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Combining the endogenous choice of price/quantity and timing

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HIGHLIGHTS

- Both the entry timing and competition version are endogenously determined in the game.
- Simultaneous quantity competition is the unique equilibrium outcome with substitutes.
- Simultaneous price competition is the unique equilibrium outcome with complements.

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ABSTRACT

This paper builds a theory of endogenous role distribution (leader, follower, and Nash player) and of endogenous choice for the type of competition strategy (price and quantity) in a product differentiated duopoly model. We examine an extended game by adding a pre-play stage in which duopoly firms simultaneously decide whether to select a price contract or a quantity contract and also whether to move in the first period or in the second period before market competition. We demonstrate that the unique equilibrium outcome is simultaneous quantity competition if the goods are substitutes and simultaneous price competition if the goods are complements.

1. Introduction

From the viewpoints of firms' competition version, quantity competition and price competition are the two classical models in the literature of industrial organization. Cournot (1838) analyzes a duopoly model where firms simultaneously compete in quantities, whereas Bertrand (1883) studies a duopoly model where firms instead simultaneously compete in prices. From firms' entry sequence, the two standard models are a static game where oligopoly firms simultaneously choose their respective actions and a dynamic game where oligopoly firms sequentially choose their respective actions. Stackelberg (1934) investigates a quantity leader–follower model, where one firm (the leader) first chooses its quantity and the other firm (the follower) then chooses its quantity.

By supposing two firms choose actions simultaneously, Singh and Vives (1984) are the seminal work that treats an interesting problem: Given the opponent's choice of offering a price (quantity) contract, does a firm have an incentive to deviate to be a quantity (price) setter, instead of choosing the same price (quantity) contract as its opponent? In this sense, the type of a firm's competition strategy is endogenously determined. Singh and Vives (1984) show that duopoly firms engaging in quantity (price) competition with substitutes (complements) is the unique equilibrium outcome.[1]

Assuming two firms engage in price (or quantity) competition, Hamilton and Slutsky (1990) carry out a pioneering work on solving an interesting problem: Why is the leader (follower)

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[1] For other related works, Maggi (1996) examines the implications of strategic trade policies with an endogenous mode of competition. Thisse and Vives (1988) analyze the implications of the strategic choice of a spatial price policy in the context of a spatial competition model.

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willing to move first (wait for his opponent's choice) and then get a lower profit than his opponent? In other words, the entry timing is endogenously determined. In the game with an observable delay and substitute products, Hamilton and Slutsky (1990) demonstrate that with price competition, both sequential play subgames are the outcomes of equilibria. In quantity competition, the simultaneous play subgame is an outcome of the unique equilibrium. In mixed quantity–price competition, only one of the sequential play subgames, where the firm choosing a quantity contract moves first and the other choosing a price contract moves later, is the unique equilibrium outcome.[2]

When the firms meet symmetric market demands and use identical production technologies, then a genuine question is raised in the Singh and Vives (1984) model: Does a firm have an incentive to move first or to wait until observing the opponent's action? A similar natural question may also arise in the Hamilton and Slutsky (1990) model: Why is a firm willing to offer a price (quantity) contract, instead of changing to offer a quantity (price) contract? In the real world, an enterprise needs to decide both at what time it will enter a market (early or late) and which kind of contract (price or quantity) it will make with its customers. In this sense, both the entry timing and competition version are endogenously determined by firms in reality.

Under general demand functions and constant-returns-to-scale technologies, this study investigates a horizontal product differentiation model with both endogenous choice for the type of competition strategy and endogenous timing. We examine an extended game by adding a pre-play stage in which duopoly firms simultaneously decide whether to select a price contract or a quantity contract and also whether to move in the first period or in the second period before market competition. Apart from symmetric demand, we assume there are concavity and smoothness in the profit function, interiority to the solution, and monotonicity of profit and marginal profit in the opponent's choice.

We find that with substitutes (complements), choosing a quantity (price) contract and moving in the first period make up a dominant strategy for each firm. In this sense, the unique equilibrium outcome is simultaneous quantity competition if the goods are substitutes and simultaneous price competition if the goods are complements.

2. The model

Consider an industry consisting of two firms, denoted by 1 and 2, that produce horizontally differentiated (substitute or complement) products using identical constant-returns-to-scale technologies, and marginal production costs are normalized to zero.

Following Singh and Vives (1984), we assume each firm i's inverse demand function is given by $p_i = f_i(q_i, q_j)$, for $i, j \in \{1, 2\}$ and $i \neq j$, which is twice continuously differentiable and downward sloping in its own quantity ($\partial f_i/\partial q_i < 0$).[3] The cross effect, $\partial f_i/\partial q_j$, is symmetric ($\partial f_1/\partial q_2 = \partial f_2/\partial q_1$) and negative with substitutes and positive with complements. Suppose the Jacobian is positive and non-vanishing – that is, $\partial f_1/\partial q_1 \cdot \partial f_2/\partial q_2 - \partial f_1/\partial q_2 \cdot \partial f_2/\partial q_1 > 0$ – then there exists a demand system, denoted by $q_i = h_i(p_i, p_j)$, for $i, j \in \{1, 2\}$ and $i \neq j$. Firm i's demand function is twice continuously differentiable, downward sloping in its own price ($\partial h_i/\partial p_i < 0$), and the cross effect, $\partial h_i/\partial p_j$, is symmetric and positive with substitutes and negative with complements.

The game proceeds in two stages. In the first stage (pre-play stage), two firms simultaneously decide the type of competition strategy – price or quantity – and also the period – first period or second period – in which a value for the competition strategy is chosen. In the game's second stage (market competition stage), they play according to these timing decisions: If one firm moves in the first period and the other moves in the second period, then they become leader and follower, respectively, according to their announced contracts with the firm that chooses a later time observing the action chosen by the firm moving first. If they move in the same period, then a simultaneous move occurs according to their announced contracts.

Firm i's profit function is denoted by $\pi_i(s_i, s_j)$, where $s_i \in \{p_i, q_i\}$ and $s_j \in \{p_j, q_j\}$ are the strategy choices of the firms, for $i, j \in \{1, 2\}$ and $i \neq j$. We note that for a given firm i's strategy choice $s_i \in \{p_i, q_i\}$, its profit function is monotonic in the opponent's choice, such that: $\partial \pi_i(s_i, q_j)/\partial q_j < (>)0$ and $\partial \pi_i(s_i, p_j)/\partial p_j > (<)0$ with substitutes (complements).[4] We further make the following assumptions to ensure a unique equilibrium in all the subgames in the game's second stage in order for our comparison to be straightforward and meaningful.

A1. $\partial^2 \pi_i(s_i, s_j)/\partial (s_i)^2 < 0$, for $s_i \in \{p_i, q_i\}$ and $s_j \in \{p_j, q_j\}$.

A2. $\partial^2 \pi_i(s_i, p_j)/\partial s_i \partial p_j > 0$ and $\partial^2 \pi_i(s_i, q_j)/\partial s_i \partial q_j < 0$, for $s_i \in \{p_i, q_i\}$, if the goods are substitutes and conversely if the goods are complements.

A3. $\partial^2 \pi_i(q_i, q_j)/\partial (q_i)^2 + \left|\partial^2 \pi_i(q_i, q_j)/\partial q_i \partial q_j\right| < 0$ and $\partial^2 \pi_i(p_i, p_j)/\partial (p_i)^2 + \left|\partial^2 \pi_i(p_i, p_j)/\partial p_i \partial p_j\right| < 0$.

A4. The equilibrium in the sequential game is interior and is not the same as in the simultaneous game.

Here, $i, j \in \{1, 2\}$ and $i \neq j$.

Assumption A1 ensures a firm's unique interior choice, which is fulfilled when a firm's (inverse) demand function is concave or is not "too convex" in its own choice.[5] Assumption A2 ensures a downward (upward) sloping Cournot reaction function and an upward (downward) sloping Bertrand reaction function with substitutes (complements). Assumption A3 guarantees that the reaction functions have a slope less than one in absolute value under Cournot competition and Bertrand competition, and thus there exist a unique Cournot equilibrium and Bertrand equilibrium. For the case of mixed quantity–price competition, the unique equilibrium is guaranteed by the fact that one firm's reaction function is upward sloping and the other firm's reaction function is downward sloping. The sequential game with perfect information has a pure strategy subgame perfect Nash equilibrium and never raises the existence problem of equilibrium. Assumption A4 is made for comparing the leader and follower payoffs in a sequential game, implying that each firm strictly prefers its leader payoff to the payoff in a simultaneous game.

[2] The literature has also proposed numerous developments. For instance, Amir (1995) completes the work of Hamilton and Slutsky (1990) by establishing the necessity of an additional monotone condition. Sadanand and Sadanand (1996) investigate demand uncertainty. Van Damme and Hurkens (1999) introduce the notion of risk-dominance. Amir and Grilo (1999) consider multiple Nash equilibria in a simultaneous game and use the theory of supermodular games.

[3] Such an inverse demand function can be derived from a representative consumer's quasi-linear utility function.

[4] The monotone property of a firm's profit in its opponent's choice follows directly from the monotonic cross effect of the demand and inverse demand functions.

[5] The assumption of strict concavity for a firm's profit function is responsible for the analysis of a sequential game. In a simultaneous game the assumption of strict concavity can be relaxed to quasi-concavity.