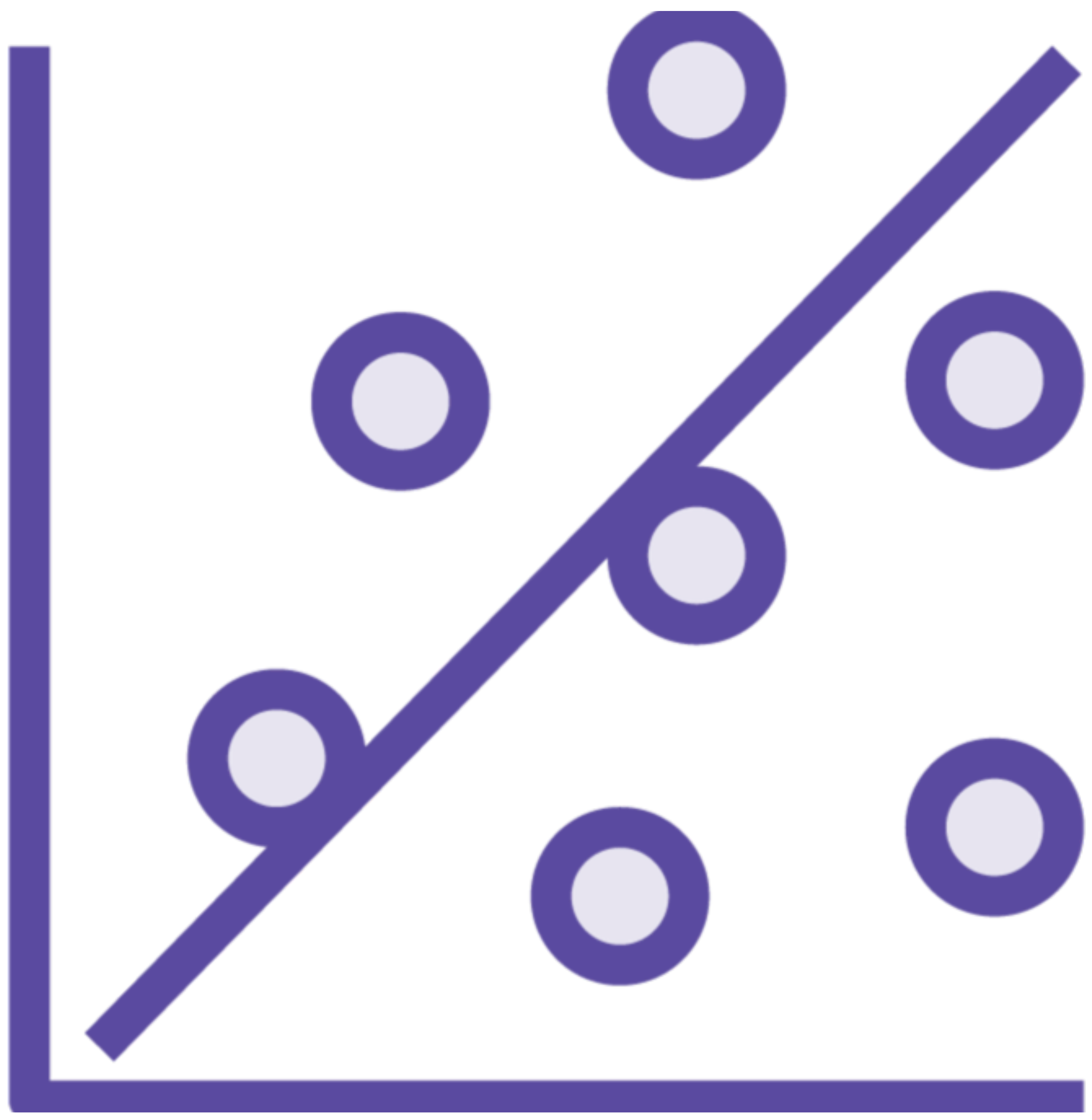
Regression models



ARIMA

Sequence model with LSTM

Regression Models



Linear regression

Random forest

XGBoost

MLP Regressor

Ensemble of all models specified above

ARIMA Model

Class of statistical models for analyzing and forecasting time series data

ARIMA Model

AutoRegressive Integrated Moving Average

ARIMA Model

Autoregression: A model that uses the dependent relationship between an observation and some number of lagged observations

Integrated: Subtracting an observation from an observation at previous time step to make the time series stationary

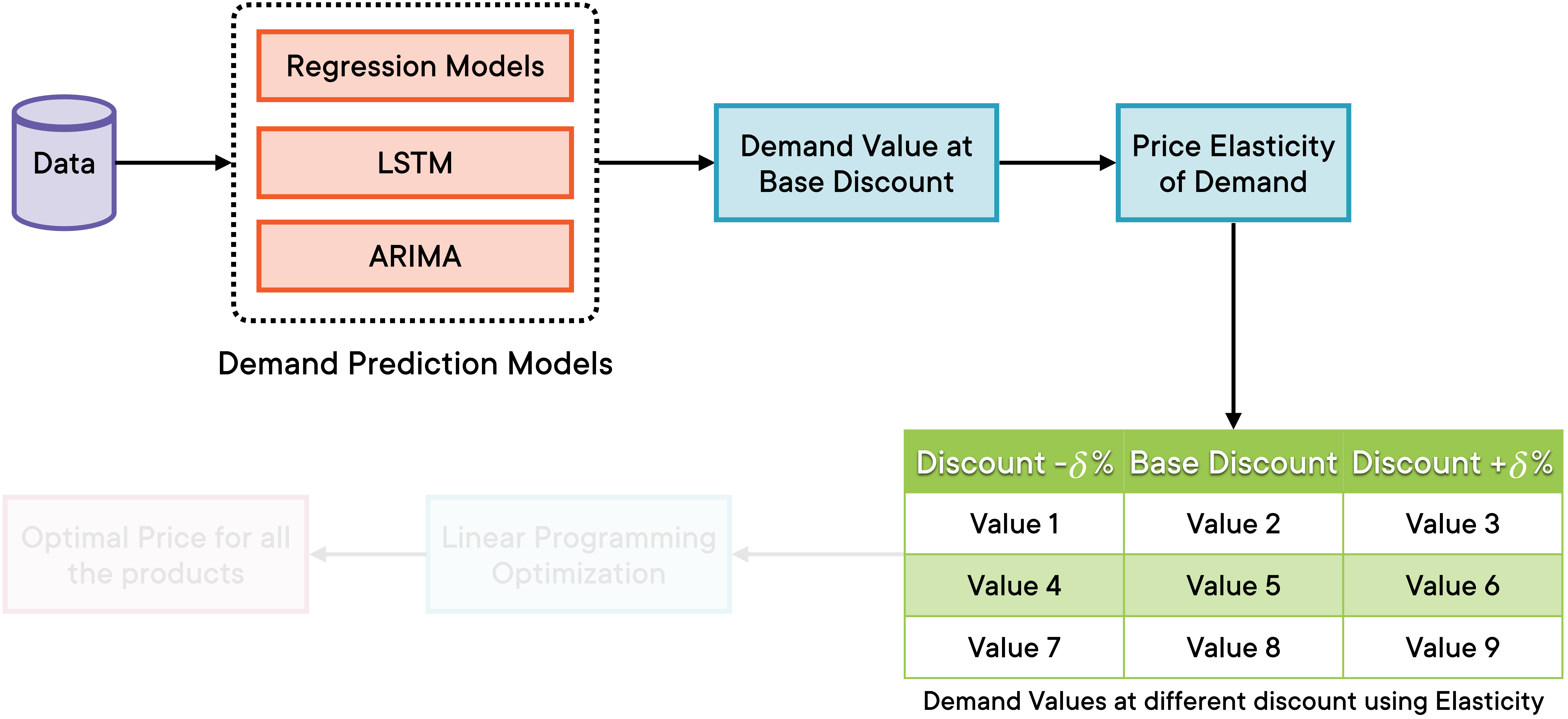
Moving Average: Uses the dependency between an observation and a residual error from a moving average model applied to lagged observations

LSTM RNNs

Recurrent Neural Networks (RNNs) a sequential model that performs well on time series data

LSTM or Long Short Term Memory cells improve the performance of RNNs

Price Optimization Workflow



Price Elasticity of Demand

Price elasticity of demand is a measure of the change in the quantity purchased of a product in relation to a change in its price.

Price Elasticity of Demand

Individual products display different kinds of price elasticity

Price elasticity cannot be computed at a brand, category, or a global level

Computed for each product individually

Based on historical price-demand pairs for the product

Price Elasticity of Demand

Demand value at base discount price available from demand prediction model

Use a discount threshold of d%

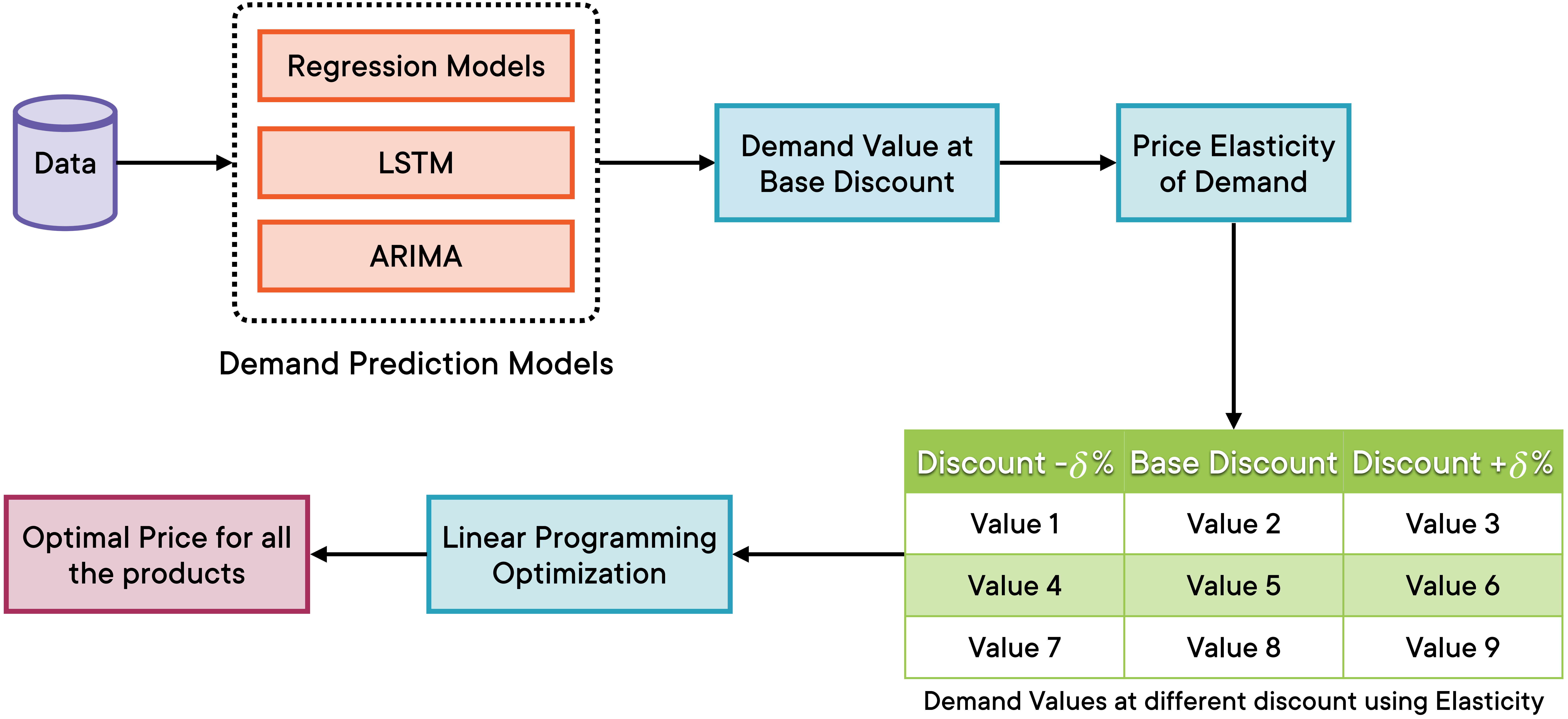
Compute 2 more demand values:

Base discount + d%

Base discount - d%

Total of 3 price points and 3 demand values for each product

Price Optimization Workflow



Linear Programming

Need to choose one of 3 prices for each product

3 price points and N products = 3^N options

Price points are discrete values not continuous

Integer programming problem

Integer programming problems very hard to solve - formulation proved computationally intractable

Linear Programming

Problem made tractable by reducing to a linear programming problem

Used Scipy to solve problem

A/B Testing

To test hypothesis that model prices are better than baseline prices

Set A - Control group shown baseline prices

Set B - Treatment group shown model prices

Percentage Increment in Revenue

	Percentage increment in Revenue	*GM % Uplift*
Test 1	0.96%	0.99%
Test 2	1.96%	0.95%
Test 3	0.09%	0.49%
Test 4	3.27%	-0.41%
Test 5	7.05%	0.15%

Different Categories of Products

	Percentage increment in Revenue	*GM % Uplift*
Test 1	0.96%	0.99%
Test 2	1.96%	0.95%
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Impact on Revenue

	Percentage increment in Revenue	*GM % Uplift*
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Impact on Gross Margin

	Percentage increment in Revenue	GM % Uplift
Test 1	0.96%	0.99%
Test 2	1.96%	0.95%
Test 3	0.09%	0.49%
Test 4	3.27%	-0.41%
Test 5	7.05%	0.15%

Approximately 1% increase in revenue of the platform and 0.81% uplift in gross margin due to model recommended prices

Summary

Price elasticity of demand

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Up Next:
Case Study: Optimizing Supply Planning Using Machine Learning