Make-to-Order vs. Make-to-Stock When Firms Compete, Input Costs, and Demand are Stochastic

Guang Xiao, Panos Kouvelis, Danko Turcic

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Introduction. Oligopoly competition is the subject of extensive study in economics and operations research (Kreps and Scheinkman, 1983; Singh and Vives, 1984; Van Mieghem and Dada, 1999; Farahat and Perakis, 2011). Two classical models in the theory of oligopoly are those of Kreps and Scheinkman (1983) and Singh and Vives (1984). In the former, two manufacturers first decide independently and simultaneously how much they will produce. They then bring these quantities to market, each learns how much the other produced and both firms engage in competition: That is, they simultaneously and independently name prices and demand is allocated in Bertrand fashion, with the constraint that each firm's production quantity represents an upper bound on how much it can sell to consumers. The unique equilibrium is that each firm produces a Cournot quantity and announces a Cournot price; that is firms are able to price *above* their marginal costs, which reveals that the first-stage quantity commitment decision reduces the intensity of the second-stage price competition. Singh and Vives (1984) refine the results in Kreps and Scheinkman (1983) by showing that when the goods are substitutes, both producers will commit to quantity by choosing to operate in a "make-to-stock" mode. (As an alternative to make-to-stock, "make-to-order" mode is considered.) Their make-to-stock mode operationalizes the quantity commitment as follows: If a producer chooses the make-to-stock mode, it is committed to supplying a *predetermined* quantity to the market at a price that will clear the predetermined quantity, regardless of what its competitor does. In both studies, manufacturers face constant marginal production costs and a deterministic demand curve.

In this paper, we consider a two-period, differentiated duopoly model proposed by Singh and Vives (1984). The demand structure is stochastic and allows products to be substitutes. (The stochastic demand means that a manufacturer who decides to produce a product in the first period is uncertain how this product will be valued when consumers preferences are revealed in the second period.) Firms have constant stochastic marginal costs and there are no fixed costs. The stochastic costs are operationalized as follows. If a firm produces in the first period, then its marginal cost is fixed. If a firm produces in the second period, then viewed from the first period, the second period marginal cost is stochastic. The first period marginal cost equals the expected value of the second-period marginal cost. Firms can decide to produce either in the first or the second period. Firms that decide to produce in the first period cannot output more in the second period than what they produced for in the first period. Firms that decide to produce in the second period are unconstrained in their output quantity. In the second period, after the stochastic demand outcome is revealed, each firm strategically decides how much to output into the market. Selling prices are derived from the firms' output quantities and the firms' inverse demand curves.

In practice, the game we describe above, could be played in variety of ways. One could consider a situation in which the duopoly firms are seasonal retailers who engage in contract manufacturing. Large contract manufacturers such as Li & Fung allow retailers to (strategically) choose lead-times. In our setting, choosing long lead time is equivalent to producing in the first period; choosing a short lead time is equivalent to producing in the second period. Consistent with our assumptions, contract manufacturing costs fluctuate over time, reflecting changing labor and raw material costs, which are ordinarily passed onto the buyer. It is well known that demand for seasonal goods tends to be volatile and often dependent on factors that are beyond the retailer's control (e.g., weather).

Model. We have an economy with a monopolistic sector with two manufacturers, each one producing a differentiated good. Each manufacturer can operate in only two types of production regimes: *make-to-stock* regime (L) and *make-to-order* regime (S). If a manufacturer chooses the *make-to-stock* regime, this means that it will have to produce at date 1, incurring a marginal cost c_1, and *then*, at date 2, bring what it have produced to the market with the proviso that it cannot satisfy more demand than it produced for at date 1. If a manufacturer chooses the make-to-order regime, this means that it produces at date 2, incurring a marginal cost c_2. Viewed from date 1, c_2 is a random variable such that $c_1 = \mathbb{E}_1 c_2$. The discount rate between dates 1 and 2 is taken to be zero. The representative consumer maximizes expected utility. As in Singh and Vives (1984), the consumer utility function is assumed to be quadratic and strictly concave, giving a rise to a linear demand structure given by $p_i = A - q_i - r q_{3-i}$, $i \in \{1, 2\}$, where A represents the baseline values (viewed from date 1, A is random variable) and r measures the level of production differentiation.

The sequence of events in our model is as follows. At date 1: both firms decide the production mode (L or S), and the L firm decides production quantity at marginal cost c_1. At date 2, the marginal cost c_2 and the value of A realize. Firm(s) that did not produce at date 1 produce. Both firms compete in the end market. In terms of the information structure, we assume that all market participants can observe the actions taken by all players and can observe all market outcomes, i.e., information is complete. We solve for the SPNE by backward induction.

Main Results. When cost and demand are deterministic, our model yields results that are consistent with previous studies. That is, the equilibrium is (L, L) in that both firms produce Cournot quantities in the first period and clear their inventories in the second period. The stochastic case yields some novel insights and its results depart from those of previous studies.

In a market, when the dominant source of uncertainty is cost (example would be markets for mature products with heavy commodity content), the equilibrium structure changes dramatically as *asymmetric* choices, either (L, S) or (S, L), occur in equilibrium when the level of product differentiation is sufficiently high. Under this equilibrium, the L firm does not clear the entire quantity it chose to produce in the first period. The existence of the asymmetric equilibria is our most important and least intuitive result because it suggests that input cost uncertainty and competition cause two completely symmetric producers to adopt asymmetric modes of operation. When the level of product differentiation and the coefficient of variation of the firms' input costs are sufficiently low, then both competing firms choose (L, L) regime in equilibrium. This *symmetric* equilibrium allows both firms to avoid the intense price competition associated with low product differentiation. We find no equilibria in which both firms choose the (S, S) regime.

In contrast, in a market where demand uncertainty dominates cost uncertainty, the equilibrium is generally symmetric (except for extreme values of model parameters): when demand uncertainty is high both manufacturers produce in the second period (S, S); when demand uncertainty is low, both produce manufacturers in the first period (L, L). (Example of markets where demand uncertainty dominates cost uncertainty include innovate products whose cost of production does not fluctuate significantly over time.) To summarize, our results reveal that a firm's decision whether to opt for long or short delivery lead times is strategically important as it subsequently affects the competitive nature of an industry. This is especially relevant as more firms have the option of adopting flexible manufacturing regimes and/or fast supply chains that can dramatically reduce lead times.