Optimal Production Strategy under Fluctuating Demands: Technology versus Capacity

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Introduction

- Flexible firm: higher ability to make adjustment throughout the manufacturing process.

- This paper focuses on two flexibility investments in a long-run: flexible technology (FT) & flexible capacity (FC)

A long-run change in market demand distribution affects product price and induces firms to alter their choice of a cost curve or improve decision-making process.
Introduction

**FT**: improve the total production cost structure by improving the existing technology, equipments or internal organizations.

To facilitate output adjustment in each market period.

(e.g., using advanced technology, upgrading equipments, changing the mix of production factors, altering the lines of administrative control.)

To facilitate output adjustment in each market period.
Introduction

**FC**: postpone production decision after knowing the real demand.

(e.g., adjusting shifting, overtime, hiring part-time worker, subcontract.)

**FT and FC** should be considered simultaneously.
Introduction

A production strategy includes: tactic hierarchy and operational hierarchy.

- Tactic hierarchy: FT?? and/or FC ??

- Operational hierarchy:
  degree of technology flexibility;
  capacity amount;
  production quantity;
  pricing.
Introduction

Research questions:

(i) Does more flexibility lead to more profit?

(ii) What are the sequential effects when a firm invests in both flexible technology and flexible capacity?

(iii) Which one is the optimal investment with respect to a firm’s production strategy under various environments?
Literature review

Flexible technology investment

- Stigler (1939): technology flexibility enables firms to hedge against demand fluctuation by varying production levels.

- Marschak and Nelson (1962): flexibility is one that varies inversely with the curvature of the total cost curve.

- Mills (1984): applies an endogenous variable in total quadratic cost function to present a firm’s flexibility which reflects a firm’s ability to adjust the production levels facing a long-run change in market demand.

\[ C_p(q) = \beta q + \frac{q^2}{2\gamma} \]

- Mills and Schumann (1985); Fraser (1984); Rller (1990); Fluet and Phaneuf (1997).
Literature review

Flexible capacity investment

- Gerwin (1993): investment in excess capacity is a method to achieve the volume flexibility.

- Van Mieghem and Dada (1999): production and pricing postponement strategy is the most effective.

- Anupindi and Jiang (2008): characterizes a set of equilibria of the competition under a general demand distribution.

- Buxey (2005): the coexisting phenomenon of prevailing flexible and traditional in-flexible capacity strategy in real business.
Model description

- **Objective function**:\[ \Pi = E(R - C) \]
- **Inverse demand function**: \[ P(q, \alpha) = (\alpha - q)^+ \]
  to consider interplay between demand and production.
- **Total production cost**: \[ C_p(q) = \beta q + \frac{q^2}{2\gamma} \]
- **Capacity cost**:
  - flexible capacity firm \[ C_F k \]
  - in-flexible capacity firm \[ C_N k \]
- **Technology investment cost**: \[ C_t(\gamma) = C_r(\gamma - \gamma_N) \]
Model description

We are going to find optimal $k$, $q$ and $\gamma$ to maximize the expected profit.

$$
\Pi = \int_{0}^{\infty} q \left( (\alpha - q)^+ - \beta - \frac{q}{2\gamma} \right) f(\alpha) d\alpha - C_F k - C_r (\gamma - \gamma_N)
$$

Subject to the following constraints.

(1) For an in-flexible technology firm: $\gamma = \gamma_N$
(2) For a flexible technology firm: $\gamma \geq \gamma_N$
(3) For an in-flexible capacity firm: $q = k$, $C_F = C_N$
(4) For a flexible capacity firm: $0 \leq q \leq k$, $C_F \geq C_N$
Model description

For flexible capacity firm, the production decision is to maximize its profit after knowing the real demand.

$$\text{Max } \pi(q|k, \gamma) = q(\alpha - q)^+ - \left( \beta q + \frac{q^2}{2\gamma} \right).$$

s.t. $0 \leq q \leq k.$
Five possible production strategies:

1. None of FT and FC (NT+NC)
2. FT only (T-only)
3. FC only (C-only)
4. FT followed by FC (T+C)
5. FC followed by FT (C+T)
Analysis

- We formulate each strategy and solve the respective optimal decisions in the operational hierarchy.

- We skip the technical points here and go ahead to research findings in the following.
Research findings

- **T+C vs. C+T:** no sequential effects when investing in both flexible technology and flexible capacity.

- **NT+NC vs. T+C:**  
  More flexibility cannot guarantee more profit and even worse -off.
Research findings

- **NT+NC vs. T-only:**
  
  NT+NC is a particular case of T-only by replacing parameters; NT+NC is a lower bound of T-only.
Research findings

- NT+NC vs. C-only:

![Diagram showing research findings]

The diagram illustrates the comparison between NT+NC and C-only conditions, highlighting the feasibility range and other key parameters.
Research findings

C-only vs. T+C:

C-only is a lower bound of T+C; the largest profit improvement by T+C compared with C-only is \( \frac{\Pi^{T+C} - \Pi^C}{\Pi^C} = \frac{1}{2\gamma_N} \cdot 100\% \).
Research findings

T-only vs. C-only:
Research findings

- **Ranking of strategies:**

  \[
  \prod^N \leq \prod^T \quad \text{and} \quad \prod^C \leq \prod^{T+C} = \prod^{C+T}
  \]

- From strategic perspective, the optimal strategy is either T-only or T+C.
Research findings

- From strategic perspective, we define an **effective strategy** like this:
  
  If strategy A is said to be more effective than Strategy B, then Strategy A makes more profit than Strategy B.

- From operational perspective, we define an **efficient strategy** like this:
  
  If strategy A is said to be more efficient than Strategy B, then Strategy A makes the same profit with fewer investments than Strategy B.
Research findings

- **T-only vs. T+C:**

![Graph showing comparison between T-only and T+C treatments](image)
Research findings

- The most effective and efficient strategy can be any one of the five possible strategies:
Q+A

Thank you!