THE STRATEGIC PERILS OF DELAYED DIFFERENTIATION

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Abstract. The value of *delayed differentiation* (aka *postponement*) for a monopolist has been extensively studied in the Operations literature. We analyze the case of (imperfectly) competitive markets with demand uncertainty, wherein the choice of supply chain configuration (early/delayed differentiation) is endogenous to the competing firms. We characterize firms' choices in equilibrium and analyze the effects of these choices on quantities sold, profits, consumer surplus and welfare. We demonstrate that *purely strategic considerations* not identified previously in the literature play a pivotal role in determining the value of delayed differentiation. In the face of either entry threats or competition, these strategic effects can significantly diminish the value of delayed differentiation. In fact, under plausible conditions, these effects dominate the traditional risk-pooling benefits associated with delayed differentiation, in which case early differentiation is the *dominant* strategy for firms, even under cost parity with delayed differentiation. We extend the main model to study the effects of alternate market structures, asymmetric markets and inventory holdback. Our results, in particular that for a broad range of parameter values early differentiation is a dominant strategy even under cost parity with delayed differentiation, are robust to these relaxations.

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1. Introduction

'Companies must be flexible to respond rapidly to competitive and market changes.'

- Michael Porter (1996)

Contemporary businesses face uncertainty due to a variety of factors, such as increasing globalization, proliferation in product varieties, disruptive changes in technology, and most importantly, uncertain demands from customers. In this context, approaches to incorporate operational flexibility

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in a firm's supply chain, to better match supply and demand, have received considerable attention. One such approach is delayed differentiation or postponement. Using delayed differentiation, a firm delays or postpones the final customization of a related bundle of products (and/or shipment of product to different geographical markets) to the extent possible, pending more accurate product and market-specific demand information. This is a form of 'risk pooling' across markets.

Delayed differentiation is well illustrated by the celebrated example of Hewlett-Packard (HP) (*cf* Lee et al. (1993)). HP manufactured its Deskjet-Plus printers in its Vancouver, Washington facility, and shipped the printers to three distribution centers in North America, Europe and Asia. The transit time by sea, to the two non-U.S. distribution centers, was about a month. Depending on the eventual destination country, different power supply modules had to be installed in the printers to accommodate local voltage, frequency and plug conventions. The manuals and labels also had to be localized due to language differences. HP redesigned the printer so that the power module could be added as a simple plug-in, manufactured a generic Deskjet-Plus printer in the U.S. (sans power supply module, manual and labels) and later localized the generic product in Europe, based on observed demand conditions. Restructuring its printer production process in this fashion enabled HP to maintain the same service levels with an 18% reduction in inventory, saving millions of dollars (Lee et al. (1993)). A recent survey across a number of industries including aerospace, automotive, education, health care, retail, high-tech and telecommunications found that 9% of firms, employed some form of postponement (Mathews and Syed (2004)).

The main model in this paper builds on Anand and Mendelson (1998) and extends their research to a competitive setting. In Anand and Mendelson (1998), a monopoly firm's supply chain consists of a production facility, a distribution center and two differentiated markets. Demand information is used to mitigate the effects of uncertainty in the output markets. They compare a firm's performance under two alternative supply chain configurations– early and delayed differentiation, to quantify the value of postponement. They compute the optimal shipping and production policies in a dynamic (multi-period) setting, and study the drivers of the value of postponement.

In the current study, we model delayed differentiation as a decision variable in a competitive scenario. Each firm in our duopoly model chooses between two different supply chain configurations- *delayed differentiation* and *early differentiation*. We derive the equilibrium choices of supply chain configurations, and analyze the corresponding sales, production, consumer surplus, welfare and profits for each firm. While the conventional risk pooling benefits of the monopoly models persist in our setup, additionally, we identify *strategic* consequences of the supply chain configuration employed. We show that for a wide variety of demand parameters, firms may prefer to deploy early rather than delayed differentiation even under cost parity between the two options. Further, under plausible conditions, *we find a dominant strategy equilibrium in early differentiation, i.e., each firm's dominant strategy (independent of the other firm's choice) is to employ early differentiation.* We observe this even when all cost and demand parameters are identical under early and delayed differentiation. To understand the drivers of these results, we parse the profits of each firm into two additively separable components. The first is the *risk-pooling premium* that favors delayed differentiation and drives the results in a monopoly setting. It is a function of the demand variances and coefficients of correlation across the different markets. We term the second component, unique to our competitive setting, the *strategic premium.* This component is a function only of the size of the market in which the two firms compete, and is higher under early differentiation. As the demand variances fall, the correlations between a firm's markets increase, or the size of the competitive market increases, the strategic premium begins to dominate the risk premium, leading to the results discussed above.

We extend the analysis to a variety of relaxations of the original model, including heterogeneous markets and retailers (Section 6) and alternative market structures (Section 7), and find that our results are consistent. A unilateral increase in the mean demand of the competitive market (keeping everything else constant) favors early differentiation, while such an increase in the size of any of the monopoly markets has no impact on either firm's choice of supply chain configuration– the absolute profits under early or delayed differentiation obviously change but their relative ordering does not. Thus, *the degree of competition (the relative size of the competitive and monopolistic markets) is an important determinant of the optimal supply chain configuration.* Similarly, the impact of a change in the demand correlation between a firm's markets is unambiguous: A unilateral decrease in this correlation increases the risk pooling premium and favors delayed differentiation for the firm, irrespective of the other firm's supply chain configuration. It is important to emphasize that, in our models, the relative disadvantage of delayed differentiation with respect to early differentiation does not arise out of different process costs, but purely due to *endogenous strategic effects.*

The rest of this paper is organized as follows. Section 2 reviews the related literature, and Section 3 describes our modeling framework. Section 4 derives and compares the equilibrium production, sales and profits under each possible supply chain configuration. In Section 5, we characterize the equilibrium choices in supply chain configurations. In Section 6, we relax the assumption of identical distribution of market demands and further extend the model and analysis by allowing for completely general distributions of demand. Next, we examine the implications of the *clearance* and *market structure* assumptions of the main model of Sections 3-5, by relaxing these assumptions in analytical models (in Sections 7.1 and 7.2 respectively). We demonstrate that our central message– that early differentiation is often the dominant strategy for firms under competition, on account of the strategic premium, and that the choice of supply chain configuration must take the industry structure into account– is robust to all the relaxations analyzed in Sections 6 and 7. Concluding remarks are in Section 8.

2. Related Literature

In addition to the studies of Hewlett-Packard's use of postponement by Lee and collaborators, there is an extensive stream of research in Operations on postponement under *monopoly* settings. The interested reader is referred to the comprehensive reviews of this literature in Anand and Mendelson (1998) and Swaminathan and Lee (2003). A second stream of research, mostly in Economics, on *early-mover commitment* also relates to our competitive setting.

Military lore is replete with stories of generals gaining commitment for battle from their troops by cutting off their retreat options– by burning the transport ships or bridges they used to reach enemy lines (from which the idiom 'burning one's bridges' derives) or by 'nailing one's colors to the mast' in Naval warfare. Troops must then win or die. Schelling (1960) provides other examples; his citation for the 2005 Nobel memorial prize in Economics read, in part, *'Schelling showed that a party can strengthen its position by overtly worsening its own options...'* . Similarly, under competition, a player who *commits* first to a course of action or (equivalently) *restricts* his own options in a manner convincing to his opponents may gain a strategic advantage, as in Stackelberg (1934). Hamilton and Slutsky (1990) and Rabah (1995) show that the signs of the slopes of the best-response functions drive players' preferences for the order of moves in a game: each player prefers his simultaneous Nash payoff to his Stackelberg follower payoff if and only if the best-response curves are downward-sloping. Stackelberg (1934)'s equilibrium arises in multistage production games in Saloner (1987), Pal (1991) and Maggi (1996). Capital investments can play a similar role. A player might invest in capacity to gain a strategic advantage in the subsequent *Cournot* (quantity-setting) competition (Dixit (1980); Spence (1977)) or second-stage *price* competition (Allen et al. (1995)). Vives (2000) provides a good overview of this literature.

The literature on dedicated versus flexible manufacturing technologies under competition is of particular interest from an Operations perspective (Roller and Tombak (1993); Boyer and Moreaux (1997); Goyal and Netessine (2003)). The main finding is that employing dedicated production technology can have commitment value under competition. Roller and Tombak (1993) analyze a two stage game, in which firms chose between a flexible and a less flexible technology in the first stage and decide on production quantities in the second stage. In equilibrium, adoption of flexible technologies is more likely in concentrated markets. Boyer and Moreaux (1997) extend the analysis to consider the effect of volatility and market size on the choice of production technology. Goyal and Netessine (2003) formally prove the existence and the uniqueness of an equilibrium in the stage games under general conditions, and characterize the restrictions that lead to specific equilibrium outcomes.

In our study, the trade-off between commitment and flexibility arises out of choosing the point of differentiation of an intermediate good into related end-products. Our results demonstrate that the rich literature on delayed differentiation arguing its superiority over early differentiation under cost-minimization or profit-maximization was predicated very strongly on the monopoly assumption. Under competition, the strategic premium plays a pivotal role, leading to early differentiation as a *dominant* strategy under a broad range of parameters, even under cost parity with delayed differentiation. Our paper demonstrates the vital importance of the link between *Operations* and *Industry Structure*. In optimizing its Operations, it is imperative for a firm to take its Industry Structure into account.

3. Model Setting

Competitive Structure. Two competing firms seek to maximize their individual expected profits under demand uncertainty. Each firm sells two related products; for concreteness, we will assume that each product is sold in a distinct product market. Each firm is the monopoly supplier in one of its two markets, which we call the *monopoly market* (denoted by the superscript M). The two firms compete in their other market (the *competitive market*, denoted by the superscript C).[1]

The model reflects a common situation wherein a firm is a strong player– a near-monopolist– in one market (say, its *home* market), and faces strong competition from local players in overseas markets.

[1]Section 7.2 shows that our central results and intuitions hold under an alternative structure, in which the firms compete in two markets without access to captive monopoly markets.

For example, in the case of inkjet printers (discussed above), Hewlett-Packard was a dominant player in the U.S., a competitive force in Europe, and a marginal presence in Japan, due to strong competition from companies like Epson.[2]

Market Model. Following Anand and Mendelson (1998)'s monopoly model, each market faces a linear and downward-sloping demand curve $p(q) = a - q$,[3] where the intercept a is random, and drawn from a distribution with mean $\bar{a}$ and variance $\hat{a}$.[4] We assume that this distribution has compact support over the interval $[a_l, a_h]$, where $a_l, a_h \geq 0$ and $a_h - a_l \leq 1.2\bar{a}$.[5] Demand is correlated between the competitive market and each monopoly market, with a correlation coefficient $\rho \in [-1, 1]$. We build on the Cournot (quantity-setting) model of imperfect competition. In the conventional Cournot setting, firms decide on quantities to be released into the market, and prices adjust to clear the total quantity. However, many other settings have been found to be isomorphic to Cournot, leading to various alternative, reasonable and appealing interpretations of this competitive model (cf. Tirole (1988)). Notable among these isomorphic reinterpretations is price-competition among firms with differentiated but partially substitutable products.

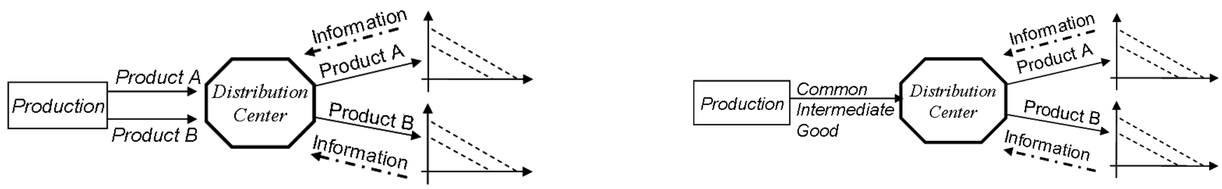
Supply Chain Configurations. As in Anand and Mendelson (1998), each firm's supply chain consists of a production facility, a distribution center (DC) and two retail outlets– one for each market. There are two stages in the firm's supply chain activities: in the first (production) stage, the firm decides on production quantities and ships these to the DC. In the second (distribution) stage, the firm allocates these quantities to its outlets. In the production stage, the firm estimates the demand for its products using the prior distributions discussed above. In the distribution stage, the firm observes the demand realizations; hence subsequent decisions (allocation to the two outlets) are based on perfect demand information. This two-stage supply chain structure, wherein the uncertainty is resolved in the second stage, is a reasonably accurate model for products with long

[2]In the period 1993-2003, HP consistently commanded larger than 55% share of the US inkjet market. In 2003, the next player had less than 20% market share (source: HP Press Release, July 1, 2003.)

[3]The linear downward-sloping demand curve has an appealing interpretation as the demand arising from the utility-maximizing behavior of consumers with quadratic, additively separable utility functions (Singh and Vives (1984)).

[4]Section 6 extends the analysis to asymmetric (*ex ante* heterogeneous) demand distributions across markets.

[5]We need to impose this restriction on the maximum spread of demand relative to the mean, to ensure that firms have an incentive to sell positive quantities of their products in all markets (post-demand realization). Absent this assumption, the trivial case can arise wherein a firm completely withdraws from one market and operates only in one of the two markets. Chod and Rudi (2005) numerically evaluate the impact of such a restriction under monopoly. They find that for typical values, the difference in the profits with and without this assumption is less than 3%.



(a) Early Differentiation (b) Delayed Differentiation

FIGURE 1. Alternate Supply Chain Configurations for a Monopoly Firm

production lead-times relative to the selling cycle, such as fashion goods (cf. Fisher et al. (1994)), in which much of the uncertainty is resolved based on early season sales or orders.

The firms may employ one of two alternative *supply chain configurations*:[6] ***e****arly differentiation* *(**e**)* or ***d****elayed differentiation* *(**d**)*. For a firm employing early differentiation, (Figure 1 (a)), the products are differentiated in the production stage. Thus the DC receives intermediate goods specialized for each product market. In the second stage, the firm then ships these goods from the DC to the appropriate market.

Under delayed differentiation (Figure 1 (b)), the intermediate good is common to both products. Thus, at the production stage, the firm has to decide only on the total production quantity of the *common intermediate good*. In the distribution stage, after observing the realizations of demand, each unit of the common intermediate good is customized at the DC and shipped to the appropriate market.

Typically, adoption of delayed differentiation entails higher costs arising out of the need for reconfiguration of the organizational processes, process and component standardization, design modularization (Schwarz (1989)) and longer lead-times (Lee and Tang (1999)). To isolate the *strategic* issues related to the choice of supply chain configuration (which is the focus of our paper), we assume that all production and process costs for early and delayed differentiation are identical. At the very least, this gives us an upper bound on the benefits from postponement. Without loss of generality, we normalize these costs to zero.

In the interest of analytical tractability, we assume for now that firms follow a *clearance strategy*– After demand is realized, the firm must allocate all available stock at the distribution center to

[6]In the game-theory literature, the term 'strategy' denotes each player's '*contingent actions*' in response to other players' actions. In our multistage game, contingent actions include not only the choice of early or delayed differentiation, but also production and shipment quantities for each market. Thus, we will use the term 'strategy' broadly to denote all three elements of the choice, and the term 'supply chain configuration' to more narrowly denote one *element* of a firm's strategy– the choice of early or delayed differentiation.

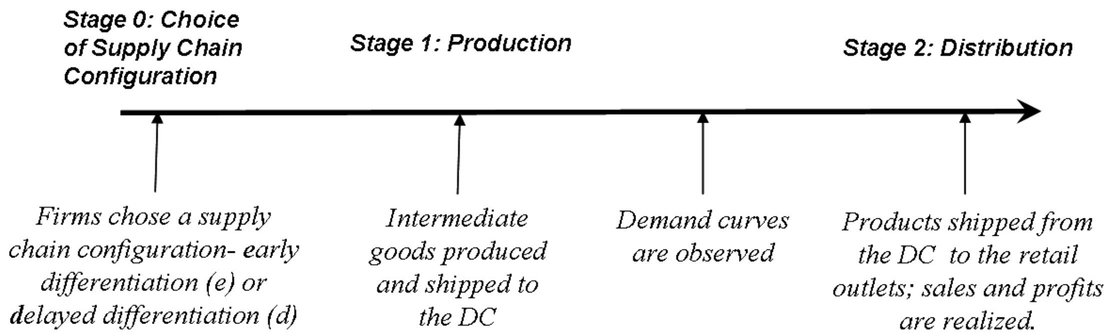


FIGURE 2. The Time-line

either of the markets.[7] Similar assumptions have been made by Goyal and Netessine (2003), Chod and Rudi (2005) and Deneckere et al. (1997). Chod and Rudi (2005) show that, under monopoly, the qualitative results derived under the clearance assumption hold even when the assumption is relaxed. In practice, many firms find it hard to change production levels in the short run owing to long term contracts with labor unions and suppliers. For example, several car makers often slash prices to maintain production levels, rather than keeping capacities idle– in effect following a clearance strategy (Mackintosh (2003)).

Sequence of Events. The sequence of events is provided in Figure 2. In stage 0, the firms choose a supply chain configuration ($\boldsymbol{e}$ or $\boldsymbol{d}$). Then in the production stage (stage 1), the firms produce the intermediate good(s) and ship these to their respective DCs. After production commitments have been made, accurate demand information becomes available. In the distribution stage (stage 2), the DCs decide on the allocation of the intermediate good to each of their markets, based on the demand information. We assume that at each stage, firms' decisions in the preceding stages are common knowledge.

In the *production stage*, a firm choosing an early differentiation configuration produces and ships differentiated quantities $q^C_{e|.}$ and $q^M_{e|.}$ to the distribution center.[8] On the other hand, a firm employing

[7]We will relax this assumption in the analysis of Section 7.1.

[8]We use the notation '$x|y$' (or, x given y) to refer to a firm with supply chain configuration x facing a competitor with supply chain configuration y, where x and y can each be set to e or d. The superscripts 'C' and 'M' denote the Competitive and Monopoly markets respectively. $q^A_{x|y}$ denotes the quantity sold by a firm employing x, facing a competitor employing y, to market A; where $x, y \in \{e, d\}$, $A \in \{C, M\}$. $Q_{x|y}$ denotes the quantity of intermediate good produced by a firm employing x, facing a competitor employing y; where $x, y \in \{e, d\}$. Similarly, the profits earned by a firm employing x facing a competitor that employs y are denoted by the Greek letter $\Pi_{x|y}$. We index particular industry structures by '$x - y$'. The consumer surplus under the industry structure $x - y$ is denoted by CS_{x-y}.

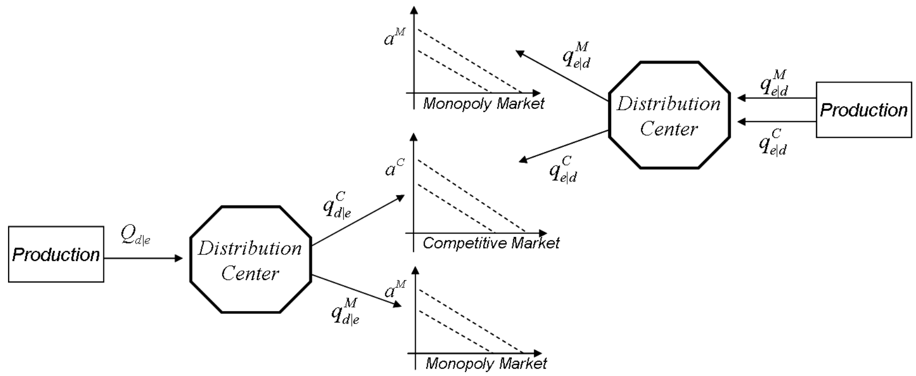


FIGURE 3. Alternate Supply Chain Configurations under Competition- The **d-e** Case

delayed differentiation produces and ships a quantity $Q_{d|.}$ of the common intermediate good to the distribution center.

In the *distribution stage*, a firm employing delayed differentiation can allocate its common intermediate good $Q_{d|.}$ to its two markets optimally, based on the realized market demands, whereas an early differentiator is *a priori* committed to the quantities allocated to each of its markets. A firm employing delayed differentiation sells quantities $q^C_{d|.}\left(a^C, a^M\right)$ and $q^M_{d|.}\left(a^C, a^M\right)$ in its competitive and monopoly markets respectively, where a^C and a^M are the observed realizations of the demand intercepts. An early differentiating firm on the other hand sells its pre-committed quantities, $q^C_{e|.}$ and $q^M_{e|.}$ in the two markets. The clearance strategy implies $q^C_{.|.}\left(a^C, a^M\right) + q^M_{.|.}\left(a^C, a^M\right) = Q_{.|.}$.

The choices supply chain configuration choices can lead to three different industry structures– *(i)* **e-e**, when both firms employ **e**arly differentiation *(ii)* **d-e** (or equivalently, **e-d**), when one firm employs **e**arly differentiation and the other employs **d**elayed differentiation , and lastly *(iii)* **d-d**, when both firms choose **d**elayed differentiation. We illustrate the second case**- d-e** in Figure 3.

4. Analysis of Supply Chain Configurations

In this Section, we derive and compare the equilibrium sales and production quantities under the different supply chain configurations. We analyze the drivers of our results, and study their implications for firm and industry profits, consumer surplus and welfare.

4.1. **Equilibria under different Supply Chain Configurations.** The expected sales for a traditional monopoly and a Cournot duopoly, under our demand assumptions, are useful benchmarks. Such a profit-maximizing monopolist sells $M = \bar{a}/2$ units, and a Cournot duopolist sells $C = \bar{a}/3$ in equilibrium, where $\bar{a}$ (recall) is the mean of the demand intercept. In Table 1, we provide each

Setting	$\mathbf{E}\left[q^M_{\cdot\mid\cdot}\right]$	$\mathbf{E}\left[q^C_{\cdot\mid\cdot}\right]$	***Competitive Market Share (firm 1/firm 2)***	***Production***, $Q_{\cdot\mid\cdot}$
d|e	$\frac{\bar{a}}{2} = 0.5\bar{a}$	$\frac{3}{10}\bar{a} = 0.3\bar{a}$	42%/58%	$\frac{4}{5}\bar{a} = 0.8\bar{a}$
e|e	$\frac{\bar{a}}{2} = 0.5\bar{a}$	$\frac{1}{3}\bar{a} = 0.33\bar{a}$	50%/50%	$\frac{5}{6}\bar{a} = 0.83\bar{a}$
d|d	$\frac{45}{86}\bar{a} = 0.52\bar{a}$	$\frac{30}{86}\bar{a} = 0.35\bar{a}$	50%/50%	$\frac{75}{86}\bar{a} = 0.87\bar{a}$
e|d	$\frac{\bar{a}}{2} = 0.5\bar{a}$	$\frac{2}{5}\bar{a} = 0.4\bar{a}$	58%/42%	$\frac{9}{10}\bar{a} = 0.9\bar{a}$

Monopoly Benchmark, $M = \frac{\bar{a}}{2} = 0.5\bar{a}$, *Cournot Benchmark,* $C = \frac{\bar{a}}{3} = 0.33\bar{a}$, *Production Benchmark,* $C + M = \frac{5}{6}\bar{a} = 0.83\bar{a}$

$\bar{a}$- mean of the intercept distribution

TABLE 1. Expected quantities sold and produced firms in equilibrium under the different supply chain configurations

firm's expected sales in each market and its production, and firms' market shares in the competitive market. Theorem 4.1, derived from Table 1, compares the expected sales and production quantities under the different supply chain configurations.[9]

Theorem 4.1. ***Sales and Production in Equilibrium***

(1) ***Expected Sales:*** *Each firm's* expected sales quantities *in equilibrium under the different supply chain configurations are related as:*

$$\mathbf{E}\left[q^C_{d|e}\right] < \mathbf{E}\left[q^C_{e|e}\right] = C < \mathbf{E}\left[q^C_{d|d}\right] < \mathbf{E}\left[q^C_{e|d}\right], \quad \textit{in the } \textbf{competitive} \textit{ market};$$

$$\mathbf{E}\left[q^M_{d|e}\right] = \mathbf{E}\left[q^M_{e|e}\right] = \mathbf{E}\left[q^M_{e|d}\right] = M < \mathbf{E}\left[q^M_{d|d}\right], \quad \textit{in the } \textbf{monopoly} \textit{ market.}$$

(2) ***Production:***

(a) *Firms'* production quantities *in equilibrium are related as:* $Q_{d|e} < Q_{e|e} = (C + M) < Q_{d|d} < Q_{e|d}$.

(b) *Total production (across both firms) under the different supply chain configurations are related as:* $2(C + M) = Q^{Tot}_{ee} < Q^{Tot}_{de} < Q^{Tot}_{dd}$, *where* $Q^{Tot}_{ee} = 2Q_{e|e}$, $Q^{Tot}_{de} = Q_{d|e} + Q_{e|d}$ *and* $Q^{Tot}_{dd} = 2Q_{d|d}$.

We discuss the intuition behind these results for each setting below.

[9]Proofs for all results are available in the Online Supplement.

(i) The e-e supply chain configuration: Under **e-e**, both firms produce differentiated products at the production stage. Thus, the decisions on production quantities for the competitive and monopoly markets are separable and independent. The sales quantities in equilibrium correspond to Cournot duopoly in the competitive market $\left(\mathbf{E}\left[q^C_{e|e}\right] = C = \bar{a}/3\right)$, and to traditional monopoly in the other market $\left(\mathbf{E}\left[q^M_{e|e}\right] = M = \bar{a}/2\right)$. Thus, each firm's production quantity $Q_{e|e} = (C + M)$.

(ii) The d-e (or e-d) supply chain configuration: Table 1 shows that the delayed differentiating firm loses market share to the early differentiator in the competitive market $\left(\mathbf{E}\left[q^C_{d|e}\right] = 3\bar{a}/10 < C = \bar{a}/3 < \mathbf{E}\left[q^C_{e|d}\right] = 4\bar{a}/10\right)$. In the production stage, the early differentiating firm can commit to sales in each market; the delayed differentiator on the other hand, commits only to a quantity of the common intermediate good. Furthermore, in the shipment stage, the delayed differentiator can allocate its production (of the intermediate good) to either the monopoly market or the competitive market, whereas the early differentiator is unable to do so, due to its commitment to each market arising from its supply chain configuration. Knowing this, the early differentiating firm can *credibly commit* in the production stage to supplying a higher quantity (more than the Cournot quantity $C = \bar{a}/3$) to the competitive market. Given this commitment by the early differentiating firm, and the strategic substitutability (decreasing best response functions) of each firm's production quantity, the delayed differentiating firm has no choice but to ship less than the Cournot quantity to the competitive market, thus giving up market share to the early differentiator. The delayed differentiator's response in turn makes it an equilibrium strategy for the early differentiator to 'oversupply' the competitive market: Thus, $\mathbf{E}\left[q^C_{d|e}\right] < C = \bar{a}/3 < \mathbf{E}\left[q^C_{e|d}\right]$. Further analysis shows that for each extra unit that the early differentiator oversupplies (above the Cournot quantity), the delayed differentiating firm cuts back its supply by only half a unit. Consequently, for each such oversupplied unit, the *total* quantity shipped to the competitive market *increases* by half a unit, thus decreasing the price. Lower prices lead to diminishing marginal returns from oversupply for the early differentiator, restraining it from forcing the delayed differentiator entirely out of the competitive market. As seen in Table 1, the early differentiator supplies $\bar{a}/15$ units more than the Cournot quantity and the delayed differentiator supplies $\bar{a}/30$ units below the Cournot quantity to the competitive market, in equilibrium.

The d|e firm cannot recoup these losses in the competitive market via additional sales in its monopoly market, since it will lose revenues and profits if it supplies more than $M = \bar{a}/2$ to the monopoly market. Thus, anticipating the early differentiator's oversupply to the competitive market and its own sub-Cournot response, the d|e firm cuts back its total production of the intermediate good such that its average shipment quantity to the monopoly market is $\mathbf{E}\left[q^M_{d|e}\right] = M$. For the e|· firm, production decisions for the monopoly market are separable and independent of the decisions for the competitive market, irrespective of the competitor's choices. Thus, in the monopoly market $\mathbf{E}\left[q^M_{e|\cdot}\right] = q^M_{e|\cdot} = \bar{a}/2$. Each firm's total production quantity mirrors the above intuition: $Q_{d|e} < Q_{e|e} = (C + M) < Q_{e|d}$. However, under **d-e**, the *total* industry production is greater than that under **e-e** $\left(Q^{Tot}_{de} = Q_{d|e} + Q_{e|d} > Q^{Tot}_{ee}\right)$, reflecting the above discussion on the slopes of the reaction functions for the d and e firms in the competitive market.

(iii) The d-d supply chain configuration: As before, decreasing best-response production functions imply that if a firm lowers its production, its competitor will increase its production, potentially leading to reduced profits for the first firm. Thus, both firms seek to credibly commit to their supply to the competitive market. However, compared to early differentiation, the ability to allocate the intermediate good to either the monopoly or the competitive market reduces the commitment potency of each extra unit produced under delayed differentiation. Hence each firm under d-d must increase their production to levels exceeding those under e-e to gain an equivalent level of credible commitment. The increased production is detrimental to both firms; nevertheless, in equilibrium, they end up supplying more than even the Monopoly and Cournot quantities to the monopoly and competitive markets– their expected marginal revenues are negative even in their monopoly markets $\left(Q_{d|d} = \left(\mathbf{E}\left[q^C_{d|d}\right] + \mathbf{E}\left[q^M_{d|d}\right]\right) > (C + M) = Q_{e|e}\right)$. The total industry production Q^{Tot}_{dd} is also greater than in the other supply chain configurations.

To summarize, the analysis of early versus delayed differentiation under competition is fundamentally different from that under monopoly due to an important additional factor irrelevant for monopoly, viz., each firm's ability to make credible supply commitments (reflected in both sales and production quantities) to the competitive market. We now analyze the impact of competition on firms' profits, consumer surplus and welfare.

4.2. **Profits, Consumer Surplus and Welfare.**

(i) Profits: Firms' expected profits, shown in Table 2, are determined by two additively separable factors- *(i)* the benefits arising out of efficient allocation under uncertainty (*risk-pooling premium*) and *(ii)* the benefits of strategic commitment (the *strategic premium*). The risk-pooling premium

Setting	***Strategic Premium***	***Risk Pooling Premium***	***Total Expected Profit***
e|e	$\frac{13}{36}\bar{a}^2 = 0.3611\bar{a}^2$	0	$\frac{13}{36}\bar{a}^2$
d|e	$\frac{17}{50}\bar{a}^2 = 0.34\bar{a}^2$	$\frac{\hat{a}}{4}(1-\rho)$	$\frac{17}{50}\bar{a}^2 + \frac{\hat{a}}{4}(1-\rho)$
e|d	$\frac{37}{100}\bar{a}^2 = 0.37\bar{a}^2$	0	$\frac{37}{100}\bar{a}^2$
d|d	$\frac{2625}{7396}\bar{a}^2 = 0.3549\bar{a}^2$	$\frac{4\hat{a}}{25}(1-\rho)$	$\frac{2625}{7396}\bar{a}^2 + \frac{4\hat{a}}{25}(1-\rho)$

$\bar{a}$- mean of the intercept distribution, $\hat{a}$- variance of the intercept distribution.

Table 2. Profits Earned

measures the benefit of risk-pooling; it includes those terms in the profit expressions that are a function of the *variance* of demand, and is realized only by firms employing delayed differentiation. The strategic premium is a function of the *scale* of demand (measured by the mean of the intercept $\bar{a}$), and is a relevant factor only in a competitive environment, in which its magnitude varies across the different supply chain configurations. It is highest for a firm when it can commit to a market and its competitor cannot (the $e|d$ case) and lowest in the reverse situation ($d|e$) when the firm cannot commit but the competitor can. When both firms have equal commitment, the strategic premium is higher when both choose e rather than d. Note that the risk-pooling premium is increasing in the variance $\hat{a}$ and decreasing in the coefficient of correlation ρ. When risk-diversification is not possible (when $\rho = 1$ in our model) or necessary ($\hat{a} = 0$), the risk-pooling premium vanishes, and the profits are driven solely by the strategic premium.

Table 2 shows that the strategic premium is always higher for early differentiation than for delayed differentiation for any configuration that the rival firm employs (Compare the strategic premiums for e|e $\left(0.3611\bar{a}^2\right)$ versus d|e $\left(0.34\bar{a}^2\right)$, and similarly for e|d $\left(0.37\bar{a}^2\right)$ versus d|d $\left(0.3549\bar{a}^2\right)$). Additionally, the strategic premium of an early differentiating firm when the competitor follows delayed differentiation is $0.37\bar{a}^2$, which is better than when the competitor is an early differentiator $\left(0.3611\bar{a}^2\right)$. Thus, on all counts, early differentiation dominates delayed differentiation from a strategic perspective. However, this dominance is tempered by the fact that only delayed differentiating firms earn a risk pooling premium.

It is interesting to compare the relative magnitudes of the risk-pooling premiums from Table 2. Under **d-d**, the risk-pooling benefits are shared by both firms, whereas under **d-e**, the **d** firm captures all the risk-pooling benefits. Hence, the risk-pooling premium earned by a delayed differentiator is

$\rho \in$	$[-1, \rho_4)$	$[\rho_4, \rho_3)$	$[\rho_3, \rho_2)$	$[\rho_2, \rho_1)$	$[\rho_1, \rho_0)$	$[\rho_0, 1]$
Profits Earned	$\Pi_{d\|e} >$ $\Pi_{d\|d} >$ $\Pi_{e\|d} >$ $\Pi_{e\|e}$	$\Pi_{d\|d} \geq$ $\Pi_{d\|e} >$ $\Pi_{e\|d} >$ $\Pi_{e\|e}$	$\Pi_{d\|d} >$ $\Pi_{e\|d} \geq$ $\Pi_{d\|e} >$ $\Pi_{e\|e}$	$\Pi_{e\|d} \geq$ $\Pi_{d\|d} >$ $\Pi_{d\|e} >$ $\Pi_{e\|e}$	$\Pi_{e\|d} >$ $\Pi_{d\|d} >$ $\Pi_{e\|e} \geq$ $\Pi_{d\|e}$	$\Pi_{e\|d} >$ $\Pi_{e\|e} \geq$ $\Pi_{d\|d} >$ $\Pi_{d\|e}$

$\rho_i = max\{-1, \rho_i'\}$, where $\rho_4' = 1 - 2759\left(\frac{1}{129\gamma}\right)^2$, $\rho_3' = 1 - 3\left(\frac{1}{5\gamma}\right)^2$, $\rho_2' = 1 - 697\left(\frac{1}{86\gamma}\right)^2$, $\rho_1' = 1 - 19\left(\frac{1}{15\gamma}\right)^2$, $\rho_0' = 1 - 2575\left(\frac{1}{258\gamma}\right)^2$; $-1 \leq \rho_4 \leq \rho_3 \leq \rho_2 \leq \rho_1 \leq \rho_0 < 1$; $\gamma = \frac{\sqrt{\hat{a}}}{\bar{a}}$- coefficient of variation of the intercept distribution.

TABLE 3. Profit Comparisons

higher when the competitor does not follow delayed differentiation. Note, however, that the *total* risk pooling benefit (across both firms) in **d-d** are higher than those under **d-e**.

Thus, profit comparisons across the different configurations are driven by the relative magnitudes of the risk-pooling and strategic premiums, which are in turn determined by the values of ρ, $\hat{a}$ and $\bar{a}$. Table 3 provides a complete ranking of firms' total profits as a function of the correlation ρ and the coefficient of variation $\gamma = \sqrt{\hat{a}}/\bar{a}$. Moving left to right in Table 3, the correlation ρ increases, reducing the risk-pooling premium and thus favoring **e** over **d** (since the strategic premium is independent of ρ). This is reflected in the rank-ordering of profits under the different supply chain configurations. However, in the entire range, $\Pi_{e|d} > \Pi_{e|e}$ since an **e** firm earns a higher strategic premium when the competitor is **d** rather than **e**, and earns zero risk-pooling premium irrespective of the competitor's choice.

(ii) Consumer Surplus and Welfare: Table 4 shows the industry profits, consumer surplus and welfare under the different supply chain configurations, where welfare is the sum of industry profits and the consumer surplus. Predictably, the ranking of industry profits (total profits across the individual firms) is ambiguous, and depends on the relative magnitudes of the risk-pooling and strategic premiums (determined by ρ, $\hat{a}$ and $\bar{a}$). Theorem 4.2 provides the ranking of consumer surpluses and welfare.

Theorem 4.2. ***Consumer Surplus and Welfare:*** *The expected Consumer Surpluses under the different supply chain configurations follow the ranking:* $CS_{e-e} < CS_{d-e} < CS_{d-d}$. *The welfare ranking is identical to that of the Consumer Surplus.*

Setting	***Industry profits***	***Consumer Surplus***	***Welfare***
e-e	$\frac{13}{18}\bar{a}^2 = 0.722\bar{a}^2$	$\frac{17}{36}\bar{a}^2 = 0.4722\bar{a}^2$	$\frac{43}{36}\bar{a}^2 = 1.1944\bar{a}^2$
d-e	$\frac{71}{100}\bar{a}^2 + \frac{\hat{a}(1-\rho)}{4} =$ $0.71\bar{a}^2 + 0.25\hat{a}\,(1-\rho)$	$\frac{99}{200}\bar{a}^2 + \frac{\hat{a}(1-\rho)}{8} =$ $0.495\bar{a}^2 + 0.125\hat{a}\,(1-\rho)$	$\frac{241}{200}\bar{a}^2 + \frac{3\hat{a}(1-\rho)}{8} =$ $1.205\bar{a}^2 + 0.375\hat{a}\,(1-\rho)$
d-d	$\frac{2625}{3698}\bar{a}^2 + \frac{8\hat{a}(1-\rho)}{25} =$ $0.7098\bar{a}^2 + 0.32\hat{a}\,(1-\rho)$	$\frac{3825}{7396}\bar{a}^2 + \frac{6\hat{a}(1-\rho)}{25} =$ $0.517\bar{a}^2 + 0.24\hat{a}\,(1-\rho)$	$\frac{9075}{7396}\bar{a}^2 + \frac{14\hat{a}(1-\rho)}{25} =$ $1.227\bar{a}^2 + 0.56\hat{a}\,(1-\rho)$

$\bar{a}$- mean of the intercept distribution, $\hat{a}$- variance of the intercept distribution.

Table 4. Consumer Surplus, Industry Profits and Welfare

The unambiguous ranking of consumer surpluses reflects the essence of the risk-pooling and strategic premiums. Risk-pooling, by definition, enables better matching of supply and demand, and thus is beneficial to consumers. This is most clearly illustrated under monopoly, wherein delayed differentiation is known to enhance both consumer surplus and welfare (cf. Chod and Rudi (2005)). On the other hand, the strategic premium is an artifact of competitive dynamics, and focused on the division of the spoils among the competing firms. So it does not contribute to (and perhaps even detracts from) the consumer surplus. *Hence the rank ordering of the consumer surpluses follows that of the industry-wide risk-pooling premiums.* The welfare ranking is also identical because the benefit to consumers from risk-pooling (when one or both firms follow **d**) dominates the profit gains to the competing firms from **e** (via the strategic premium). Thus, from the perspective of a social planner intent on maximizing consumer surplus and/or welfare, delayed differentiation outperforms early differentiation under both monopoly and competition.

5. Endogenizing the choice of Supply Chain Configuration

Our model setting was a three-stage game where firms choose their supply chain configurations in the first stage, determine production quantities in the second stage, and allocate their production to the individual markets in the third and final stage (recall Figure 2). In the previous section, we analyzed the last two stages of this game. We now derive the sub-game perfect equilibrium[10] of the entire

[10] *Sub-game perfection* is the refinement of the basic Nash equilibrium concept for dynamic games. All sub-game perfect equilibria are also Nash equilibria, but the converse is not true. A dominant strategy equilibrium is of course even stronger than Nash, and a rare occurrence in models (cf. Fudenberg and Tirole (1991)).

game, treating each firm's *choice* of supply chain configuration (early or delayed differentiation) as a strategic decision variable. We assume that firms *simultaneously* choose their supply chain configurations.[11] Theorem 5.1 below, which derives the best response functions for each firm, is the essential building block for the rest of this Section.

Theorem 5.1. ***Best Responses:*** *A firm's Best Response strategy (BR) to its competitor's supply chain configuration is as given below*

$$\mathbf{BR}\,(x) = \begin{cases} \mathbf{d} & if \quad \rho < \rho_2 \qquad \textbf{or} \\ & if \quad x = e \quad and \quad \rho \in [\rho_2, \rho_1) \\ \mathbf{e} & if \quad \rho \geq \rho_1 \qquad \textbf{or} \\ & if \quad x = d \quad and \quad \rho \in [\rho_2, \rho_1) \end{cases} \tag{1}$$

where $x \in \{\mathbf{e}, \mathbf{d}\}$ *is the competitor's supply chain configuration. Here,* $\rho_1 = \max\left\{-1,\, 1 - \frac{19}{(15\gamma)^2}\right\} \geq \rho_2 = \max\left\{-1,\, 1 - \frac{697}{(86\gamma)^2}\right\}$ *and* $\gamma = \frac{\sqrt{\hat{a}}}{\bar{a}}$ *is the coefficient of variation.*

Theorem 5.1 derives from the profit comparisons of Table 3. Note that the threshold values ρ_1 and ρ_2 for the coefficient of correlation, given in Theorem 5.1, are increasing functions of the coefficient of variation, $\gamma \left(= \frac{\sqrt{\hat{a}}}{\bar{a}}\right)$. Thus, early differentiation is the dominating strategy for low γ (i.e., relatively low $\hat{a}$ and high $\bar{a}$) and/or high ρ. As Table 2 showed, this corresponds precisely to the case where the *strategic premium* (which is an increasing function of $\bar{a}$; recall Table 2) dominates the *risk pooling premium* (which is increasing in $\hat{a}$ and decreasing in ρ). Under the reverse conditions, the risk pooling premium dominates the strategic premium, and d is the dominant strategy. As was shown in Table 2, when a firm employs d, the risk pooling premium is higher but the strategic premium is lower when the competitor employs e rather than d. This trade-off drives the best-response function in the intermediate range ($\rho \in [\rho_2, \rho_1)$): here, $\mathbf{BR}(d) = e$ and $\mathbf{BR}(e) = d$.

To summarize, Theorem 5.1 demonstrates that *early differentiation is the dominant strategy, vis-à-vis delayed differentiation, whenever the strategic effects play a prominent role relative to risk pooling as a driver of profits* ($\rho \geq \rho_1$). The extant Operations literature on postponement, by focusing on the monopoly analysis, effectively drove the strategic premium to zero, leading to the dominance of delayed differentiation strategies through the risk pooling premium. The next Theorem characterizes the equilibrium supply chain configuration choices.

[11] The *sequential game*, in which one firm chooses its supply chain configuration first, followed by the other firm's response, is discussed later.

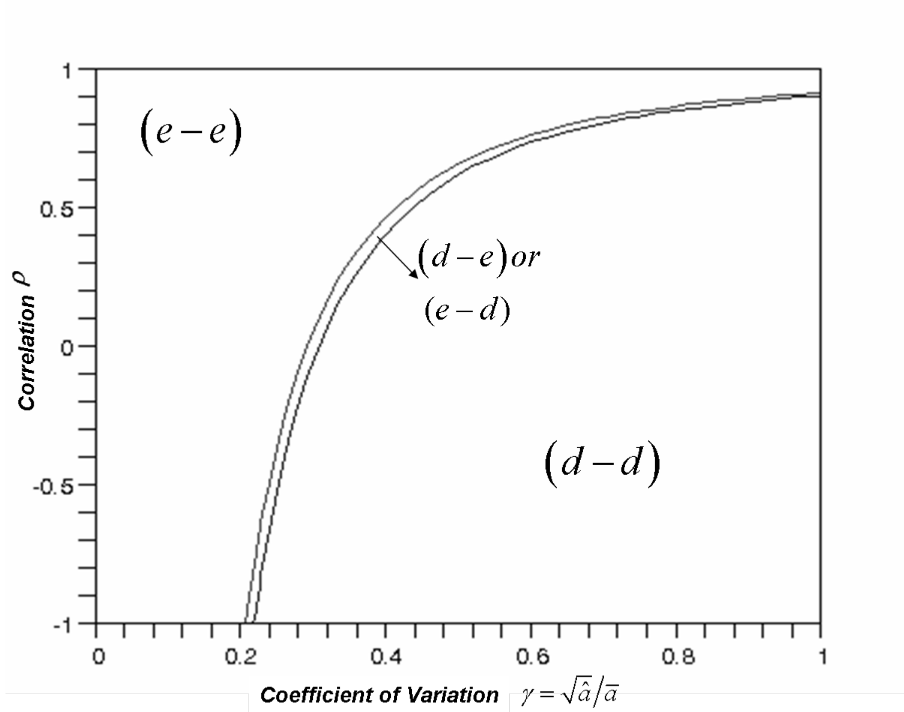


FIGURE 4. Equilibrium Supply Chain Configurations

Theorem 5.2. ***Equilibrium Characterization:*** *The unique dominant strategy equilibrium is* $(\mathbf{d}-\mathbf{d})$*, when* $\rho < \rho_2$ *and* $(\mathbf{e}-\mathbf{e})$ *when* $\rho \geq \rho_1$*. For* $\rho \in [\rho_2, \rho_1)$*, the pure strategy sub-game perfect equilibrium is* $(\mathbf{d}-\mathbf{e})$ *(or equivalently* $(\mathbf{e}-\mathbf{d})$*).*

The derivation is straight-forward from the best-response mappings of Theorem 5.1. In the range of parameters for which a firm's best response is **d** (or **e**) *irrespective* of the other firm's choice, **d-d** (or, **e-e**) is not just a sub-game perfect equilibrium, but in fact the dominant strategy equilibrium. In the range where the firm's best response is **d** for **e** and **e** for **d**, $(\mathbf{d}-\mathbf{e})$ (or $(\mathbf{e}-\mathbf{d})$) is an equilibrium.[12] Figure 4 shows the equilibrium supply chain configurations for different values of the coefficient of correlation and the coefficient of variation. We see that for a very large range of parameter values, either **d-d** or **e-e** are the equilibria. For a narrow sliver of intermediate values of γ and ρ, the equilibrium is asymmetric $(\mathbf{d}-\mathbf{e})$. In this range ($\rho \in [\rho_2, \rho_1)$), the game in supply chain choices is isomorphic to the well-known '*battle of the sexes*' game, where 'coordinated' moves are an equilibrium. Interestingly, for $\rho \in [\rho_1, \rho_0)$, both firms are better off under **d-d** than under **e-e** (see the profit comparisons in Table 3). However, early differentiation is the dominant strategy

[12]This is similar to the mixed-market equilibrium in Goyal and Netessine (2003) under a different market structure. Section 7.2 revisits our analysis under a market structure akin to theirs.

for each firm individually, and so there is no way for either firm to credibly commit to **d**. Hence firms do not cooperate and end up in the Pareto-dominated outcome **e-e**. This case is isomorphic to the traditional '*prisoner's dilemma*' problem.

Sequential Game: The analysis of the *sequential game*, in which one firm chooses its supply chain configuration first, followed by the other firm's response, is straight-forward from the preceding results. Dominant strategy equilibria are invariant to the timing of moves, and so, **d-d** (or **e-e**) is the equilibrium in the sequential game for the same range of parameter values as in the simultaneous game (as given by Theorem 5.2). The one twist with respect to the simultaneous game is that in the range $\rho_2 \leq \rho < \rho_1$ the first-mover computes that $\Pi_{e|d} > \Pi_{d|e}$, and so it always picks **e** as its supply chain configuration. The follower-firm then chooses **d** as its best response.

Entry Deterrence: We conclude this Section by comparing the effectiveness of the two supply chain configurations (**e** and **d**) for an incumbent firm seeking to deter entry in *one* of its markets. Consider the case of a firm being a monopoly in two (related) markets. It may chose to serve the two markets by employing early or delayed differentiation. Suppose that the firm faces a potential entrant in one of the two markets. The entrant trades off the various entry costs (Capital and Labor investments in infrastructure) with its potential profits, in making its entry decision. Of course, the incumbent prefers to deter competition and retain its monopoly power in both its markets.

Theorem 5.3. ***Entry Deterrence and choice of Supply Chain Configuration:*** *For an incumbent facing a potential entrant in one of its markets, early differentiation is a better entry deterrence strategy than delayed differentiation.*[13]

6. Heterogeneous Markets

The model of Sections 3-5 assumed that the *ex-ante* distributions of the monopoly and competitive markets were identical. This eliminated confounding market-size effects and reduced the number of demand parameters, leading to sharp intuitions and insights. In this Section, we extend the model and analysis to non-identical distributions of market demands. While this leads to more complex expressions for equilibrium solutions and profits, involving many more model parameters, the virtues

[13]The result applies when the entrant is a 'new' firm, or at least one that is *not* operating currently in any related product/market. This implies that the entrant is an early differentiator in the proposed market of entry. In the specific case where *(i)* the entrant currently operates in *related* products/markets; *and* *(ii)* it threatens to employ delayed differentiation across its existing markets and the market of potential entry, early differentiation is the preferred strategy for entry deterrence if and only if $\rho > \rho_4$– a result that follows straight-forwardly from Table 3.

Setting $(i\|j)$	$\mathbf{E}\left[q^M_{\cdot\|\cdot}\right]$	$\mathbf{E}\left[q^C_{\cdot\|\cdot}\right]$	***Expected Profits***
d|e	$\frac{1}{2}\bar{a}_{mi}$	$\frac{3}{10}\bar{a}_c$	$\frac{9}{100}\bar{a}_c{}^2 + \frac{1}{4}\bar{a}^2_{mi} + \frac{1}{8}Var\left(a_c - a_{mi}\right)$
e|e	$\frac{1}{2}\bar{a}_{mi}$	$\frac{1}{3}\bar{a}_c$	$\frac{1}{9}\bar{a}^2_c + \frac{1}{4}\bar{a}^2_{mi}$
d|d	$\frac{1}{43}\bar{a}_c + \frac{1}{2}\bar{a}_{mi}$	$\frac{15}{43}\bar{a}_c$	$\frac{194}{1849}\bar{a}_c{}^2 + \frac{1}{4}\bar{a}^2_{mi} + \frac{2}{225}Var\left(3a_c - 4a_{mi} + a_{mj}\right)$
e|d	$\frac{1}{2}\bar{a}_{mi}$	$\frac{2}{5}\bar{a}_c$	$\frac{3}{25}\bar{a}^2_c + \frac{1}{4}\bar{a}^2_{mi}$

TABLE 5. Heterogeneous Markets: Expected Sales and Profits under different supply chain configurations for firm i, where $i,\, j \in \{1, 2\}\,;\, i \neq j$.

of this approach are that it allows us to study *(i)* the impact of varying the relative market sizes and risk-profiles of the monopoly and competitive markets on the equilibrium; *(ii)* the effects of retailer heterogeneity on the choice of supply chain configurations; and *(iii)* the robustness of the previous results (e.g., **e** being a dominant strategy for firms) to relaxing the symmetry assumption. As in Section 3, we consider two firms, each with their own monopoly (captive) market, which compete in a common competitive market. The monopoly markets are characterized by the linear downward-sloping inverse demand curves $p_{mi}\left(q\right) = a_{mi} - q;\, i \in \{1, 2\}$. The competitive market is, similarly, characterized by the inverse demand curve $p_c\left(q\right) = a_c - q$. Further, each intercept $a_{\cdot}$ is random and drawn from a distribution with mean $\bar{a}_{\cdot}$ and variance $\hat{a}_{\cdot}$. We denote the correlation between each monopoly market and the competitive market by $\rho_i,\ i \in \{1, 2\}$, and the correlation between the two monopoly markets by ρ_m. To ensure that the joint distribution of the random variables corresponding to the intercepts is well-defined, we assume that the variance-covariance matrix of the random vector $\left[a_{m1},\, a_c,\, a_{m2}\right]^T$ is non-negative definite.[14]

6.1. **Equilibrium.** Table 5 shows the expected quantities sold in each market and the profits in equilibrium under the different supply chain configurations. The expected quantities sold in the monopoly and competitive markets are identical to the expressions before, albeit with the appropriate mean demand intercepts. For the **d-d** supply chain configuration, the quantities sold in the monopoly market can now be clearly parsed into two components- the quantity 'planned' for the monopoly market and the spillover from the competitive market, consistent with our earlier

[14]In addition, to avoid the trivial case of either firm exiting a market completely, we need (probabilistic) bounds on the spread of these random variables. *Sufficient* technical conditions are: $Pr\left(\left|a_c - a_{mi}\right| \leq \bar{a}_{mi} + \frac{1}{5}\bar{a}_c\right) = 1$ and $Pr\left(-\frac{96}{43}\bar{a}_c - 4\bar{a}_{mi} + \bar{a}_{mj} \leq \left(3a_c - 4a_{mi} + a_{mj}\right) \leq \frac{144}{43}\bar{a}_c + \frac{7}{2}\bar{a}_{mi} + \bar{a}_{mj}\right) = 1$, for $i,\, j \in \{1, 2\}\,;\, i \neq j$.

intuition from the symmetric model (Recall the discussion of the **d-d** supply chain configuration following Theorem 4.1, in Section 4.1).

It is easy to check that the sales (and production) quantities derived in Table 5 are related as in Theorem 4.1. The equilibrium profits can, once again, be parsed into the *strategic* and *risk-pooling* components– the latter a function of demand variances and covariances. While only delayed differentiating firms earn the risk-pooling premium, the strategic premium is higher for early differentiating firms. This trade-off drives the profit comparisons, firms' best responses and the ensuing equilibria, derived below.

Theorem 6.1. *(1)* ***Best Responses:*** *A firm's best response strategy to its competitor's supply chain configuration is as given below*

$$\mathbf{BR_i}\left(e\right) = \begin{cases} e & if\, C_i \leq \frac{38}{225} \\ d & otherwise \end{cases}$$
$$\mathbf{BR_i}\left(d\right) = \begin{cases} e & if\, D_i \leq \frac{6273}{3698} \\ d & otherwise \end{cases}$$

where $C_i = \frac{Var(a_c - a_{mi})}{\bar{a}_c^2}$ *and* $D_i = \frac{Var(3a_c - 4a_{mi} + a_{mj})}{\bar{a}_c^2}$; $i, j \in \{1, 2\}, i \neq j$.

(2) The equilibrium choice of supply chain configurations is given in Table 6.

6.2. **Comparative statics on demand parameters.** The impact of changing parameters on firms' best responses, given in Table 7, is driven by their impact on the strategic and risk pooling premiums, since the choice of **e** or **d** is, in effect, a trade-off between the two.

Factors that affect the strategic premiums only: Recall that the strategic premium is the benefit from strategic commitment to the *competitive* market, which is determined by the size of this market. Thus a unilateral increase in the mean demand of this market ($\bar{a}_c$) favors **e**, while an increase in the size of either monopoly market ($\bar{a}_{mi}$ *or* $\bar{a}_{mj}$) has no impact on supply chain strategy– the profits under **e** and **d** obviously change but their relative ordering does not [First two columns of Table 7]. Thus, *the degree of competition (the relative size of the competitive and monopolistic markets) is an important determinant of the optimal supply chain configuration.*

Factors that affect the risk-pooling premiums only: The risk-pooling premiums, on the other hand, arise from the efficient allocation of available goods to the different markets to mitigate the effects

i-j	$D_i, D_j < \frac{6273}{3698}$ $[BR_{\cdot}(d) = e]$	$D_i < \frac{6273}{3698} \leq D_j$ $[BR_i(d) = e$ $BR_j(d) = d]$	$D_i, D_j \geq \frac{6273}{3698}$ $[BR_{\cdot}(d) = d]$
$C_i, C_j \geq \frac{38}{225}$ $[BR_{\cdot}(e) = d]$	$d - e$, $e - d$	$e - \mathbf{d}$	$\mathbf{d} - \mathbf{d}$ (Dominant Strategy Eq.)
$C_i \geq \frac{38}{225} > C_j$ $[BR_i(e) = d$ $BR_j(e) = e]$	$d - \mathbf{e}$	*Infeasible*	$\mathbf{d} - d$
$C_i, C_j < \frac{38}{225}$ $[BR_{\cdot}(e) = e]$	$\mathbf{e} - \mathbf{e}$ (Dominant Strategy Eq.)	$\mathbf{e} - e$	$d - d \succ e - e^{\dagger}$

$C_i = \frac{Var(a_c - a_{mi})}{\bar{a}_c{}^2}$; $D_i = \frac{Var(3a_c - 4a_{mi} + a_{mj})}{\bar{a}_c^2}$; $i, j \in \{1, 2\}$, $i \neq j$. **Bold** typeface indicates a dominant strategy. † - Nash Equilibrium *d-d* Pareto-dominates Nash Equilibrium *e-e*.

TABLE 6. Heterogeneous Markets: Equilibrium choice of supply chain configurations (i-j).

	Increasing Mean Demand		Increasing Variance of Demand		Decreasing Correlations		Increasing Market Sizes	
	$\bar{a}_c \uparrow$ (1)	$\bar{a}_{mi} \uparrow$ (2)	$\hat{a}_c \uparrow$ (3)	$\hat{a}_{mi} \uparrow$ (4)	$\rho_i \downarrow$ (5)	$\rho_m \downarrow$ (6)	$\bar{a}_c$, $\hat{a}_c \uparrow$; γ_c constant (7)	$\bar{a}_{mi}, \hat{a}_{mi} \uparrow$; γ_{mi} constant (8)
$\mathbf{BR_i}\,(\mathbf{e})$	$\rightarrow e$	0	$\rightarrow d$ iff $T_i > 0$	$\rightarrow d$ iff $M_i > 0$	$\rightarrow d$	0	$\rightarrow e$ iff $P_i < 0$	$\rightarrow e$ iff $M_i < 0$
$\mathbf{BR_j}\,(\mathbf{e})$	$\rightarrow e$	0	$\rightarrow d$ iff $T_j > 0$	0	0	0	$\rightarrow e$ iff $P_j < 0$	0
$\mathbf{BR_i}\,(\mathbf{d})$	$\rightarrow e$	0	$\rightarrow d$ iff $U_i > 0$	$\rightarrow d$ iff $N_i > 0$	$\rightarrow d$	$\rightarrow d$	$\rightarrow e$ iff $R_i < 0$	$\rightarrow e$ iff $N_i < 0$
$\mathbf{BR_j}\,(\mathbf{d})$	$\rightarrow e$	0	$\rightarrow d$ iff $U_j > 0$	$\rightarrow d$ iff $O_i > 0$	$\rightarrow e$	$\rightarrow d$	$\rightarrow e$ iff $R_j < 0$	$\rightarrow e$ iff $O_i < 0$

$\gamma_c = \hat{a}_c / \bar{a}_c^2$, $\gamma_{mi} = \hat{a}_{mi} / \bar{a}_{mi}^2$, $T_i = 1 - \rho_i \sqrt{\hat{a}_{mi} / \hat{a}_c}$, $U_i = 3 - 4\rho_i \sqrt{\hat{a}_{mi} / \hat{a}_c} + \rho_j \sqrt{\hat{a}_{mj} / \hat{a}_c}$, $M_i = 1 - \rho_i \sqrt{\hat{a}_c / \hat{a}_{mi}}$, $N_i = 4 - \rho_m \sqrt{\hat{a}_{mj} / \hat{a}_{mi}} - 3\rho_i \sqrt{\hat{a}_c / \hat{a}_{mi}}$, $O_i = 1 - 4\rho_m \sqrt{\hat{a}_{mj} / \hat{a}_{mi}} + 3\rho_i \sqrt{\hat{a}_c / \hat{a}_{mi}}$, $P_i = 1 - \frac{38}{225\gamma_c} - \rho_i \sqrt{\hat{a}_{mi} / \hat{a}_c}$, $R_i = 3 - 4\rho_i \sqrt{\hat{a}_{mi} / \hat{a}_c} + \rho_j \sqrt{\hat{a}_{mj} / \hat{a}_c} - \frac{2091}{3698\gamma_c}$.

TABLE 7. Effect of altering demand parameters on Best Response choices, for i, $j \in \{1, 2\}$; $i \neq j$. Each column illustrates the effect of increasing (denoted by the symbol '$\uparrow$') or decreasing (denoted by '$\downarrow$') the value of a parameter. The symbol '$\rightarrow e\,[d]$' denotes an increasing tendency to adopt early [delayed] differentiation.

of demand uncertainty. Hence these are functions of the variance of the demand in the individual markets ($\hat{a}_c,\ \hat{a}_{mi}\ and\ \hat{a}_{mj}$) and demand correlations ($\rho_i,\ \rho_j\ and\ \rho_m$). Since the risk-pooling premiums are *functions* of the random variables a_{mi}, a_c, and a_{mj}, the net effect of a change in any one of $\hat{a}_c,\ \hat{a}_{mi}$ or $\hat{a}_{mj}$ depends on their interactions. Columns (3) and (4) of Table 7 completely characterize the effect of a marginal change in the variance of demand of any individual market.

The impact of a change in demand correlations ($\rho_i,\ \rho_j\ and\ \rho_m$) is unambiguous [columns (5) and (6) of Table 7]. A decrease in the correlation ρ_i between firm i's monopoly and competitive markets increases the risk pooling premium and favors delayed differentiation for firm i, irrespective of firm j's supply chain configuration [First and third rows of Column (5)]. If firm i employs **e**, its two markets are decoupled, and so, a change in ρ_i has no impact on firm j's choice [Second row of Column (5)]. On the other hand, if firm i employs **d**, firm j is more likely to employ **e**, which yields a higher strategic premium [Fourth row of Column (5)].

Finally, the two monopoly markets are decoupled when *either* firm employs **e**. Hence ρ_m, the correlation between the two monopoly markets, affects only the best responses to **d**. A lower ρ_m favors **d**, on account of better ability of firms to pool risks and match supply and demand in the markets [Column (6) of Table 7].

Other factors: It should be clear from the preceding that a change in the market *size* (wherein the mean $\bar{a}_.$ and the variance $\hat{a}_.$ of a market move simultaneously, while keeping the coefficient of variation $\gamma_.$ constant) will affect both risk-pooling and strategic premiums. The net impact depends on their relative magnitudes, and is completely characterized in Table 7 [Columns (7) and (8)].

Finally, it should be noted that the directional impact of changing a parameter on the *equilibrium* is easily derived from its impact on each firm's best response, characterized in Table 7.

6.3. **Identical Retailers.** The trade-offs between the risk-pooling and strategic premiums can be clearly illustrated in the case of *identical* retailers, obtained by setting $\bar{a}_{mi} = \bar{a}_{mj} = \bar{a}_m$, $\hat{a}_{mi} = \hat{a}_{mj} = \hat{a}_m$ and $\rho_i = \rho_j = \rho$ in the above model (Note that the demand distributions in the monopoly and competitive markets are distinct, and further, ρ_m need not be equal to ρ). This symmetry renders the middle row and column of Table 6 infeasible; however, any of the equilibria characterized by the remaining four cells of Table 6 can arise with appropriately chosen parameters.[15]

[15] We require that $\rho^2 \leq \frac{1+\rho_m}{2}$. This condition guarantees positive Eigen vectors (equivalent to non-negative definiteness) for the variance-covariance matrix.

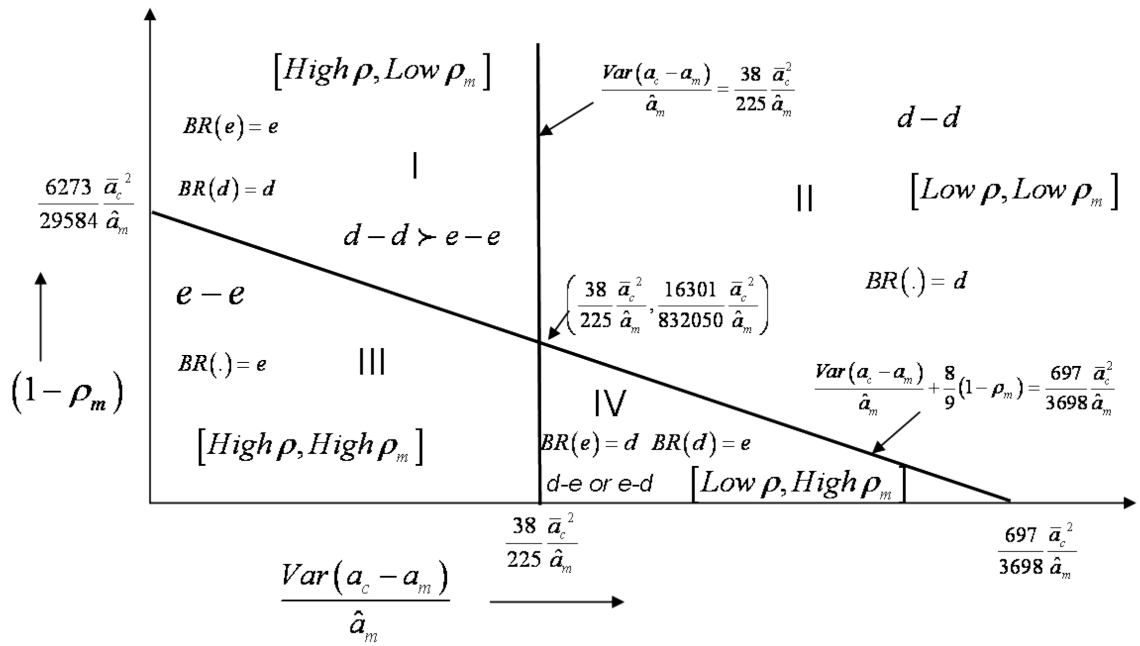


FIGURE 5. Identical Retailers: Best Response Mappings & Equilibria

This is succinctly illustrated in Figure 5. As discussed above, the risk-pooling premium *increases* unambiguously as ρ or ρ_m *decrease*. When both ρ and ρ_m are small, the risk-pooling premium is maximized, and **d-d** is the dominant strategy equilibrium (Region II of Figure 5). Conversely, when ρ and ρ_m are large enough, the strategic premium outweighs the risk-pooling premium, leading to **e-e** as the dominant strategy equilibrium (Region III of Figure 5). In the remaining regions, neither early nor delayed differentiation are dominant strategies.

7. Model Extensions

In Section 6, we generalized the demand assumptions of Section 3, allowing for heterogeneous retailers and market-sizes, and found that our results were robust to these relaxations. In this penultimate Section, we study the implications of two other assumptions inherent in the main model by relaxing the model appropriately.

The first assumption we study is that of *clearance*. Section 7.1 relaxes the clearance assumption and develops a model allowing both firms to hold back some or all of their inventory in the distribution stage of the game. Second, in Section 7.2 we analyze an alternate market structure– that of two firms competing in two correlated markets. In this alternate structure, the two firms compete in two markets and unlike the main model neither firm has recourse to a captive (monopoly) market.

7.1. **Holdback Strategies.**

7.1.1. *Why assume Clearance?* As noted in Section 3, the main model of the paper (Sections 4 and 5) assumed that firms follow a clearance strategy in the distribution of their products. Thus, firms allocate all of their available goods to the markets, with the appropriate adjustments in price. Analytical tractability was the primary consideration for this assumption– academic precedents show that the clearance assumption is sometimes necessary even in a monopoly setting.[16] Chod and Rudi (2005) show that their qualitative results under monopoly are robust to relaxations of the clearance assumption. Further, firms are often less flexible in their production commitments than in their prices– necessitating price-adjustments to clear their stock (cf. Mackintosh (2003)).

Allowing *holdback* in a model of competition is fraught with additional complexities. The option of salvaging affects firms' effective marginal-revenue curves, and hence affects production and distribution decisions for the firms. Further, the assumption of *linear* salvaging costs, ubiquitous in the extant literature, introduces points of non-differentiability in the reaction curves. A firm's salvaging decision is in turn a function of the realized demand in both its markets (monopoly and competitive), available quantities, and the competitor's shipment decisions. Thus, salvaging is state-dependent– firms may salvage under certain demand outcomes and not under others. These complex interactions of firms' reaction curves under salvaging render the analysis of optimal policies doubly (or triply) hard under competition. Nevertheless, the question remains whether the clearance assumption, by enhancing the credibility of quantity-commitment to the competitive market (and raising the strategic premium) particularly under $\mathbf{e}$, unduly biases our results in favor of early differentiation. If so, the addition of a salvage market would dilute the credibility of commitment (and hence, the strategic premium) for both early and delayed differentiation, with the greater adverse impact on early differentiation. This motivates our study of optimal supply chain configurations under holdback, with the demand model of Section 3 simplified as below.

7.1.2. *Model allowing Holdback.* We assume that the demand intercept in the competitive market is a binary random variable that may take one of two values- a_h with probability p or a_l with probability $(1-p)$, where $0 < p < 1$. The demand intercept in the monopoly markets takes a

[16]See page 7 (Section *3*).

constant (and known) value of a. We relax the clearance assumption: Firms may sell some of their production quantities in the markets and salvage the rest at a unit cost s, where $s > 0$.[17].

Now, firms must make their salvaging choice for two possible states of nature- *high* or *low* demand in the competitive market. We will focus on the case of firms salvaging only when the demand is low.[18]

7.1.3. *Analysis.* Table 8 lists the quantities produced, sold and salvaged in equilibrium under the different combinations of supply chain configurations.[19] Recall the conjecture that motivated this Section, viz., that the clearance assumption in the analysis of Sections 4 and 5 biased our results in favor of **e** by inflating the strategic premium excessively for **e** compared to **d**. If this were true, the addition of the salvage market should reduce the strategic premium for **e** more than for **d**. In fact, a comparison of salvage quantities (from Table 8) appears to lend support to this conjecture. We find that *(i)* under the **e-d** (or **d-e**) configuration, the **e** firm salvages more than **d** $\left(q^s_{e|d} > q^s_{d|e}\right)$; and *(ii)* fixing the competitor's choice of supply chain configuration (at **e** or **d**), a firm always salvages more in equilibrium if it adopts **e** rather than **d** (mathematically, $q^s_{e|e} > q^s_{d|e}$ and $q^s_{e|d} > q^s_{d|d}$). Excessive salvaging under **e** points to a disproportionate weakening of its ability to commit to the competitive market (compared to **d**).

However, when firms' choices of supply chain configurations are endogenized, we find that both **d** and **e** can arise as dominant strategies, leading to **d-d** and **e-e** as *dominant strategy equilibria*. Thus, allowing holdback does not preclude **e** from being a dominant strategy. Figure 6 graphically illustrates our closed-form results. The feasible range of values for a_l is $(0,\ 0.9a_h)$, as noted in footnote 19. Thus, the area below the curve $a_l = 0$ is relevant for our analysis. Two features of Figure 6 are especially striking and, at first glance, counter-intuitive. The first is the wide range

[17]Salvaging costs must be greater than production costs (which were normalized to 0), else firms may produce solely to salvage, generating infinite profits. Equivalently, the salvage value is $-s$.

[18]The case when firms never choose to salvage reduces to our earlier analysis with the clearance assumption. A little thought reveals that the remaining salvaging strategies are suboptimal and hence eliminated. If a firm salvaged under both states of nature (i.e., irrespective of the demand realization), it would always earn a marginal revenue of $-s$. This cannot be optimal, since the firm can strictly improve profits by marginally decreasing production and salvage quantities equally. Finally, consider the case of a firm salvaging only under high demand and not under low demand. This implies that the firm earns a marginal revenue of -s under high demand (through salvaging), but, *with the same production quantity*, reaps a higher marginal revenue under low demand (since that is when it would choose not to salvage) – a contradiction.

[19]To ensure that firms choose to salvage in the low demand state, the salvage cost needs to be small enough (to make salvaging worthwhile), and both the demand spread and the probability of high demand in the competitive market need to be large enough (so that the production quantity (which is determined *ex ante*) is large, leading to salvaging under low demand). The precise *sufficient* technical condition under which the results of Table 8 hold is that $s\left(1+\frac{24}{p}\right) < 9a_h - 10a_l$.

Setting	Low Demand			High Demand		Quantities Produced
	$q^C_{.\|.}$	$q^M_{.\|.}$	$q^s_{.\|.}$	$q^C_{.\|.}$	$q^M_{.\|.}$	
e|e	$\frac{a_l+s}{3}$	$\frac{a}{2}$	$\frac{a_h p - a_l p - s}{3p}$	$\frac{(a_h p-(1-p)s)}{3p}$	$\frac{a}{2}$	$\frac{a_h+s}{3} - \frac{s}{3p}; \frac{a}{2}$
d|e	$\frac{a_l+s}{3}$	$\frac{a+s}{2}$	$\frac{9a_h p-10a_l p-(24+p)s}{30p}$	$\frac{3(a_h p-(1-p)s)}{10p}$	$\frac{a}{2} - \frac{(1-p)s}{2p}$	$\frac{5a+3a_h}{10} - \frac{8s(1-p)}{10p}$
e|d	$\frac{a_l+s}{3}$	$\frac{a}{2}$	$\frac{6a_h p-5a_l p-(6-p)s}{15p}$	$\frac{2(a_h p-(1-p)s)}{5p}$	$\frac{a}{2}$	$\frac{2(a_h p-(1-p)s)}{5p}; \frac{a}{2}$
d|d	$\frac{a_l+s}{3}$	$\frac{a+s}{2}$	$\frac{96a_h p-86a_l p-5(45-2p)s}{258p}$	$\frac{15(a_h p-(1-p)s)}{43p}$	$\frac{a}{2} + \frac{2ap-45(1-p)s}{86p}$	$\frac{a}{2} + \frac{32a_h p-75s(1-p)}{86p}$

TABLE 8. Quantities Produced, Sold and Salvaged in Equilibrium, under Holdback. q^C and q^M are the quantities sold in the Competitive and Monopoly markets respectively; q^s denotes the quantity salvaged.

of values for which **e-e** is the dominant strategy, even under holdback. For instance, *in the entire range* $a_l \geq 0.5a_h$, **e-e** *is the unique (dominant strategy) equilibrium for* all *feasible values of* s *and* p*– delayed differentiation is* always *suboptimal for firms, irrespective of the competitor's choice.* A second notable feature is that, holding other model parameters constant, **e-e** *is more likely to be the equilibrium when the salvage cost* s *decreases (equivalently, when the salvage value increases), i.e., when holdback is favored.*

These results are explained as follows. While the additional salvage market disproportionately reduces the strategic premium for **e** compared to **d**, it also facilitates greater risk-pooling under both **d** and **e**– *with a disproportionately favorable impact on* ***e***. Both these observations (on the relative impact of the strategic and risk-pooling premiums on **d** and **e**) stem from the greater marginal impact of a second market (on **e**) than that of a third market (on **d**). The net impact of allowing holdback (via salvaging) on the risk-pooling premium evidently trumps its effect on the strategic premium, leading to the above results. Thus, our central result – that early differentiation is a dominant strategy under broadly plausible conditions – is robust to allowing holdback (i.e., relaxing the clearance assumption).

7.2. **An Alternative Market Structure– Two Competitive Markets.** In this Section, we consider an alternative market structure– that of two firms competing in two (possibly correlated) markets, as in Goyal and Netessine (2003) and others. Markets i and j have intercepts a_i and a_j,

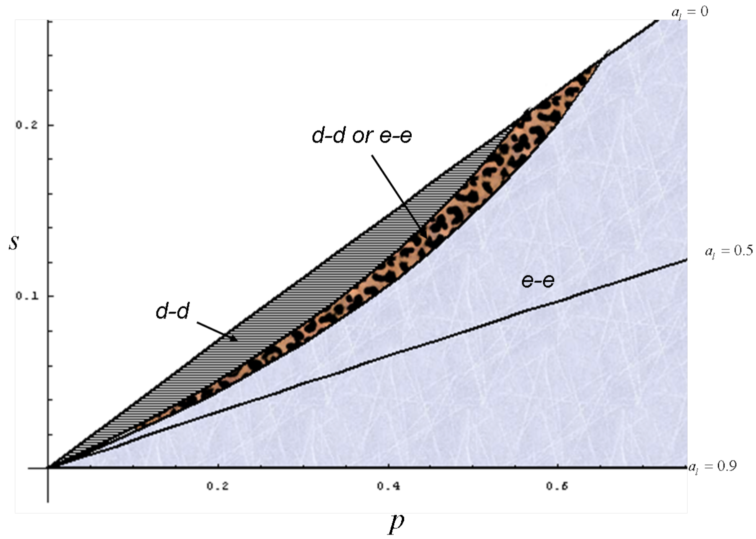


FIGURE 6. Equilibrium Choice of Supply Chain Configurations as a function of s, a_l and p under holdback. The feasible range of values for a_l is $(0,\ 0.9a_h)$. In the figure, a_h is normalized to 1 . For each iso-curve $a_l = k$, the corresponding feasible range of parameter values is the region below the iso-curve.

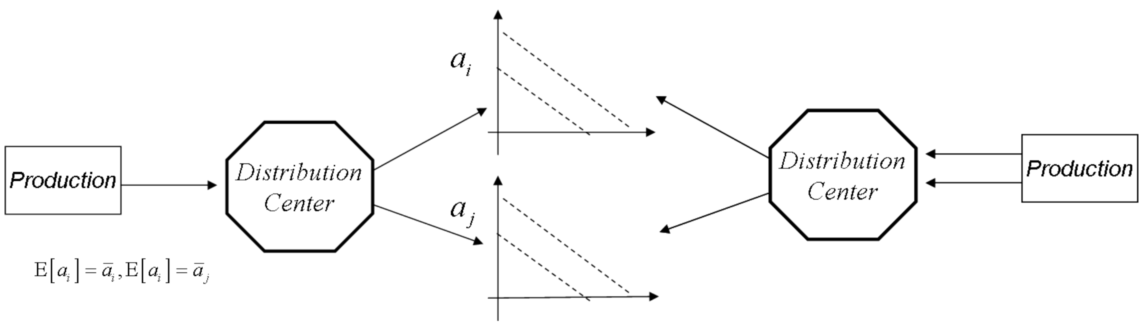


FIGURE 7. Alternate Market Structure: Two Competitive Markets

drawn from distributions with mean $\bar{a}_i$ and $\bar{a}_j$ respectively (Figure 7). We assume that firms employ a clearance strategy.

Table 9 summarizes the results of our analysis of the expected sales, production and profits under the different supply chain configurations. As before, the **e-e** configuration leads to the standard Cournot outcome. Further, only a **d** firm earns the risk-pooling premium, which is higher when the competing firm is unable to pool risks (i.e., employs **e**). In the **d-d** supply chain configuration, both firms can opportunistically reallocate their production to the market with higher demand. This flexibility earns each of them an additional risk-pooling premium leading to higher profits than under **e-e**. We find that **d-d** Pareto-dominates **e-e**.

Setting	Expected Sales in market i, $\mathbf{E}\left[q^i_{.\|.}\right]$	Total Production	Strategic Premium	Risk Pooling Premium
e|e	$\frac{\bar{a}_i}{3}$	$\frac{\bar{a}_i+\bar{a}_j}{3}$	Π_{cc}	0
d|e	$\frac{7\bar{a}_i+\bar{a}_j}{24}$	$\frac{\bar{a}_i+\bar{a}_j}{3}$	$\Pi_{cc} - \frac{7(\bar{a}_i-\bar{a}_j)^2}{288}$	$\frac{Var(a_i-a_j)}{8}$
e|d	$\frac{5\bar{a}_i-\bar{a}_j}{12}$	$\frac{\bar{a}_i+\bar{a}_j}{3}$	$\Pi_{cc} + \frac{(\bar{a}_i-\bar{a}_j)^2}{144}$	0
d|d	$\frac{\bar{a}_i}{3}$	$\frac{\bar{a}_i+\bar{a}_j}{3}$	Π_{cc}	$\frac{Var(a_i-a_j)}{18}$

TABLE 9. Alternate Market Structure: Expected Sales, Production and Profits under each supply chain configuration. $\Pi_{cc} \triangleq \frac{\bar{a}_i^2+\bar{a}_j^2}{9}$, denotes a firm's profits under Cournot competition in both markets.

The two-competitive-markets structure leads to an interesting twist with regard to the strategic premium under the **d-e** supply chain configuration. The **e** firm cannot compel the competing **d** firm to divert its production into an alternative monopoly market– no such alternatives exist. In fact, as Table 9 shows, under *every* possible supply chain configuration, each firm's total production is identical (and equal to $\frac{\bar{a}_i+\bar{a}_j}{3}$, the outcome under Cournot competition). However, when the market sizes are asymmetric ($\bar{a}_i \neq \bar{a}_j$), the **e** firm gains a competitive advantage over the **d** firm by *simultaneously* committing greater-than-Cournot quantities to the larger market and lesser-than-Cournot quantities to the smaller market. This combination of actions induces the **d** firm to divert production from the larger to the smaller market (with lower prices and smaller profits). As a result, in the **d-e** configuration, the **e** firm gains a significant strategic premium over **d**. The equilibria, derived in Theorem 7.1 below, are determined by the relative magnitudes of the risk-pooling and strategic premiums.

Theorem 7.1. *Analysis of equilibria for two competitive markets*

(i) *When* $(\bar{a}_i - \bar{a}_j)^2 > 8 \cdot Var\,(a_i - a_j)$, ***e-e*** *is the (unique)* dominant strategy equilibrium*, even though* ***e-e*** *is Pareto-dominated by* ***d-d****.*

(ii) *When* $(\bar{a}_i - \bar{a}_j)^2 < \frac{36}{7} \cdot Var\,(a_i - a_j)$, ***d-d*** *is the* dominant strategy equilibrium.

(iii) *In the intermediate region* $\frac{36}{7} \cdot Var\,(a_i - a_j) \leq (\bar{a}_i - \bar{a}_j)^2 \leq 8 \cdot Var\,(a_i - a_j)$*, both* ***e-e*** *and* ***d-d*** *are pure-strategy Nash equilibria, but* ***d-d*** *Pareto-dominates* ***e-e****.*

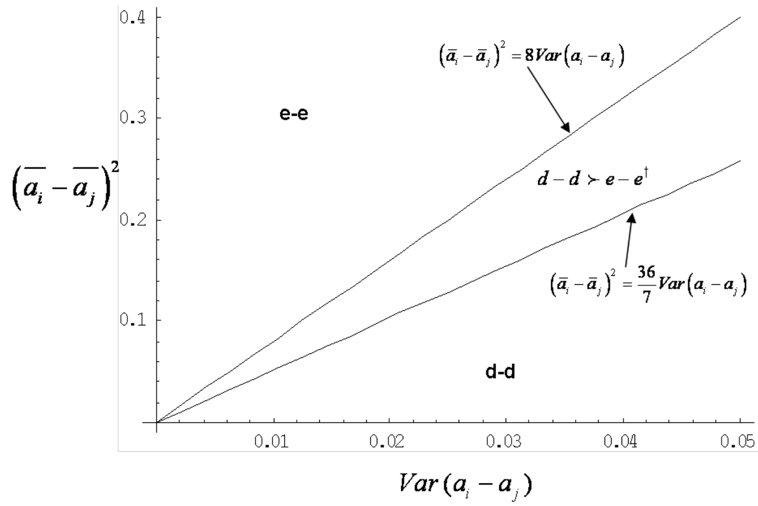


FIGURE 8. Alternate Market Structure: Equilibrium Choice of Supply Chain Configuration. Bold typeface indicates a dominant strategy. †−Nash equilibria **d-d** Pareto dominates Nash equilibria **e-e**

Figure 8 illustrates these results. Yet again, for a substantial range of parameter values, early differentiation is the *dominant* strategy due to the strategic premium. In this range, firms settle for the Pareto-dominated **e-e**, as in the classical *'prisoner's dilemma'.*

These results parallel those in Goyal and Netessine (2003)'s model of production technology choices. Our risk pooling premium corresponds to their 'stochastic effect'; our strategic premium to their 'market size effect'. In their model, the tension between the difference in mean market sizes and demand variances drives firms' choices in equilibrium, which parallels Theorem 7.1 above.

8. Concluding Remarks

In this study, we identified *endogenous strategic effects* that significantly diminish the value of delayed differentiation under competition. We isolated these strategic effects from the conventional risk pooling benefits, and identified conditions under which the strategic effects dominate the risk pooling benefits from postponement. Under these conditions, our results depart significantly from those of the extant literature: delayed differentiation is not the preferred supply chain configuration to manage the effects of demand uncertainty under competition.

The strategic weakness of delayed differentiation arises from the inability to make market-specific quantity commitments. Early differentiating competitors can exploit this to their advantage. When both firms deploy delayed differentiation, the lack of commitment leads to both firms oversupplying the markets to preempt aggression by the other. Moreover, markets served by delayed differentiating firms are attractive targets for entry.

From the perspective of a social planner intent on maximizing consumer surplus and/or welfare, delayed differentiation is always preferable to early differentiation under both monopoly and competition– a result reflecting the essential difference between the risk-pooling and strategic premiums. Risk-pooling, by definition, enables better matching of supply and demand, and thus is beneficial to consumers. On the other hand, the strategic premium is an artifact of competitive dynamics, and focused on the division of the spoils among the competing firms. In fact, the rank ordering of the consumer surpluses from the various supply chain configurations follows that of the industry-wide risk-pooling premiums– highest when both firms employ delayed differentiation and lowest when both employ early differentiation.

We extended the main model to analyze the cases of asymmetric markets, inventory holdback, and an alternate market structure, with the firms competing in two markets. We proved that in all these cases, early differentiation is the dominant strategy equilibrium for a broad range of parameter values (even under cost parity with delayed differentiation).

A central message of this paper is the importance of the link between a firm's Operations (supply chain design) and its competitive environment (industry structure). Researchers in Operations need to test the robustness of their prescriptions to varying industry structures. A cross-sectional, empirical study of the link between a firm's choice of supply chain configuration and prices, market concentration and the threat of competitive entry would be of interest for future research.

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