Teaching Complex Decision Making with Partial Information: The Two Dimensional \((P,Q)\) News Vendor Online Competition

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Rochester, New York
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Game selection

Create a Competitive pricing game
Players choose a price each round to sell their products at. They have to choose the best price to maximize profits based on stats each round.

Create a Fishing game
Players have to determine the profit maximizing production capacity at each round while competing with other companies who make similar decisions in an oligopolistic market.

Create a Two sided platform game
Choose how much to charge for the device, and how much to charge developers for licensing.

Create a Pricing & quantity news vendor game
In this advanced news vendor game, a manager sells a product during a short selling season with stochastic demand. The manager has to determine both the sales price and the order quantity. Each business may face a different demand realization, which is a stochastic decreasing function of their sales price decision.

Create a Stock trading game
Players get stocks and cash. Each round they can trade with each other while trying to make the most profit before the game ends and stocks are all sold.

Create a News vendor game
In the news vendor problem a manager sells a product during a short selling season with stochastic demand. The manager has one opportunity to order inventory before the selling season, and no further replenishments are possible.

Create a Beer supply chain game
Players join a supply chain and have to place orders based on demand and information that is shared with them and others in the supply chain.
The Big Picture

1. Our Classic **News Vendor (Q) Game** has been very popular:
   Used by many in teaching OM, Analytics, HC OM (Nurse Scheduling, Bed Allocation...), and in IS (finding the ‘true demand’ from truncated ‘sales data.’)

2. The **new Two Dimensional (P,Q) News Vendor Game**: Teaches students how to use ‘Decision Support Systems’ and to use statistics/analytics to ‘estimate the demand curve’ and the optimal (P,Q) with noisy information: truncated sales data, and ‘price dependent’ stochastic demand realization.

3. **Call/Email me to use it, for FREE**
In the traditional newsvendor problem, seller determines order quantity for an uncertain demand \( d(p) \):

**Known Parameters**
- Sale price (\( p \))
- Unit cost (\( c \))
- Backorder cost (\( b \))
- Salvage value (\( s \))
- Demand randomness (\( \varepsilon \))

**Decision:**
- Order quantity (\( q \))

Optimal order quantity \( q^* \) can be calculated using \( P(Demand \leq q^*) = r \),

where the critical ratio is given by \( r = \frac{p + b - c}{p + b - s} \)

(\( * \) can be set to zero)
However!

Most businesses determine their own prices for their own product. Therefore, exogenous price assumption might not be valid in many practical cases.

To overcome this issue, the traditional newsvendor problem has been generalized to the price-setting newsvendor problem where the seller also determines sale price ($p$).
### Theoretical Background – The Price-Setting Newsvendor Problem

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Unit cost (c)</td>
<td>- Order quantity (q)</td>
</tr>
<tr>
<td>- Backorder cost (b)</td>
<td>- Sale price (p)</td>
</tr>
<tr>
<td>- Salvage value (s)</td>
<td></td>
</tr>
<tr>
<td>- Demand randomness ($\epsilon$ is a r.v. $\in [L_\epsilon, U_\epsilon]$)</td>
<td></td>
</tr>
</tbody>
</table>

Total profit for any realized random demand $d(p, \epsilon)$:

$$\Pi(q, p, \epsilon) = p \min\{q, d(p, \epsilon)\} + s[q - d(p, \epsilon)]^+ - b[d(p, \epsilon) - q]^+ - cq$$

Expected profit function:

$$\pi(q, p) = \mathbb{E}[\Pi(q, p, \epsilon)] = (p+b-c)q - (p+b-s) \int_0^q (q-x) \, dG(p,x) - b\mathbb{E}[d(p,\epsilon)]$$

Price setting newsvendor problem on our platform is based on the work of Karlin and Carr (1962) and Xu et al. (2010)*


Theoretical Background - Price-Setting Newsvendor Problem

This setting can be used with any distribution function and demand function that satisfies
- $d(p, \varepsilon)$ is decreasing in $p$, increasing in $\varepsilon$ and twice differentiable in $p$ and $\varepsilon$.
- $d(p, \varepsilon) = 0$ for $p \geq p_{\max}$

In our game we used additive demand function with uniform distribution with mean zero

$$d(p, \varepsilon) = d(p) + \varepsilon \text{ where } \varepsilon \in [-x, +x].$$

Also, demand-price function is represented as linear function:

$$d(p) = D - t*p$$
where $D$ is the maximum demand.
Finding **optimal price and quantity** for generalized additive demand function \( d(p, \varepsilon) \):

1. Taking first order condition (FOC) of the expected profit function \( \pi(q, p) \) wrt \( q \)
2. Finding optimal \( q \) as a function of \( p \) (represented as \( \bar{q}(p) \))
3. Place \( \bar{q}(p) \) into the expected profit function \( \pi(q, p) \)
4. Differentiate the new profit function \( \pi(\bar{q}(p), p) \) wrt \( p \) (FOC) and find optimal \( p^* \)
5. Place \( p^* \) into the function \( \bar{q}(p) \) to find optimal quantity \( q^* \)
Theoretical Background - Price-Setting Newsvendor Problem

Step 1 and 2 come from traditional newsvendor game:

In the traditional newsvendor game with additive demand function, the optimal quantity can be derived as a function of price: \( \bar{q}(p) = d(p) + F^{-1}(r) \), where \( F \) is a cdf of \( \varepsilon \).

3- Place \( \bar{q}(p) \) into the expected total profit function:
\[
\pi(\bar{q}(p), p) = \mathbb{E}[\prod(\bar{q}(p), p, \varepsilon)] = (p-c) d(p) + (p+b-s) \int_{L_{\varepsilon}}^{F^{-1}(r)} x \, dF(x) - b\mathbb{E}[\varepsilon]
\]

4- First order condition:
\[
\frac{d\pi(\bar{q}(p), p)}{dp} = (p-c)d'(p) + d(p) + L_{\varepsilon} + \int_{L_{\varepsilon}}^{F^{-1}(r)} (1 - F(x))dx = 0
\]

5- Optimal order quantity: \( q^* = \bar{q}(p^*) = d(p^*) + F^{-1}(r^*) \)

Optimal expected profit: \( \pi(\bar{q}(p^*), p^*) \)
In our game we used additive demand function with uniform distribution with mean zero
\[ d(p, \varepsilon) = d(p) + \varepsilon \text{ where } \varepsilon \in [-x, +x]. \]

Example:

Price-Demand Curve

\[ d(p) = 1000 - 4p \]

\[ \varepsilon \in [-100, 100] \]
In our game we used additive demand function with uniform distribution with mean zero:

\[ d(p, \varepsilon) = d(p) + \varepsilon \text{ where } \varepsilon \in [-x, +x]. \]

Example:

\[ d(p) = 1000 - 4p \]

\[ \varepsilon \in [-100, 100] \]
Price – Setting Newsvendor Game

Setup
Gameplay
Post-Game Analysis

TradeWindBusiness.com
Price – Setting Newsvendor Game

Setup
Gameplay
Post-Game Analysis

TradeWindBusiness.com

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Game Settings for Professors – Parameter Setup

**Economic Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum demand</td>
<td>$500</td>
</tr>
<tr>
<td>Maximum price</td>
<td>$200.00</td>
</tr>
<tr>
<td>Backorder cost</td>
<td>$15.00</td>
</tr>
<tr>
<td>Unit salvage value</td>
<td>$15.00</td>
</tr>
<tr>
<td>Unit cost</td>
<td>$40.00</td>
</tr>
</tbody>
</table>

After parameter entry, click “Redraw Demand Curve”

Demand curve will be updated and the maximum submittable price \( p_{\text{max}} \) will be shown to the professor.

Maximum submittable price: $180
**Price-Setting Newsvendor Game**

**Game Settings for Professors – Student Display Configuration**

### Student Display

<table>
<thead>
<tr>
<th>Option</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit rank</td>
<td>Enabled</td>
</tr>
<tr>
<td>Cumulative profit rank</td>
<td>Enabled</td>
</tr>
<tr>
<td>Quantity rank</td>
<td>Enabled</td>
</tr>
<tr>
<td>Price rank</td>
<td>Enabled</td>
</tr>
<tr>
<td>Optimal quantity</td>
<td>Disabled</td>
</tr>
<tr>
<td>Optimal price</td>
<td>Disabled</td>
</tr>
<tr>
<td>Optimal profit</td>
<td>Disabled</td>
</tr>
<tr>
<td>Probability of stock running out</td>
<td>Disabled</td>
</tr>
</tbody>
</table>

### Display options for ranking amongst students:
- Profit
- Cumulative Profit
- Quantity and Price rankings amongst students

### Display options for long-run *optimal values*:
- Optimal price
- Optimal profit
- Optimal quantity
- Prob. of running out of stock
Price – Setting Newsvendor Game

Setup

Gameplay

Post-Game Analysis

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Price – Setting Newsvendor Game

Setup
Gameplay
Post-Game Analysis

TradeWindBusiness.com
Tradewind business

Price-Setting Newsvendor Game

Round 8

Profit change from last round

Student Input

Screen

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Demand</td>
<td>2500</td>
</tr>
<tr>
<td>Maximum Price</td>
<td>$1,104.00</td>
</tr>
<tr>
<td>Purchase Price</td>
<td>$240.00</td>
</tr>
<tr>
<td>Salvage Price</td>
<td>$124.00</td>
</tr>
<tr>
<td>Backorder Cost</td>
<td>$200.00</td>
</tr>
</tbody>
</table>

Amount to order

You must submit a positive quantity to order.

Price to sell at

You must submit a positive price to sell at.

Submit
Tradewind business

Price-Setting Newsvendor Game

Round 8 Ended

Student
Between Rounds
Screen

Your business decisions

<table>
<thead>
<tr>
<th>Order quantity</th>
<th>1100 units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order sell price</td>
<td>$780.00</td>
</tr>
</tbody>
</table>

Your business performance

<table>
<thead>
<tr>
<th>Amount sold</th>
<th>1036 units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount salvaged</td>
<td>64 units</td>
</tr>
<tr>
<td>Amount backordered</td>
<td>0</td>
</tr>
</tbody>
</table>

Profit calculation

<table>
<thead>
<tr>
<th>Sales revenue</th>
<th>(+) 1100 x $780.00 = $858,000.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salvage revenue</td>
<td>(+) 64 x $124.00 = $7,936.00</td>
</tr>
<tr>
<td>Total revenue</td>
<td>(-) $816,016.00</td>
</tr>
<tr>
<td>Order cost</td>
<td>(-) 1100 x $240.00 = $264,000.00</td>
</tr>
<tr>
<td>Backorder cost</td>
<td>(-) 0 x $290.00 = $0.00</td>
</tr>
<tr>
<td>Total cost</td>
<td>(-) $264,000.00</td>
</tr>
</tbody>
</table>
Animated Move
Price-Setting Newsvendor Game

Round 7 Ended

Students

Round Stats

Round 7 Statistics

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Parameters/display options can be changed between rounds.
### Professor Between Rounds Screen

The image displays a screenshot from Tradewind business's Price-Setting Newsvendor Game.

**Round 7 Ended**

- **Round Stats**: Shows various statistics for each round.
- **Round Configuration**: Options to show different performance metrics.
- **Students**: A list of students with options to hide/show and their actions (send messages).

**Round Stats**

The table titled **Round 7 Statistics** provides a summary for each round, including:
- **Average decision time**
- **Number of decisions**
- **Quantity**
- **Price**
- **Demand**
- **Amount sold**
- **Salvage**
- **Backorder**
- **Net profit**
- **Cumulative profit**

For Round 7, the statistics are as follows:

<table>
<thead>
<tr>
<th>Name</th>
<th>Decision time</th>
<th>Quantity</th>
<th>Price</th>
<th>Demand</th>
<th>Amount sold</th>
<th>Salvage</th>
<th>Backorder</th>
<th>Net profit</th>
<th>Cumulative profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>demo1</td>
<td>13.07</td>
<td>220</td>
<td>$105.00</td>
<td>201</td>
<td>19</td>
<td>0</td>
<td>31</td>
<td>$12,590.00</td>
<td>$89,430.00</td>
</tr>
<tr>
<td>demo4</td>
<td>29.73</td>
<td>190</td>
<td>$120.00</td>
<td>221</td>
<td>190</td>
<td>0</td>
<td>31</td>
<td>$14,735.00</td>
<td>$80,575.00</td>
</tr>
</tbody>
</table>

This round's statistics give insights into the best (demo1) and worst (demo4) performers for that round, showing their decision time, quantity, and financial outcomes.

**Gives the stats of the best/worst performer for that round**
Professor

Between Rounds

Screen

Price-Setting Newsvendor Game

Round 7 Ended

Top Income from Round 7

Income: $14,735.00
Quantity: 190
Price: $120.00

Round 7 Statistics

Average decision time: 21.40 seconds

Name | Made decision | Decision time | Quantity | Price | Demand | Amount sold | Salvage | Backorder | Net profit | Cumulative profit
--- | --- | --- | --- | --- | --- | --- | --- | --- | --- | ---

demo1 | ✓ | 13.97 | 220 | $105.00 | 201 | 201 | 19 | 0 | $12,568.00 | $89,432.00

demo4 | ✓ | 29.73 | 190 | $120.00 | 221 | 190 | 0 | 31 | $14,735.00 | $23,575.00
Price – Setting Newsvendor Game

Setup

Gameplay

Post-Game Analysis

TradeWindBusiness.com
Price – Setting Newsvendor Game

Setup
Gameplay
Post-Game Analysis

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Price-Setting Newsvendor Game

Participants

<table>
<thead>
<tr>
<th>Display name</th>
<th>First name</th>
<th>Last name</th>
</tr>
</thead>
<tbody>
<tr>
<td>demo1</td>
<td>demo1</td>
<td>demo1</td>
</tr>
<tr>
<td>demo2</td>
<td>demo2</td>
<td>demo2</td>
</tr>
<tr>
<td>demo4</td>
<td>demo4</td>
<td>demo4</td>
</tr>
</tbody>
</table>

Statistics - Download statistics CSV

Overall statistics

- Round: 4
- Average Demand: 214 units
- Optimal Quantity: 221 units
- Average Quantity: 206 units
- Average Sales: 212 units
- Average Salvage: 84 units
- Average Backorder: 2 units
Post-Game Display

All parameters and outputs can be downloaded as csv file.
Post-Game Display

Statistics for each round

Overall statistics

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Each round can be analyzed separately at student level.
Tradewind business

Price-Setting Newsvendor Game

Participants

<table>
<thead>
<tr>
<th>Display name</th>
<th>First name</th>
<th>Last name</th>
</tr>
</thead>
<tbody>
<tr>
<td>demo1</td>
<td>demo1</td>
<td>demo1</td>
</tr>
<tr>
<td>demo2</td>
<td>demo2</td>
<td>demo2</td>
</tr>
<tr>
<td>demo4</td>
<td>demo4</td>
<td>demo4</td>
</tr>
</tbody>
</table>

Statistics - Download statistics CSV

Overall statistics

Can be toggled on/off
Post-Game Display

<table>
<thead>
<tr>
<th>Display name</th>
<th>First name</th>
<th>Last name</th>
<th>Email</th>
<th>ID</th>
<th>Platform</th>
<th>WebSocket</th>
</tr>
</thead>
<tbody>
<tr>
<td>demo1</td>
<td>demo1</td>
<td>demo1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>demo2</td>
<td>demo2</td>
<td>demo2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>demo4</td>
<td>demo4</td>
<td>demo4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Statistics - Download statistics CSV

Overall statistics

- Round 4: Average Demand: 214 units
- Optimal Quantity: 229 units
- Average Quantity: 296 units
**Possible Different Scenarios to Simulate Real Life Situations**

High Margin vs Low Margin: Decrease or Increase of Cost of Supply
High Variance vs Low Variance: Fluctuation of Demand

More examples can be added...

**Parameter Example**

<table>
<thead>
<tr>
<th>High Margin</th>
<th>Low Margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum demand= $275</td>
<td>Maximum demand= $275</td>
</tr>
<tr>
<td>Maximum price = $55</td>
<td>Maximum price = $55</td>
</tr>
<tr>
<td>Uniform distn. parameter=$25</td>
<td>Uniform distn. parameter=$25</td>
</tr>
<tr>
<td>Unit cost= $8</td>
<td>Unit cost=$30</td>
</tr>
<tr>
<td>Salvage value=$10</td>
<td>Salvage value=$10</td>
</tr>
<tr>
<td>Backorder cost=$20</td>
<td>Backorder cost=$20</td>
</tr>
</tbody>
</table>
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