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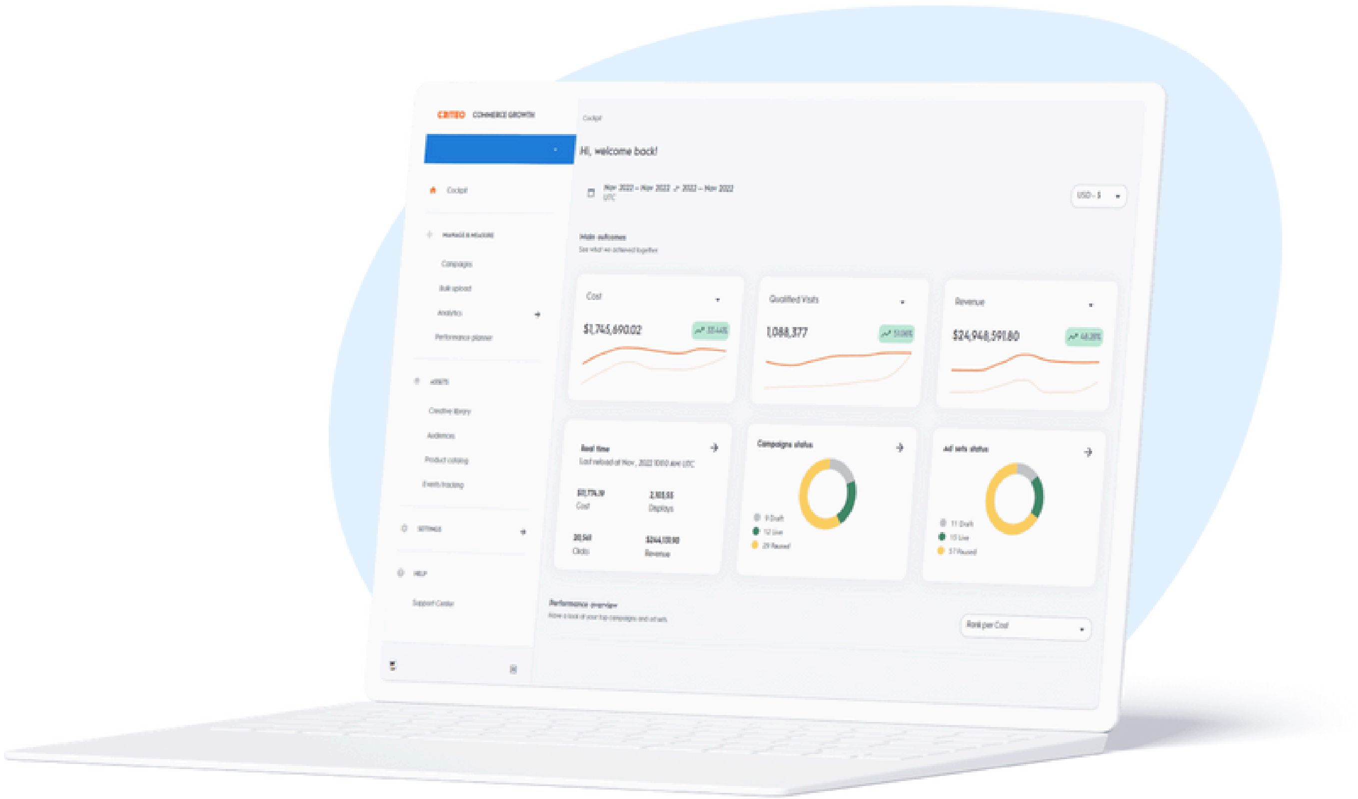
Bidding Model Evaluation at Criteo

Ecem Bayındır
Product Analytics



Project Objective

- Investigate and compare two **model-based bidding** strategies:
  - Linear Regression Bidding Model
  - Deep Learning Bidding Model

- Evaluate models using **profitability**, **prediction performance**, and **business impact**

- Recommend a **strategy for production deployment** at Criteo

Business Context

- **1,000 display** ad slots on CNN.com are auctioned for Criteo clients
- Two brands, Hollister and Fridge, bid using with **Linear Regression and Deep Learning Bidding Models**
- Clicks and conversions lead to **client's ROI** and **Criteo's revenue**

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Dataset Overview

- 30-day sample of **Criteo’s live traffic**
- **16.5M** impressions, **45K** conversions, **700** campaigns
- **Features** include:
  - Timestamp, User ID, Campaign ID, Conversion, Click, Cost, etc.
  - Categorical contextual features (cat1 to cat9).
- Public dataset **Link**
  - Released with AdKDD 2017 paper **by Criteo AI Lab**

Workflow Summary

- Data Cleaning & Preprocessing
- Feature Engineering
- Model Development (Linear Regression & Deep Learning)
- Threshold Optimization & Bidding Simulation
- A/B Testing (Simulated)
- Business Impact Evaluation

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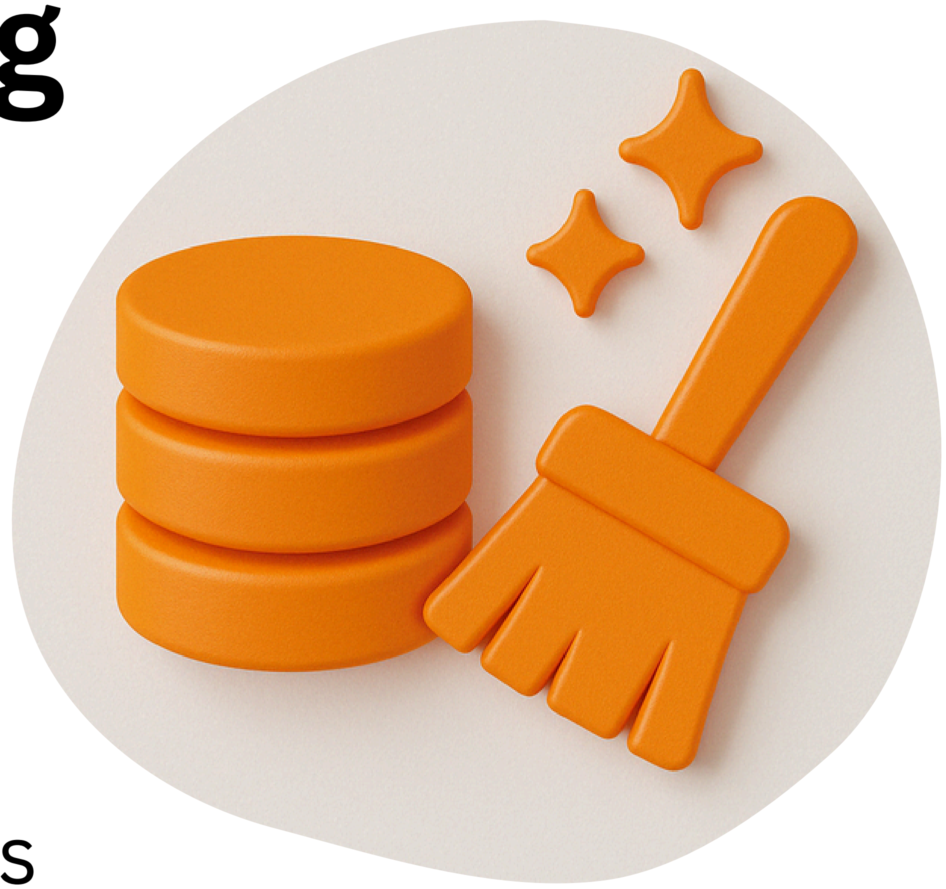
Data Cleaning and Processing



Data Cleaning & Processing

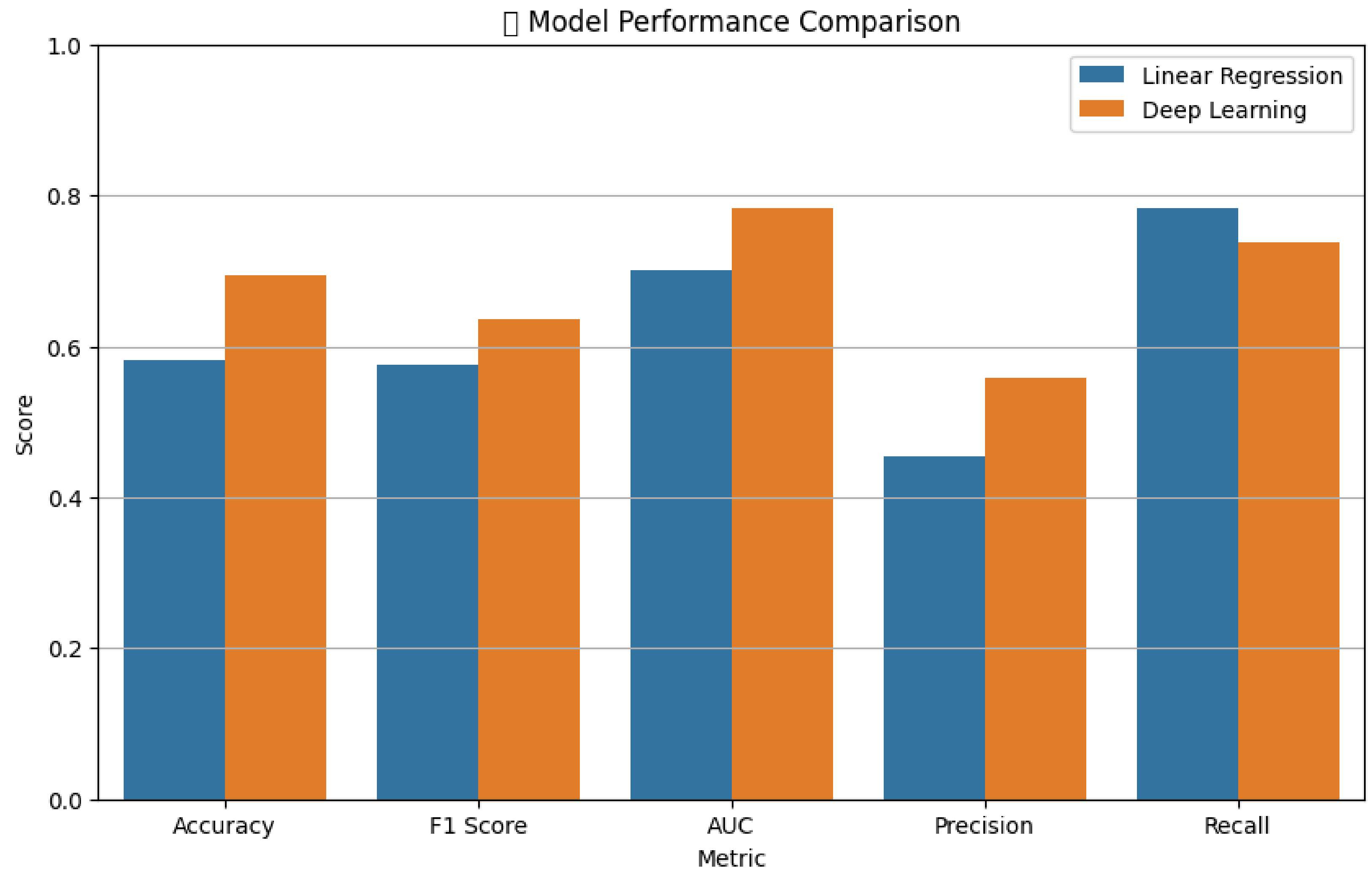
- Removed invalid or placeholder values (e.g. -1 for conversion timestamps, time since last click).
- Replaced missing time values with NaN; created is_first_click flag.
- Sampled 1M impressions stratified on target (click) to ensure class balance.
- Split into Train (70%), Validation (10%), Test (20%).

Feature Engineering

- Used all contextual features: cat1–cat9.
- Applied frequency encoding: cat2, cat3, cat7 and one-hot encoding for others
- Created: time_since_last_click_cleaned, is_first_click.

Model Performance Comparison

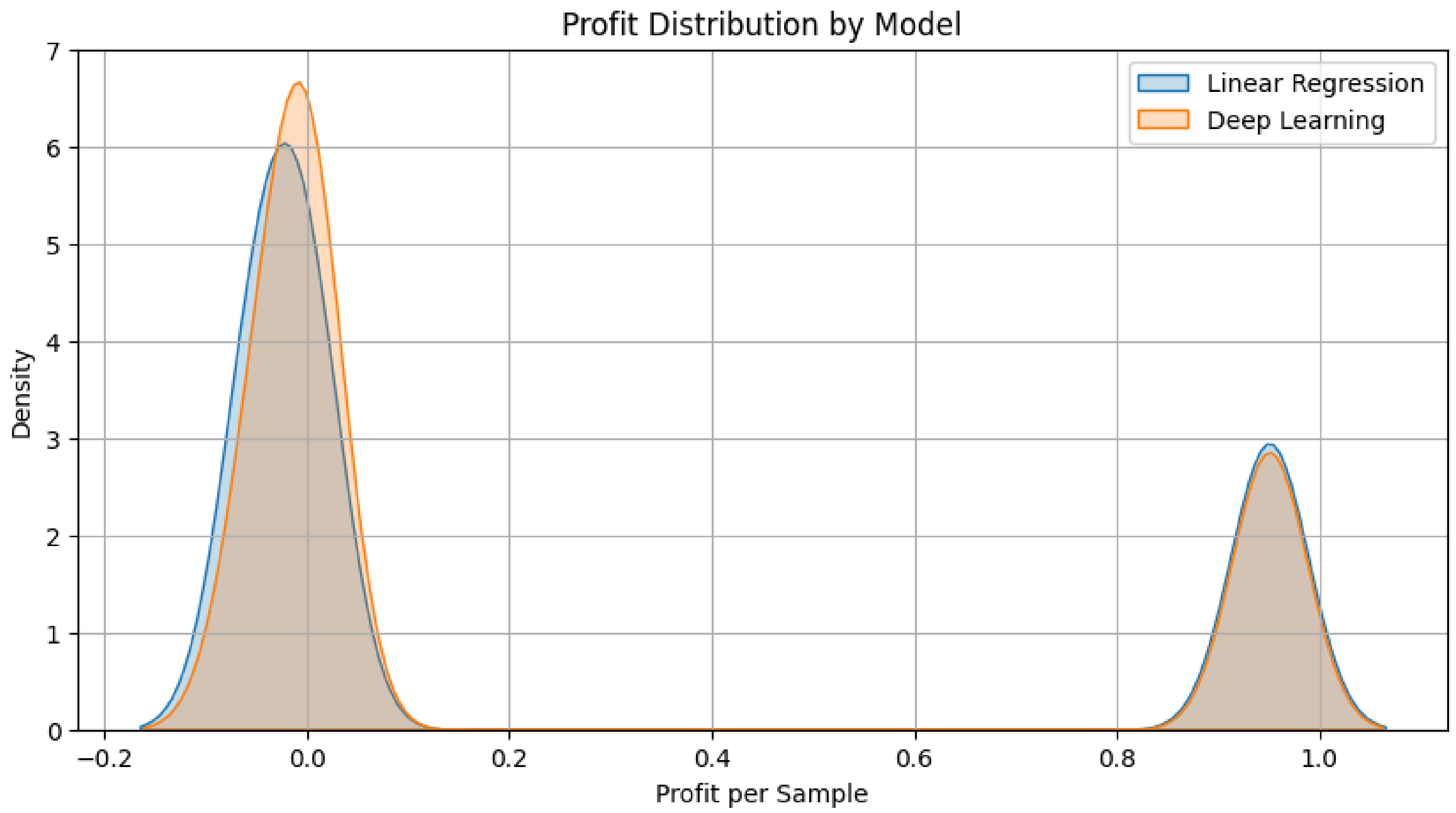
Metrics	Linear Regression	Deep Learning
Accuracy	0.582355	0.693485
F1 Score	0.575398	0.634860
Precision	0.454627	0.557126
Recall	0.783545	0.737803
AUC	0.701133	0.781959
Profit ($)	**$ 50372.45**	$ 48510.15



- **DL** outperforms in all **prediction metrics**, **LR** delivers **higher profit,** highlighting a trade-off between accuracy and ROI.
- **Optimized threshold** to maximize F1 Score.
- **Simulated bids**: base_bid × predicted_CTR.
- **Evaluated** with classification metrics + profit simulation.

A/B Testing Design (Simulated)

- **Hypotheses**
  - H_0: No statistically significant difference in avg. user-level profit between LR and DL
  - H_1: There is a statistically significant difference
- **Profit Formula:**
  - profit = (conversion * 1.0) - (bid * 0.05)
- **Profit Distribution:** KDE plots show a bimodal shape:
  - Peak at $0: Bids with no conversions.
  - Peak at $0.95: Bids resulting in conversions.
  - DL has a stronger skew toward higher-profit conversions.
- **Statistical Test:** Mann-Whitney U Test on 200000 samples:
  - U statistic: 18358902678.5
  - p-value: less than 0.000
  - Alpha (α): 0.05
  - Result: Statistically significant difference between models. **(Reject H_0)**



Key Outcome: Linear Regression profit ($50372.45) exceeds Deep Learning ($48075.55) by $2296.90 (about 4.7 percent).

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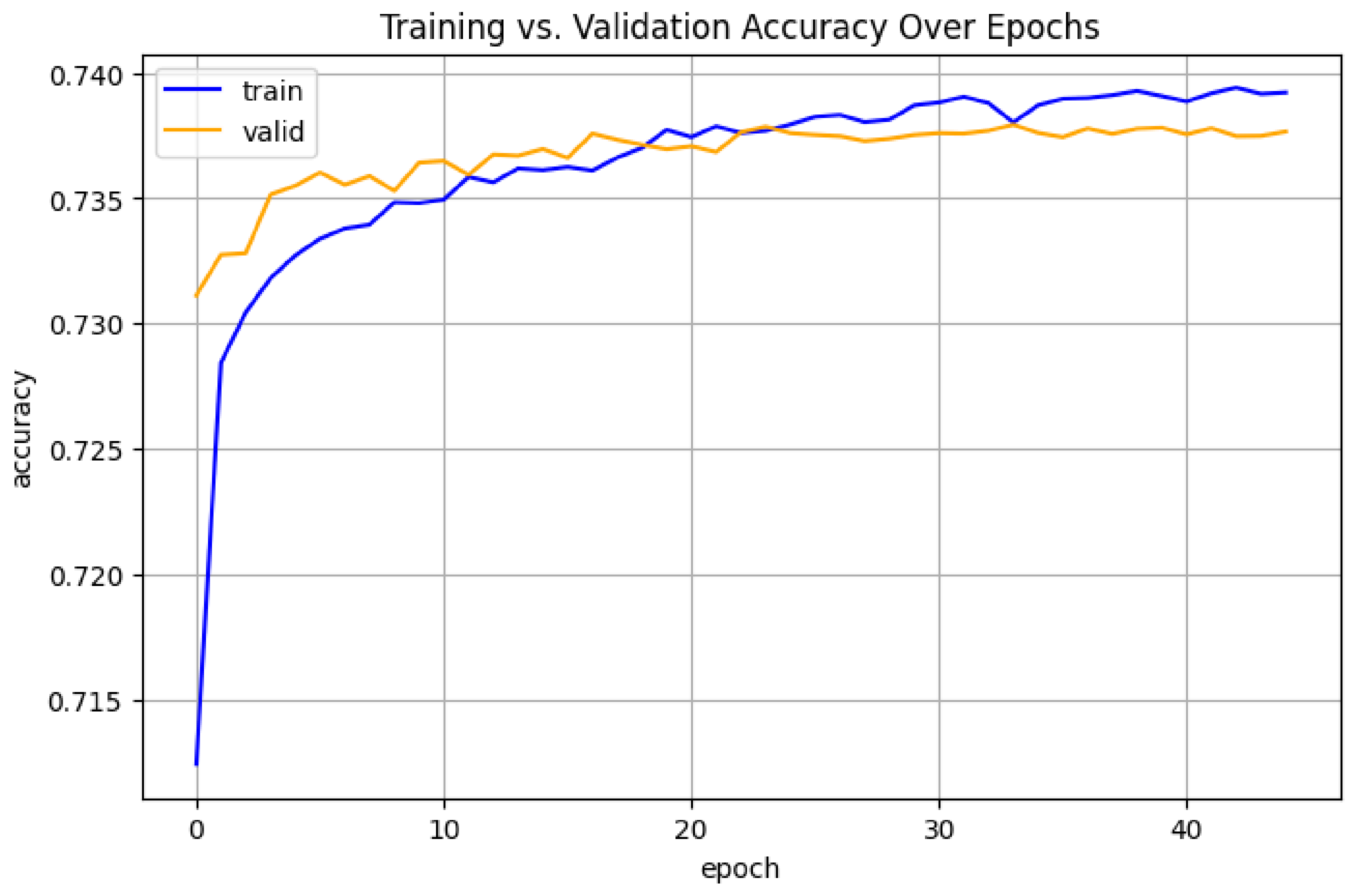
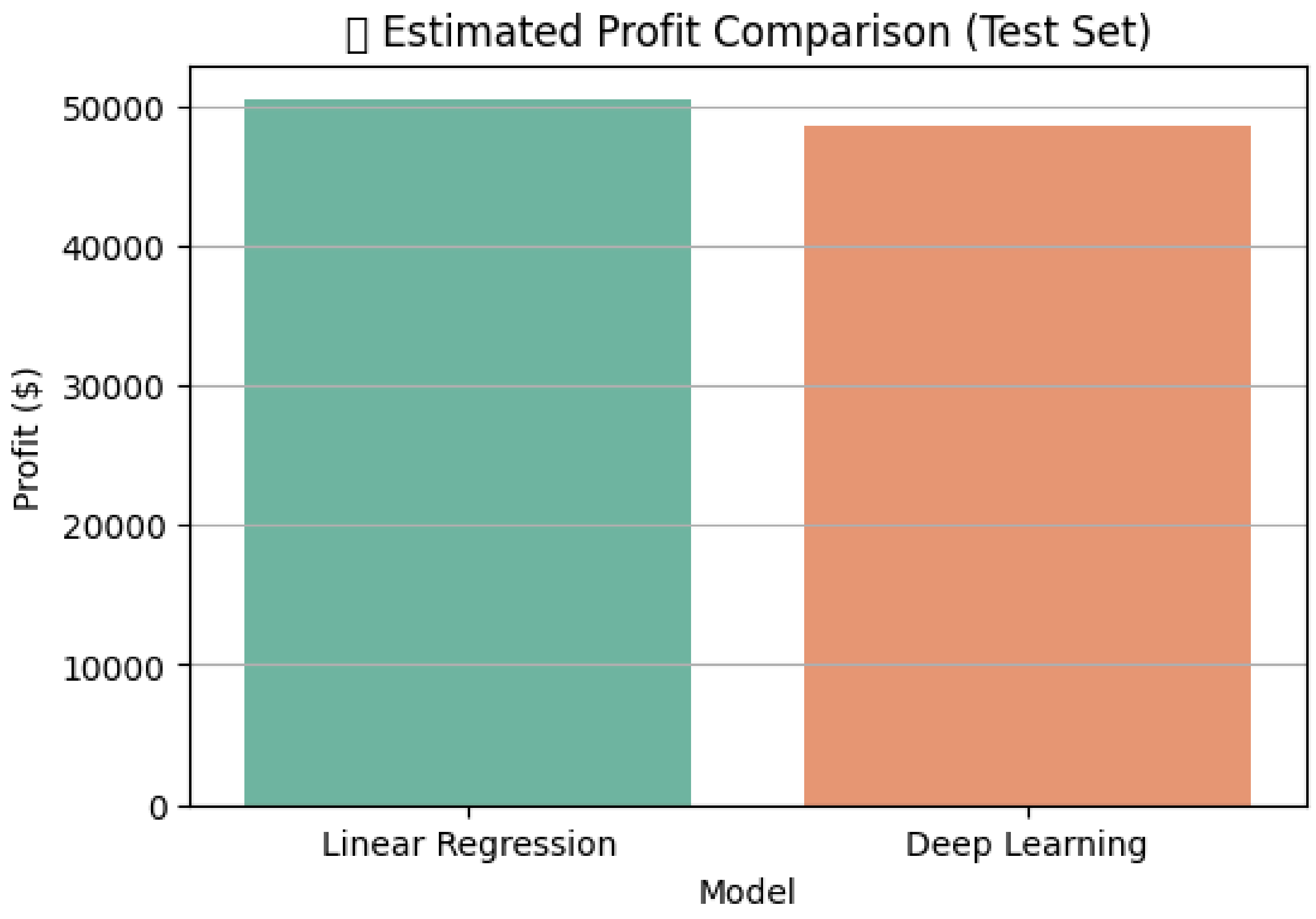
Conclusion

- **Deep Learning Model:**
  - Superior predictive power
  - Higher classification accuracy (**69.5% vs. 58.2%**)
  - Better precision and recall
- **Linear Regression Model:**
  - Slightly higher total profit (**$50,372 vs. $48,076**)
  - Statistically significant difference in profit distributions
  - More lightweight and easier to deploy
- **A/B test:**
  - (Mann-Whitney U, $p < 0.0001$) confirms a **statistically significant** difference in user-level profits between models





Recommendation

- **Short-Term:**
  - Deploy the Linear Regression model for production.
- **Long-Term:**
  - Continue iterating on the Deep Learning pipeline for future improvements.
- **Further Testing:**
  - Conduct online A/B testing and explore dynamic bidding thresholds before full deployment of the Deep Learning model.