Market Forces meet Behavioral Biases

Cost Mis-allocation and Irrational Pricing

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Evidence of Sunk Cost Bias in Pricing

The evidence that firms take sunk and fixed cost into account in pricing decisions is overwhelming.

- In a survey of Fortune 100 companies, Govindan and Anthony (1995) found that most firms price their products based on average cost, computed according to a “full costing” methodology.

- Maher, Stickney and Weil (2004) assert that, when it comes to pricing practices: “Overwhelmingly, companies around the globe use full costs rather than variable costs.”

They cite surveys of U.S. industries “showing that full-cost pricing dominated pricing practices (69.5 percent), while only 12.1 percent of the respondents used a variable-cost based approach.”
A management book (Shank and Govindarajan) state (p. 29, emphasis in original):

“Looking at incremental business on an incremental cost basis will, at best, incrementally enhance overall performance. It cannot be done on a big enough scale to make a big impact. If the scale is that large, then an incremental look is not appropriate!”

Shank and Govindarajan make it clear that they believe that managers should incorporate sunk costs into pricing decisions:

“Business history reveals as many sins by taking an incremental view as by taking the full cost view.”
Edgar Bronfman, former owner of Universal Studios, proposes charging higher prices for movies that cost more to make.

"He ... observed that consumers paid the same amounts to see a movie that costs $2 million to make as they do for films that cost $200 million to produce. ‘This is a pricing model that makes no sense, and I believe the entire industry should and must revisit it.’ "

But does the sunk cost bias *matter* in pricing?

Offerman and Potters (2003)’s experiments

**Price competition treatment**

Symmetric Bertrand games with product differentiation, linear demand, and constant marginal cost

- **Baseline treatment**: No fixed or sunk cost
  - prices converge to the Bertrand equilibrium

- **Sunk cost treatment**: Subjects pay a sunk entry fee
  - prices are significantly higher
  - average markup over marginal cost increased by 30%
The sunk cost bias does not always persist

Monopoly treatment

- There was no final difference between the sunk cost and baseline treatments for a monopolist
- ..prices went to “rational” monopoly prices despite the presence of sunk cost!
We introduce *psychologically plausible* biases in a model of price competition

- The presence of irrelevant costs (e.g., sunk cost) triggers a predisposition among firms to use full-cost pricing.
- Myopic, boundedly rational players; little understanding of their environments.
- When subjected to competitive pressures, firms adjust their prices and, less frequently, their “costing methodologies” by reinforcing the practices that yielded the best past results.
- Firms adjust prices and costing practices based on naive learning rules
The sunk cost bias not only survives in certain market structures—but not others.

Where it survives, it is in fact self-reinforcing: firms achieve better outcomes, and firms’ distorted perceptions is not contradicted by evidence.
Outline of the talk

1. Introduction
   - evidence
   - overview of the paper
   - Literature

2. Static model
   - Model overview
   - Static price competition
   - Linear example

3. Dynamics and learning
   - adaptive learning; Theorem 1
   - reinforcement learning; Theorem 2

4. Implications and conclusions
   - Linear special case; experimental Tests
   - No distortion results
   - literature revisited
The basic idea is old: **Commitment alters outcomes in oligopoly**

- Delegation literature
- Evolution of preferences
Delegation

Fershtman-Judd (1987) and others..

Key assumptions:

- players are fully rational, fully anticipating the strategic consequences of their commitments
- commitments are observable
Evolution of preferences

- Guth-Yaari (1991)
- JET special issue (2001)

Key assumptions: players are fully rational and commitments are observable.
Accounting literature

- Cost accounting as a compilation of “best practices”
- No rigid prescriptive recommendations on how to imbed cost
- Recommendation: be flexible; do what seems to work best

- Empirical regularities
  - simplicity
  - Prevalence of cost-plus-pricing
  - Costing methodologies change slowly relative to prices
Our model of costing procedure

- Determine amount of sunk cost allocated as relevant cost
  - Textbooks recommends flexibility and have no rigid prescriptions.

- Compute per-unit distortion to relevant costs and price accordingly
  - Firms forecast budgets of costs and sales based on recent experience. E.g. unit cost based on recent output.

- Reconcile actual and budgeted profits
  - Variances are the difference between actual and budgeted performance. Hence, a firm can determine the impact of its costing approach on economic profits.
Timing

$p_1, p_2, \ldots, p_t, \ldots$

$\tau=1$  $\tau=2$  $\tau=3$  \ldots

\textit{time}
N firms engaged in differentiated product Bertrand competition
- constant marginal cost $c_n$
- Rental cost of sunk capital $F_n \geq 0$.

Firm $n$’s demand is $q_n = D_n(p)$, where $p = (p_1, \ldots, p_N)$.
$D_n$ is differentiable (and a bunch of other things..) and log-supermodular,

$$\frac{\partial^2 \log D_n(p_n, p_{-n})}{\partial p_n \partial p_m} \geq 0.$$  

Firm $n$’s objective measure of success is economic profit

$$\pi_n^e(p) \equiv (p_n - c_n)D_n(p) - F_n$$
Firm $n$’s perception of economic profits is distorted:
- It inflates its true marginal cost by a constant distortion component, $s_n$.
- $s_n$ is the part of sunk cost (mis-) allocated as variable cost.

The firm’s **accounting profit** (gross of unallocated sunk cost)

$$\pi_n(p, s_n) \equiv (p_n - c_n - s_n)D_n(p).$$

This is the measure of performance relevant to the manager’s decision making.
Coherence and Self-justification

Firms display a minimum degree of coherence:

\[ F_n = 0 \implies s_n = 0 \]

Firms do not “make-up” fixed and sunk costs where there are none.

A more elaborate and detailed version of this assumption is in the paper.

Justifications:

- Psychological: *Eyster, Arkes-Ayton*
- Accounting practices: *Faithful representation; GAAP*
- Long-run consistency
The Game with Cost Distortions

- Given a vector of distortions $s$, we have a game $\Gamma(s)$

- This is the same as the original game, except that the payoff function of player $n$ is $\pi_n(p, s_n)$

- Vector of reaction functions

$$r(s) : P^N \rightarrow P^N$$
A Simple Example to build Intuition

(... and why it is misleading)

- Two firms, \( n \), \( m \), each with marginal cost of 10.
- Demand for firm \( n \) is
  \[
  D_n = 124 - 2p_n + 1.6p_m.
  \]
- Imagine that we are initially in a situation where no firm distorts, then Nash equilibrium is \( p_n = p_m = 60 \).
- Now suppose the manager of firm 1 “mutates” so he distorts with \( s = 10 \).
Linear example

Two firms
Marginal cost 10
Demand: \( D_n = 124 - 2p_n + 1.6p_m \)
Suppose Firm 1 management `mutates.’

The new *management is confused* about cost.

It believes each unit incurs an additional $10/unit as a charge for fixed and/or sunk cost.
Linear example

Suppose firms, somehow, reach the NE of the game with `MC' of 10 and 20 resp.
Linear example

Then Firm 1’s ‘fitness,’ measured by its *true economic profit*
increases by about 2.4% (from 5000 to 5142)
Why the Story in the Example is Incoherent

1. How would firms reach NE if cost distortions are, presumably, unobservable by opponents.
2. There is fundamental inconsistency in assuming that firms who are confused about cost can figure out equilibrium by introspection.
3. What if there is multiple equilibria in the pricing game.

ISSUES DEALT WITH IN THEOREM 1

4. Precisely what sort of mechanism gives rise to the distortion ‘mutations’

ISSUES DEALT WITH IN THEOREM 2
Adaptive Learning: Motivation

We use (a slight modification of) the Milgrom-Roberts (1990) model of adaptive learning:

Boundedly rational players who only know their own payoff functions and the prices of their rivals.

Player act adaptively...
Adaptive learning

$P_1$ $P_2$

$P_{t=1}$ $P_{t=2}$ $P_{t=3}$ $P_{t=4}$ $P_{t=5}$ $P_{t=6}$
Adaptive learning

Consider the smallest cube containing recent play.

\[ \inf \{p_1, ..., p_t, \gamma \} \rightarrow \sup \{p_1, ..., p_{t-\gamma} \} \]
Adaptive Learning: Details 1

- Fix an integer $\gamma \geq 1$

- Start with an old equilibrium $\bar{p}$, and suppose that $s$ changes.

- Consider a sequence of price vectors
  \[ \bar{p} = p_0, p_1, p_2, \ldots \]
Adaptive Learning: Details 2

\{p_t\} is an adaptive pricing adjustment for $\Gamma(s)$ starting at $\bar{p}$ if at every time $t$ every player $n$ plays a best response to a belief with support in the cube:

$$\left[ \inf \{p_{t-\gamma}, \ldots, p_{t-1}\}, \sup \{p_{t-\gamma}, \ldots, p_{t-1}\} \right]$$

Milgrom-Roberts (90): Any adaptive sequence converges to the set of serially undominated strategy profiles.

This class includes as special cases:

- Fictitious play (with bounded memory)
- Sequential best response dynamic
- Cournot Dynamic
Theorem 1: **Statement**

Fix any:

- Firm $n$
- Vector of distortions by other firms $\bar{s}_n \geq 0$
- Any equilibrium $\bar{p}$ of $\Gamma(\bar{s}_n, s_n = 0)$

Then, there exists $\hat{s}_n > 0$ such that for any adaptive pricing adjustment $\{p_t\}$ for $\Gamma(\bar{s}_n, \hat{s}_n)$ starting at $\bar{p}$ there is a time $T$ such that:

$$\pi^e_n(p_t) > \pi^e_n(\bar{p}) \quad \text{for every } t \geq T$$
What can go wrong ..

Suppose the game has multiple equilibria
- Start with \((s_n = 0, s_{-n})\) and an equilibrium \(\bar{p}\) of \(\Gamma(s_{-n}, s_n = 0)\)
- \(s_n \uparrow s'_n > 0\)
- \(p_t\) adjust to a new equilibrium \(p'\) of \(\Gamma(s_{-n}, s'_n)\)

If \(p' < \bar{p}\), then firm \(n\) is worse off under the cost distortion;
While if \(p' > \bar{p}\), then firm \(n\) is better off under the cost distortion;

The conclusion of the analysis hinges on equilibrium selection rather than the fundamentals of the game
Learning gives the right Comparative Statics

Suppose that $\bar{p} \leq r(\bar{p}, s)$. Then for any adaptive pricing adjustment $\{p_t\}$ for $\Gamma(s)$ starting at $\bar{p}$,

$$\lim_{t \to \infty} p_t = \inf\{z \geq \bar{p}; \ z \text{ is a NE of } \Gamma(s)\}$$

This is basically Echenique (2003)

Theorem 1 requires more: it is not enough that prices increase, but payoffs must increase.
The effect of a cost distortion by firm 1
Equilibrium Selection
Equilibrium Selection
Main Theorem: Case I
Main Theorem: Case 2
Adaptive Adjustments of Cost Distortions: *Motivation*

Each firm chooses from a finite grid of possible cost distortions

\[ \{0, \Delta, 2\Delta, \ldots, K\Delta\} \]

where \( \Delta > 0 \) is a small positive number

- Costing methodologies change *much more slowly* than prices
- Firms reinforce the practices that seem to generate the highest payoff
Timing

$P_1, P_2, \ldots, P_t, \ldots$

$\tau=1 \quad \tau=2 \quad \tau=3 \quad \text{time}$
How are Payoffs Determined?

- Given the prevailing equilibrium price from the last period \( p_{\tau-1} \),
- And given firms’s choice of distortions in the current period \( s_\tau \),
- Prices adjust, \( \{p_t\} \), generating a new equilibrium \( p_\tau = \lim_{t \to \infty} p_t \)
- Payoffs in round \( \tau \) are those calculated at \( p_\tau \)
How payoffs are computed at time $\tau$

Given a vector of distortions $(s_1, s_2, .., s_N)$ chosen at time $\tau$

And given:
The limiting price from last period $p_{\tau-1}$

Compute the limit $p_{\tau} = \lim p_t$

Payoffs at time $\tau$ are $\pi^e_n(p_{\tau})$
Problems

This is a well defined dynamic game. But there are problems:

**Problem 1:** Firms do not know the costing practices of their opponents

**Problem 2:** It is not reasonable to assume that firms know their payoffs!
Learning models

We know of three learning models that can deal with games where players do not observe others’ actions or know their payoff function:

- Hart-Mas-Colell (Econometrica 2001)
- Friedman-Mezzetti (JET 2001)
- Milgrom and Roberts (GEB 91)

All of these models require experimentation.
We consider a model of random, infrequent, experimentation (a la Milgrom-Roberts, 1991)

- Firms experiment with new distortions at random
  - Probability of experimentation $\epsilon_{n\tau}$
- In an experimentation period, the firm chooses uniformly from
  \[ \{0, \Delta, 2\Delta, \ldots, K\Delta\} \]
- Firms experiment independently from each other and over time.
- Experimentations are rare: $\epsilon_{n\tau} \to 0$. 
Theorem 2

All firms eventually suffer from the sunk cost bias and choose a positive distortion is all non-experimental periods, almost surely.

Intuition:

- When firms use adaptive pricing adjustments, choosing zero distortion is a “dominate” action (Theorem 1).
- Hence, the expected payoff from a small positive distortion to relevant costs is greater than the expected payoff to zero distortion.
- Expected payoffs are eventually reflected in realized average payoffs.
Firms face symmetric linear demand with equal marginal costs. In this case, the distortion game is itself:

- supermodular
- Dominance solvable
- Has a unique correlated equilibrium, which is in pure strategies.

The dynamic of Theorem 2 converges almost surely to the equilibrium level of distortions. The magnitude of the limiting level of distortion is the same as the one derived from solving a two-stage game.
Experimental Test

Offerman and Potter’s (2003) tested a two-firm symmetric model:

- Each firm has marginal cost of 10.
- Demand for firm $n$ is

$$D_n = 124 - 2p_n + 1.6p_m.$$ 

- Symmetric Nash equilibrium prices is 60.

Our model predicts a price of 78.18
In two treatments, Offerman and Potters obtain prices of 75.65 and 72.73
No Distortion Results

Our explanation of the sunk bias implies that no such bias should be observed in:

- **Homogenous good Bertrand competition**
- **Monopoly**
  - In Offerman-Potter’s experiment, subject in a monopoly position do not display the sunk cost bias.
- **Perfect competition**
  - We only have indirect evidence. A leading managerial accounting textbook (Maher, Stickney and Weil) notes: “Cost-based pricing is far less prevalent in Japanese process-type industries (for example, chemicals, oil, and steel).”
Evolution of Preferences Literature (EPL)

- Small point: Ours is a model based on learning rather than evolution
- Results in EPL have no bite when preferences are not observable
- EPL usually does not
  - model the stage game
  - deal with multiple equilibria and comparative statics issues
- We look at the consequences of a specific, psychologically plausible preference distortion
- The logic of the EPL literature is independent of whether there is sunk cost
Delegation Literature (DL)

- As in the EPL
  - The logic of the DL literature is independent of whether there is sunk cost
  - DL usually does not deal with multiple equilibria and comparative statics issues
- Our model predicts sunk cost effects in experiments, where delegation is not an issue
- Sophisticated backward induction vs. naive adaptive learning
- There is no evidence of a “vast right-wing conspiracy against” consumers ... but there is lots of evidence of a collective, self-reinforcing confusion about cost
Methodological points:

- Evidence whether firms play equilibrium in high-stake decisions, like pricing, is, at best, scant;
- The standard argument is that rational behavior and equilibrium are plausible theoretical predictions because systematic deviations from rationality will be eliminated by the forces of competition, learning, and evolution.

What we do in this paper:

- We examine whether psychological biases disappear once confronted with competitive forces in the context of cost allocations and pricing decisions;
- We show that whether or not biases disappear depends on market structure, thus generating testable predictions on the way biases vary across environments.
THE END !!