

# Market Dynamics and Social Networks in Online Retail: An Integrated Nash Equilibrium Analysis

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GitHub Repository: [https://github.com/AghoyPandaaa/OnlineMarketPlace\\_Simulation\\_GT\\_SN.git](https://github.com/AghoyPandaaa/OnlineMarketPlace_Simulation_GT_SN.git)

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## Abstract

This report presents an integrated simulation study of price competition and social network effects in online retail. Using a real e-commerce transaction dataset, we model seller behavior, simulate Nash equilibrium with and without word-of-mouth effects, and quantify the added economic value of social influence. Our results demonstrate how network effects alter competitive dynamics and market outcomes.

## 1 Introduction

- Briefly explain the motivation: understanding how prices, advertising, and word-of-mouth shape online retail markets.
- State goals: build realistic seller models, run game-theoretic simulations, quantify value of networks.

## 2 Data and Preprocessing

- Source: UCI Online Retail Dataset.
- Preprocessing steps: data cleaning, merging, extracting relevant fields (Invoices, Prices, Quantities, Country, etc).
- Dataset summary: e.g., 407,664 rows, 9 columns. (Add table if wanted!)

## 3 Seller Modeling

- Product selection criteria: chose top-selling products with price variation.
- Seller segmentation: Defined 3 price-tiered sellers (Low, Mid, High), each with empirically derived cost, price, demand, ad budget.
- Show statistics for each seller:

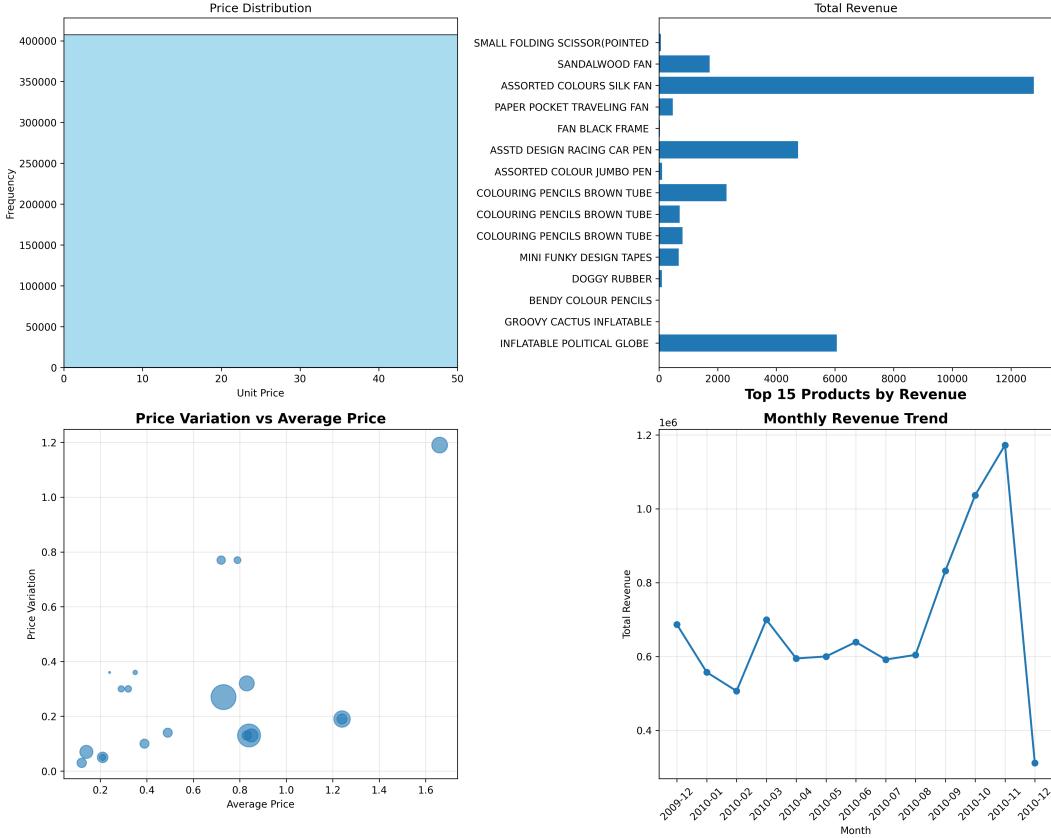


Figure 1: Exploratory Data Analysis: Distribution of key variables and outlier handling results.

## 4 Market Model and Equilibrium Simulation

- Defined a MarketModel class; demand is affected by price, ads, and (in Network Mode) social influence.
- Parameters:
  - $\alpha$ : advertising effectiveness (0.01)
  - $\beta$ : price sensitivity (5.0)
  - $\epsilon$ : price elasticity (0.5)
  - $\gamma$ : social influence (0 or 2.0)
- Simulation process: iterative best-response for Nash equilibrium.

## 5 Profit Landscape and Parameter Sensitivity

- Describe grid search for price and ad strategies, visualized as landscape (insert figure).
- Summarize how equilibrium profit moves for different  $\alpha$  and  $\beta$ .

Seller	Price Range	Avg Price	Base Demand	Total Revenue
Seller A	€1.90–€2.36	€2.09	464	€2,000
Seller B	€2.36–€2.95	€2.55	53	€99,558
Seller C	€2.95–€3.24	€2.95	7	€50,066

Table 1: Key metrics for each seller segment.

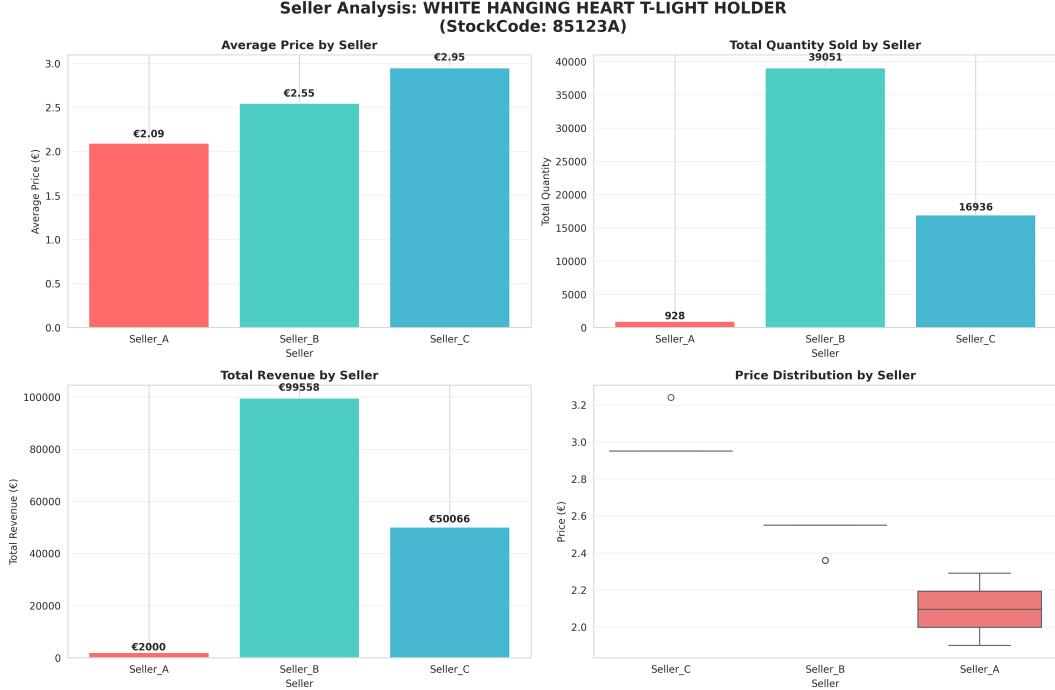


Figure 2: Seller comparison: Average prices, total quantities, revenues, and price distributions.

## 6 Social Network Analysis

- Constructed a customer influence network (e.g., PageRank, centrality, 500 nodes/64K edges).
- Quantified average influence per seller.
- Insert summary and network visualization if available.

## 7 Integrated Simulation: Nash Equilibrium with Network Effects

- Compared equilibrium with  $\gamma = 0$  and with  $\gamma = 2.0$  (network influence).
- Main result: Social networks increased total profit by €1.83 (~0.6%), skewed toward more influential sellers.

## 8 Key Insights and Conclusion

- Network word-of-mouth produces tangible economic value in competitive markets.
- Sellers with more influential customers benefit the most.
- Changing  $\alpha, \beta, \gamma$  shifts equilibrium in asymmetric and nonlinear ways.
- Suggest further work: richer network inference, more sophisticated demand models, alternative game structures.

**Code and data available on request. Figures generated using Python and Matplotlib.**

## 9 Appendix

- Show code snippets for key simulation/modeling logic (optional).
- Extra tables or figures (optional).

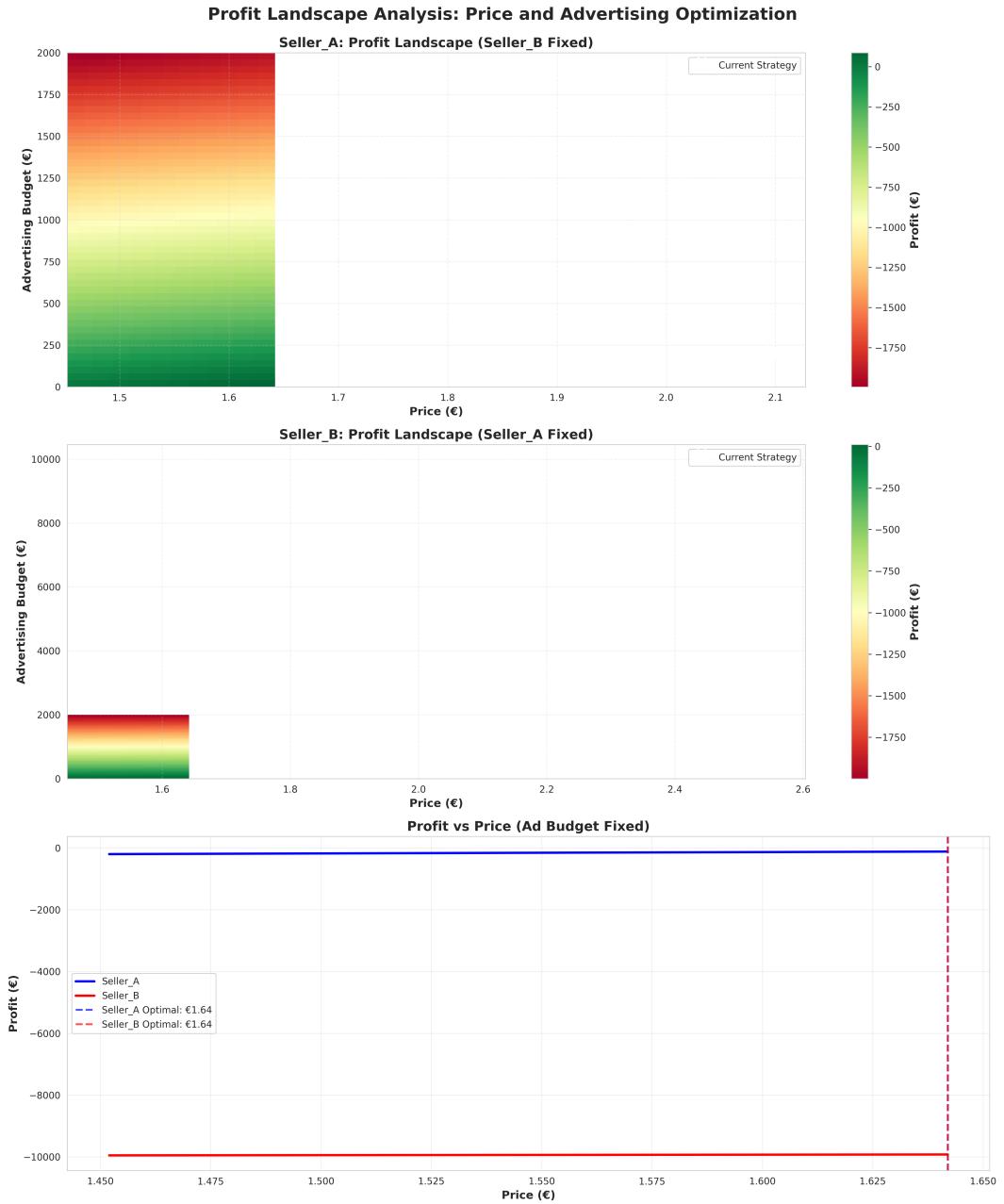


Figure 3: Profit landscape for Seller A given competitor's fixed strategy.

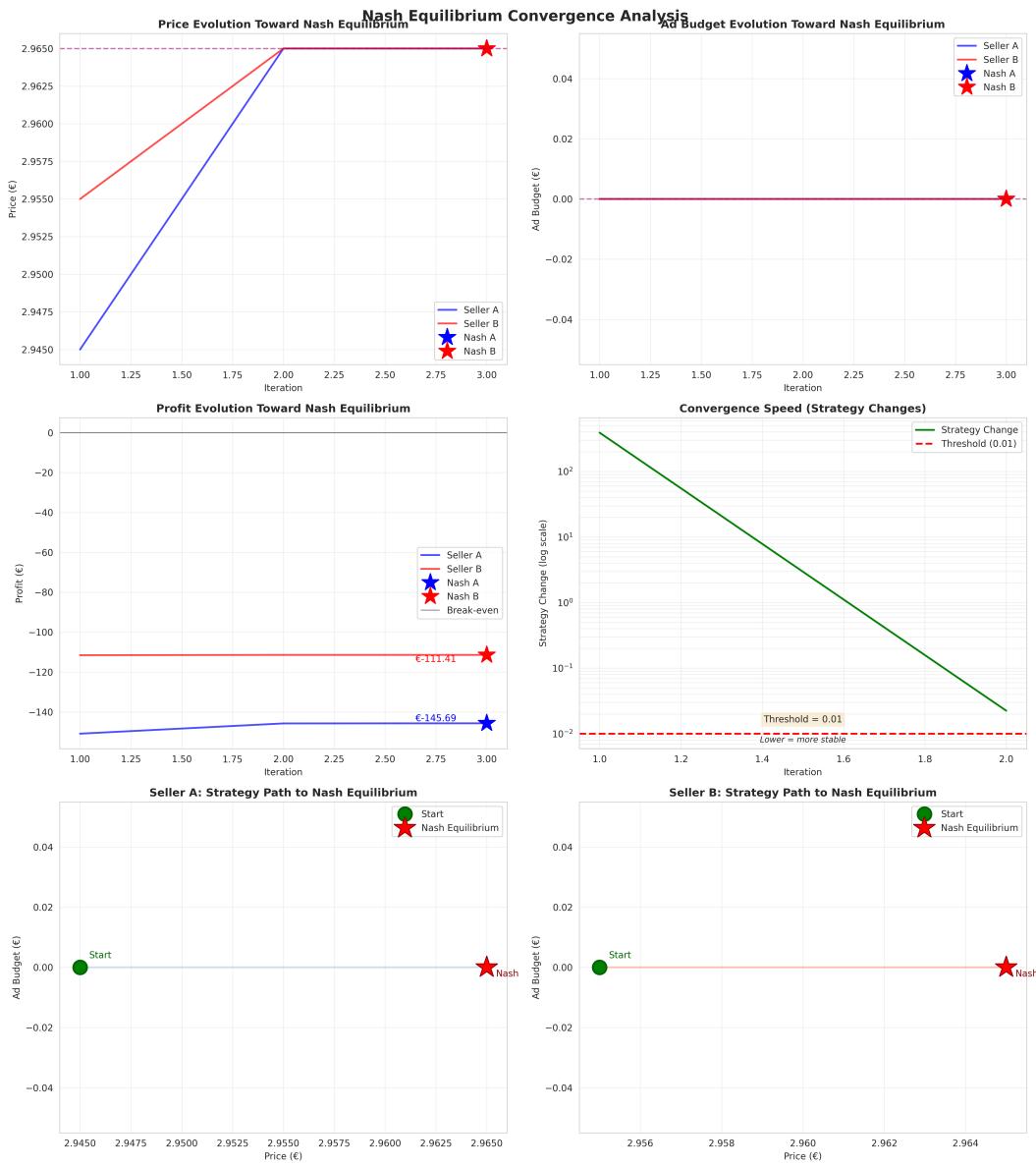


Figure 4: Nash equilibrium convergence: Price, ad budget, profit evolution and strategy trajectories.

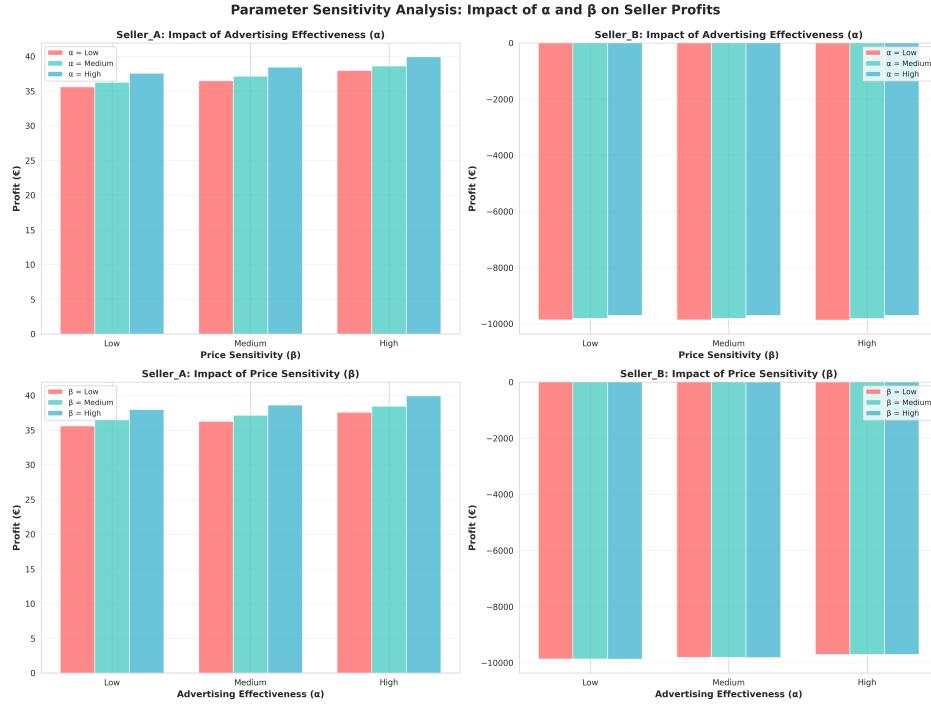


Figure 5: Parameter sensitivity analysis showing impact of advertising effectiveness ( $\alpha$ ) and price sensitivity ( $\beta$ ) on profits.

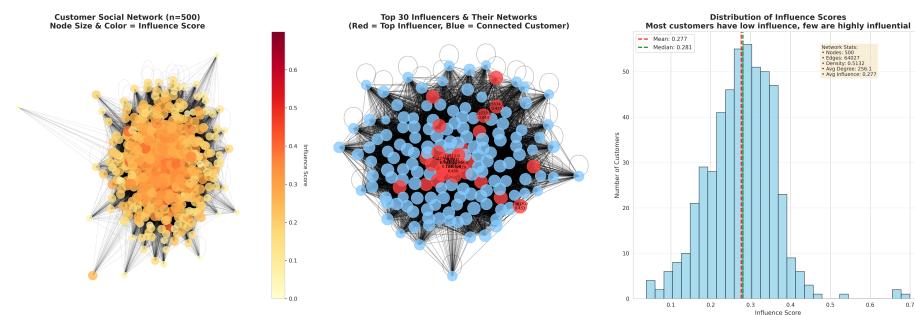


Figure 6: Customer social network visualization showing influence connections and community structure.

