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Online Supplement

Part 1. Continuum of Configuration Choices

In the main paper, we saw that early differentiation was often a firm's dominant strategy, when each firm's choice was either early or delayed differentiation. In this online supplement we examine the robustness of our results to the binary-choice assumption, by expanding the model of §§3–5 from the main paper to allow firms to choose from a continuum of interim (cost) configurations.

We assume that firms i and j produce specialized goods for their markets; however, they may reconfigure production intended for their monopoly market to sell in the competitive market (or vice versa) after demand realization in the two markets. Firm i's costs of reconfiguring a quantity q^r are $\theta_i \cdot (q^r)^2$, where $\theta_i \geq 0$.[EC1] We let $q^r \in [-Q_i^C, Q_i^M]$, where Q_i^M and Q_i^C are firm i's production quantities for the monopoly and competitive markets respectively. A positive value of q^r corresponds to a reconfiguration of goods from the monopoly to the competitive market; a negative value of q^r reflects the reverse flow. Firm j has a similar quadratic cost structure with parameter $\theta_j \geq 0$. Further, firms can set their reconfiguration cost parameters $\theta_i, \theta_j \in [0, \infty)$ costlessly; the parameters θ_i, θ_j are common knowledge (observed by all parties).[EC2] Delayed and early differentiation then arise as polar cases, corresponding to θ_i (or θ_j), set to 0 or ∞, respectively. Intermediate settings of θ_i (or θ_j) correspond to interim supply chain configurations, a via media between early and delayed differentiation.

Thus, in this game, firms' decision variables are their reconfiguration cost parameters $\{\theta_i, \theta_j\} \in [0, \infty)$, production quantities for their monopoly and competitive markets, and finally, the quantity to be reconfigured from one market to the other after demand realization. A lower θ_i (or θ_j), in addition to lowering reconfiguration costs, facilitates risk pooling by enhancing firms' flexibility. Clearly, delayed differentiation offers both the lowest costs and maximum flexibility. Nevertheless, as the following theorem demonstrates, for a broad range of parameters, neither firm wants to employ delayed differentiation as a strategy.

Theorem (Equilibrium Characterization Under Endogenous Reconfiguration Costs)

(1) *Delayed differentiation is a* dominated *strategy for high enough values of the demand correlation and low coefficients of variation, specified mathematically by the condition* $\rho \gtrsim 1 - 0.091/\gamma^2$. *The precise technical result (derived in Part 2 of this supplement) is that the optimal* $\theta_i > 0$ *iff* $\rho > 1 - (1/\gamma^2) g(\theta_j)$, *where the polynomial* $g(\theta_j) \in [3{,}209{,}625/35{,}142{,}094,\ 12/125] \equiv [0.091, 0.096]$. *A symmetrical condition applies for* θ_j. *Thus the equilibrium (fixed point)* (θ_i^*, θ_j^*) *derived from the optimal-reaction functions is bounded away from* $(0, 0)$ *when* $\rho \gtrsim 1 - 0.091/\gamma^2$.

(2) *The equilibrium choices of* θ_i *and* θ_j *increase with* ρ *and decrease with* γ.[EC3]

[EC1] The model, cast in the language of multiple, closely related products, equally applies to selling a single product in multiple, horizontal markets, with product reconfiguration costs reinterpreted as transshipment costs. The quadratic cost function ensures differentiability in the entire domain of q^r, and is hence easier to work with than the linear-modulo cost function $\theta \cdot |q^r|$.

[EC2] The assumption that the reconfiguration cost parameters $[\theta_i, \theta_j]$ can be adjusted downwards costlessly (without additional investments) is conservative. It will be obvious that incorporating any such investment costs in the model, while muddying the waters, will further skew the outcome in favor of our principal results (Theorem above). Simple revealed-preference arguments can be applied to extend the results to general investment costs.

[EC3] Proof for this theorem is provided in Part 2, §EC.7 of this supplement.

Table EC.1 Symbols Used

Symbol	Meaning
a^C, a^M	Realized value of the demand intercept
$\bar{a}$	Mean of the demand intercept distribution
$\hat{a}$	Variance of the demand intercept distribution
ρ	Correlation between the demand intercepts in each of the monopoly markets and the competitive market
γ	The coefficient of variation of the demand intercept distribution which is $\sqrt{\hat{a}}/\bar{a}$
e	Subscript to denote a firm deploying early differentiation
d	Subscript to denote a firm deploying delayed differentiation
$q^A_{x\mid y}$	Quantity sold by a firm employing x, facing a competitor employing y, to market A; where $x, y \in \{e, d\}$, $A \in \{C, M\}$
$Q_{x\mid y}$	Quantity of intermediate good produced by a firm employing x, facing a competitor employing y; where $x, y \in \{e, d\}$
p^A_{xy}	The clearing prices in market A, in the setting where one firm employs x and the other firm employs y; where $x, y \in \{e, d\}$
$\Pi_{x\mid y}$	Profits earned by a firm employing x, facing a competitor employing y; where $x, y \in \{e, d\}$
CS_{x-y}	The expected consumer surplus in the setting where one firm employs x and the other firm employs y; where $x, y \in \{e, d\}$
W_{x-y}	The expected welfare in the setting where one firm employs x and the other firm employs y; where $x, y \in \{e, d\}$

If risk pooling and the lowest operational costs were the only criteria, firms' dominant choice would be to set $\theta_\cdot = 0$ (costless delayed differentiation). Countering these benefits is the strategic premium from credible commitment in the competitive market, which is increasing in $\theta_\cdot$. Because the risk-pooling premium falls as the correlation increases and/or the demand uncertainty decreases, the strategic premium begins to dominate for high ρ and low γ. This leads to equilibria with both θ_i and θ_j bounded away from 0, even though these would result in higher reconfiguration costs for both firms.

Part 2. Proofs for All Results

EC.1. Equilibrium Under Each Supply Chain Configuration (Model of §§3–5)

In this section, we derive three basic sets of results: The equilibrium sales, the production quantities, and the profits for each of the three supply chain configurations (*e-e*, *d-e*, *d-d*). These basic results lay the foundations for the subsequent proofs. The notation used in this supplement is summarized in Table EC.1.

Our assumptions on the distribution of the demand intercepts imply that

$$\mathrm{E}[(a^C)^2] = \mathrm{E}[(a^M)^2] = \bar{a}^2 + \hat{a} \qquad \mathrm{E}[a^C a^M] = \rho\hat{a} + \bar{a}^2. \tag{EC1}$$

EC.1.1. The *e-e* Case

Lemma EC.1.1. *When the two firms employ early differentiation, the expected sales, quantity of the intermediate goods produced, and the revenues earned by the firms are given as follows*:

$$\mathrm{E}\big[q^C_{e\mid e}\big] = q^C_{e\mid e} = \tfrac{1}{3}\bar{a}; \qquad \mathrm{E}\big[q^M_{e\mid e}\big] = q^M_{e\mid e} = \tfrac{1}{2}\bar{a}; \qquad Q_{e\mid e} = \tfrac{5}{6}\bar{a}; \qquad \mathrm{E}[\Pi_{e\mid e}] = \tfrac{13}{36}\bar{a}^2.$$

Proof. Because both firms employ early differentiation, no decisions are made at the distribution stage. Both firms sell the available quantities of differentiated goods ($q^C_{e\mid e}$ and $q^M_{e\mid e}$) in the appropriate markets. In the production stage firms choose these quantities. Further, the choices for each market are independent of the other (under early differentiation).

Stage 1: Production

Competitive Market. The payoff maximizing production quantity is given by

$$\max_{q^C_{e\mid e}} \mathrm{E}\big[\big\{a^C - \big(q^C_{e\mid e} + \tilde{q}^C_{e\mid e}\big)\big\} q^C_{e\mid e}\big],$$

where $\tilde{q}^C_{e\mid e}$ is the quantity produced by the competitor. From the first-order condition, we get the best response

$$q^C_{e\mid e}\big(\tilde{q}^C_{e\mid e}\big) = \frac{\bar{a} - \tilde{q}^C_{e\mid e}}{2}. \tag{EC2}$$

The best response for the other firm is symmetric. Note that the second order condition is trivially satisfied,

$$q^C_{e\,|\,e} = \tfrac{1}{3}\bar{a}.$$

The profits from the competitive market are given as

$$\mathrm{E}\big[\Pi^C_{e\,|\,e}\big] = \tfrac{1}{9}\bar{a}^2.$$

Monopoly Market. The payoff maximizing production quantity is given as

$$\max_{q^M_{e|e}} \mathrm{E}\big[\{a^M - q^M_{e\,|\,e}\}q^M_{e\,|\,e}\big].$$

From the first-order condition, we get the monopoly production quantity

$$q^M_{e\,|\,e} = \tfrac{1}{2}\bar{a}.$$

The clearance strategy implies that $Q_{e\,|\,e} = q^M_{e\,|\,e} + q^C_{e\,|\,e} = (5/6)\bar{a}$. The profits from the monopoly market are given as

$$\mathrm{E}\big[\Pi^M_{e\,|\,e}\big] = \tfrac{1}{4}\bar{a}^2.$$

The total profits are thus

$$\mathrm{E}[\Pi_{e\,|\,e}] = \tfrac{13}{36}\bar{a}^2 \quad \square$$

EC.1.2. The *d*-*e* Case

Lemma EC.1.2. *When one of the two firms employs delayed differentiation and the other employs early differentiation, the expected sales, quantity of the intermediate good produced, and the revenues earned by the firms are given as follows*:

$$\mathrm{E}\big[q^C_{d\,|\,e}\big] = \tfrac{3}{10}\bar{a}; \qquad \mathrm{E}\big[q^C_{e\,|\,d}\big] = \tfrac{2}{5}\bar{a};$$
$$\mathrm{E}\big[q^M_{d\,|\,e}\big] = \mathrm{E}\big[q^M_{e\,|\,d}\big] = \frac{\bar{a}}{2};$$
$$Q_{d\,|\,e} = \tfrac{4}{5}\bar{a}; \qquad Q_{e\,|\,d} = \tfrac{9}{10}\bar{a};$$
$$\mathrm{E}[\Pi_{d\,|\,e}] = \tfrac{17}{50}\bar{a}^2 + \tfrac{1}{4}\hat{a}(1-\rho); \qquad \mathrm{E}[\Pi_{e\,|\,d}] = \tfrac{37}{100}\bar{a}^2.$$

Proof. We consider the problem as a two stage dynamic game. We first compute the best choices in the distribution stage as a function of the market demands and production quantities. Next, we use this distribution equilibrium to derive the production equilibrium.

Stage 2: Distribution

The Delayed-Differentiating Firm. The firm employing delayed differentiation has a quantity $Q_{d\,|\,e}$ on hand and chooses quantities $q^C_{d\,|\,e}$, $q^M_{d\,|\,e}$ to maximize its payoff.

$$\max_{q^C_{d|e},\, q^M_{d|e}} \big(\big[a^C - \big(q^C_{d\,|\,e} + q^C_{e\,|\,d}\big)\big]q^C_{d\,|\,e} + \big[a^M - q^M_{d\,|\,e}\big]q^M_{d\,|\,e}\big),$$

where the clearance strategy implies $q^C_{d\,|\,e} + q^M_{d\,|\,e} = Q_{d\,|\,e}$, and $q^C_{d\,|\,e}, q^M_{d\,|\,e} \geq 0$. Parameters of the demand curves (a^C, a^M) are known. The first-order condition for the payoffs gives us the best responses below:

$$\begin{aligned} q^C_{d\,|\,e}(a^C, a^M; q^C_{e\,|\,d}, Q_{d\,|\,e}) &= \frac{Q_{d\,|\,e}}{2} + \frac{a^C - a^M - q^C_{e\,|\,d}}{4}, \\ q^M_{d\,|\,e}(a^C, a^M; q^C_{e\,|\,d}, Q_{d\,|\,e}) &= \frac{Q_{d\,|\,e}}{2} - \frac{a^C - a^M - q^C_{e\,|\,d}}{4}. \end{aligned} \tag{EC3}$$

Note that the second-order condition for the above is trivially satisfied. Also, our assumption on the support of the distribution $a_h - a_l \leq 1.2\bar{a}$ ensures that we do not have corner solutions for equilibrium production levels. Because $\mathrm{E}[a^C] = \mathrm{E}[a^M]$, we have

$$\mathrm{E}\big[q^C_{d\,|\,e}\big] = \frac{Q_{d\,|\,e}}{2} - \frac{q^C_{e\,|\,d}}{4}; \qquad \mathrm{E}\big[q^M_{d\,|\,e}\big] = \frac{Q_{d\,|\,e}}{2} + \frac{q^C_{e\,|\,d}}{4}. \tag{EC4}$$

Early Differentiating Firm. The other firm employs early differentiation. Thus, there are no choices to be made for this firm at the distribution stage.

Stage 1: Production

Delayed-Differentiating Firm. Given the above allocation decisions; the optimization problem facing the delayed-differentiating firm is

$$\max_{Q_{d|e}} \mathrm{E}\big[\big\{a^C - \big(q^C_{d|e}(\cdot) + q^C_{e|d}\big)\big\}q^C_{d|e}(\cdot) + \big\{a^M - q^M_{d|e}(\cdot)\big\}q^M_{d|e}(\cdot)\big], \tag{EC5}$$

where $q^{\cdot}_{d|e}(\cdot)$ refers to $q^{\cdot}_{d|e}(a^C, a^M; q^C_{e|d}, Q_{d|e})$. From the first-order condition, we get the best response.

$$Q_{d|e}\big(q^C_{e|d}\big) = \bar{a} - \frac{q^C_{e|d}}{2}, \tag{EC6}$$

where $\mathrm{E}[q^C_{d|e}]$ and $\mathrm{E}[q^M_{d|e}]$ are substituted from (EC4). Again the second-order condition is trivially satisfied.

Early Differentiating Firm. For the firm employing early differentiation, the problem is separable in the production quantities for the two markets. The payoff from the competitive market is maximized as

$$\max_{q^C_{e|d}} \mathrm{E}\big[\big\{a^C - \big(q^C_{d|e} + q^C_{e|d}\big)\big\}q^C_{e|d}\big].$$

Substituting $q^C_{d|e}$ from (EC3) and differentiating the above we get, the best response of the early differentiating firm for the competitive-market production quantities as

$$q^C_{e|d}(Q_{d|e}) = \frac{2}{3}\left(\bar{a} - \frac{Q_{d|e}}{2}\right). \tag{EC7}$$

Solving Equations (EC6) and (EC7) gives us the following equilibrium production quantities

$$q^C_{e|d} = \tfrac{2}{5}\bar{a}, \tag{EC8}$$

$$Q_{d|e} = \tfrac{4}{5}\bar{a}. \tag{EC9}$$

Firm 2 also produces a quantity $q^M_{e|d}$ for the monopoly market, $q^M_{e|d} = \bar{a}/2$. Substituting the equilibrium production and shipping quantities ((EC8), (EC9)) in the expected sales (EC4) and revenue expressions (EC5) and using (EC1) gives us

$$\Pi_{d|e} = \tfrac{17}{50}\bar{a}^2 + \tfrac{1}{4}\hat{a}(1-\rho); \qquad \Pi_{e|d} = \tfrac{37}{100}\bar{a}^2$$

$$\mathrm{E}\big[q^C_{d|e}\big] = \tfrac{3}{10}\bar{a}; \qquad \mathrm{E}\big[q^M_{d|e}\big] = \tfrac{1}{2}\bar{a}; \qquad Q_{d|e} = \tfrac{4}{5}\bar{a}; \qquad Q_{e|d} = \tfrac{9}{10}\bar{a}. \quad \square$$

EC.1.3. The *d*-*d* Case

Lemma EC.1.3. *When the two firms employ delayed differentiation; the expected sales, quantity of the intermediate good produced, and the revenues earned by the firms are given as follows:*

$$\mathrm{E}\big[q^C_{d|d}\big] = \tfrac{30}{86}\bar{a}; \qquad \mathrm{E}\big[q^M_{d|d}\big] = \tfrac{45}{86}\bar{a}; \qquad Q_{d|d} = \tfrac{75}{86}\bar{a}; \qquad \mathrm{E}[\Pi_{d|d}] = \tfrac{2{,}625}{7{,}396}\bar{a}^2 + \tfrac{4}{25}\hat{a}(1-\rho).$$

Proof. We consider the problem as a two-stage dynamic game. We first compute the best choices in distribution stage as a function of the market demands and production quantities. Next, we use the distribution equilibria to derive the production equilibria.

Stage 2: Distribution
We let $\tilde{q}^C_{d|d}$ denote the quantity sold by the competitor and $\tilde{Q}_{d|d}$ denote the competitor's production quantity. The firm has a quantity $Q_{d|d}$ on hand and chooses quantities $q^C_{d|d}$, $q^M_{d|d}$ to maximize the payoff in (EC10).

$$\max_{q^C_{d|d},\, q^M_{d|d}} \left(\left[a^C - \left(q^C_{d|d} + \tilde{q}^C_{d|d}\right)\right] q^C_{d|d} + \left[a^M - q^M_{d|d}\right] q^M_{d|d}\right), \tag{EC10}$$

such that $q^C_{d|d} + q^M_{d|d} = Q_{d|d}$, $q^C_{d|d}, q^M_{d|d} \geq 0$. Parameters of the demand curves (a^C, a^M) are known. The other firm faces a symmetric maximization problem. The first-order condition gives us the best responses as

$$q^C_{d|d}\left(a^C, a^M; \tilde{q}^C_{d|d}, Q_{d|d}\right) = \frac{Q_{d|d}}{2} + \frac{a^C - a^M - \tilde{q}^C_{d|d}}{4},$$
$$q^M_{d|d}\left(a^C, a^M; \tilde{q}^C_{d|d}, Q_{d|d}\right) = \frac{Q_{d|d}}{2} - \frac{a^C - a^M - \tilde{q}^C_{d|d}}{4}.$$

The expressions for $\tilde{q}^C_{d|d}$ and $\tilde{q}^M_{d|d}$ are symmetric. The second-order condition is trivially satisfied. Also, our assumption on the support of the distribution $a_h - a_l \leq 1.2\bar{a}$ ensures that we do not have corner solutions for equilibrium production levels.

Solving the four equations simultaneously gives us the equilibrium sales by each firm as

$$q^C_{d|d}\left(a^C, a^M; Q_{d|d}, \tilde{Q}_{d|d}\right) = \frac{8Q_{d|d} - 2\tilde{Q}_{d|d} + 3(a^C - a^M)}{15}, \tag{EC11}$$

$$q^M_{d|d}\left(a^C, a^M; Q_{d|d}, \tilde{Q}_{d|d}\right) = \frac{7Q_{d|d} + 2\tilde{Q}_{d|d} - 3(a^C - a^M)}{15}. \tag{EC12}$$

The expected sales are given as

$$\mathrm{E}\left[\bar{q}^C_{d|d}\right] = \mathrm{E}\left[q^C_{d|d}\right] = \frac{8Q_{d|d} - 2\tilde{Q}_{d|d}}{15} \qquad \mathrm{E}\left[\bar{q}^M_{d|d}\right] = \mathrm{E}\left[q^M_{d|d}\right] = \frac{7Q_{d|d} + 2\tilde{Q}_{d|d}}{15}. \tag{EC13}$$

Stage 1: Production
Given the above allocation decisions, the optimization problem facing the delayed differentiating firm is

$$\max_{Q_{d|d}} \mathrm{E}\left[\left\{a^C - \left(q^C_{d|d}(\cdot) + \tilde{q}^C_{d|d}(\cdot)\right)\right\} q^C_{d|d}(\cdot) + \left\{a^M - q^M_{d|d}(\cdot)\right\} q^M_{d|d}(\cdot)\right], \tag{EC14}$$

where $q^{\cdot}_{d|d}(\cdot)$ refers to $q^{\cdot}_{d|d}(a^C, a^M; Q_{d|d}, \tilde{Q}_{d|d})$. From the first-order condition, we get the best response in production quantities

$$Q_{d|d}(\tilde{Q}_{d|d}) = \tfrac{225}{194}\left[\bar{a} - \tfrac{64}{225}\tilde{Q}_{d|d}\right], \tag{EC15}$$

where $\mathrm{E}[q^C_{d|d}]$ and $\mathrm{E}[q^M_{d|d}]$ are substituted from (EC13). Again the second-order condition is trivially satisfied. $\tilde{Q}_{d|d}(Q_{d|d})$ is symmetrically defined.

Solving the equations in (EC15) gives us the equilibrium production levels as

$$\tilde{Q}_{d|d} = Q_{d|d} = \tfrac{75}{86}\bar{a}.$$

Substituting the above production level in the expressions for revenue (EC14) and expected sales (EC13) and using (EC1) gives us the equilibrium sales, and the revenues

$$\mathrm{E}\left[q^C_{d|d}\right] = \tfrac{30}{86}\bar{a} \qquad \mathrm{E}\left[q^M_{d|d}\right] = \tfrac{45}{86}\bar{a} \qquad Q_{d|d} = \tfrac{75}{86}\bar{a} \qquad \mathrm{E}[\Pi_{d|d}] = \tfrac{2{,}625}{7{,}396}\bar{a}^2 + \tfrac{4}{25}\hat{a}(1-\rho). \quad \square$$

EC.2. Proofs for Results in §4

Proof for Table 1. Table 1 follows directly from Lemmas EC.1.1, EC.1.2, and EC.1.3.

Proof for Theorem 4.1. Theorem 4.1 follows directly from Table 1 (in §4 of the main paper) or Lemmas EC.1.1, EC.1.2, and EC.1.3.

Proof for Table 2. Table 2 follows directly from Lemmas EC.1.1, EC.1.2, and EC.1.3.

Proof for Table 3. First note from Table 2 of the main paper, that $\Pi_{e|d} > \Pi_{e|e}$. Solving the inequality $\Pi_{d|e} \le \Pi_{d|d}$ (linear in ρ) gives us $\rho \ge \rho_4' = 1 - 2{,}759(1/129\gamma)^2$. Solving the inequality $\Pi_{d|e} \le \Pi_{e|d}$ (linear in ρ) gives us $\rho \ge \rho_3' = 1 - 3(1/5\gamma)^2$. Solving the inequality $\Pi_{d|d} \le \Pi_{e|d}$ (linear in ρ) gives us $\rho \ge \rho_2' = 1 - 697(1/86\gamma)^2$. Solving the inequality $\Pi_{d|e} \le \Pi_{e|e}$ (linear in ρ) gives us $\rho \ge \rho_1' = 1 - 19(1/15\gamma)^2$. Solving the inequality $\Pi_{d|d} \le \Pi_{e|e}$ (linear in ρ) gives us $\rho \ge \rho_0' = 1 - 2{,}575(1/258\gamma)^2$. Now note that for $\rho = -1$, $\Pi_{d|e} > \Pi_{d|d} > \Pi_{e|d} > \Pi_{e|e}$. Define $\rho_i = \max\{-1, \rho_i'\}$. Now observe that

$$-1 \le \rho_4 \le \rho_3 \le \rho_2 \le \rho_1 \le \rho_0 < 1.$$

Table 3 now follows.

Proof for Table 4. In Table 4, the industry profits are obtained by adding the profit expressions from Lemmas EC.1.1, EC.1.2, and EC.1.3. The welfare is the sum of the consumer surplus and the industry profits. We compute the consumer surplus now.

Computing the Consumer Surplus. The consumer surplus from any market for the linear demand curve $p(q) = a - q$ (where a is the uncertain intercept) is defined as

$$\mathrm{CS}^A_{x-y} = \tfrac{1}{2}\,\mathrm{E}\big[\big(q^A_{x-y}\big)^2\big],$$

where $x, y \in \{e, d\}$ and $A \in \{C, M\}$.

The e-e **Case.** In the e-e case, the total consumer surplus is given as

$$\mathrm{CS}_{e\text{-}e} = \mathrm{CS}^C_{e\text{-}e} + 2\mathrm{CS}^M_{e\text{-}e}.$$

The quantities supplied to the competitive market and the monopoly markets are given as $(2/3)\bar{a}$ and $(1/2)\bar{a}$. Thus, $\mathrm{CS}_{e\text{-}e} = (2/9)\bar{a}^2 + \bar{a}^2/4 = (17/36)\bar{a}^2$.

The d-e **Case.** In the d-e case, the total consumer surplus is given as

$$\mathrm{CS}_{d\text{-}e} = \mathrm{CS}^C_{d\text{-}e} + \mathrm{CS}^M_{e|d} + \mathrm{CS}^M_{d|e}.$$

The quantities supplied to the three markets are

$$q^C_{d\text{-}e} = \frac{7}{10}\bar{a} + \frac{a^C - a^M}{4} \qquad q^M_{d|e} = \frac{\bar{a}}{2} - \frac{a^C - a^M}{4} \qquad q^M_{e|d} = \frac{\bar{a}}{2}.$$

The consumer surplus is thus,

$$\begin{aligned}\mathrm{CS}_{d\text{-}e} &= \tfrac{1}{2}\big(\mathrm{E}\big[\big(q^C_{d\text{-}e}\big)^2\big] + \mathrm{E}\big[\big(q^M_{d|e}\big)^2\big] + \mathrm{E}\big[\big(q^M_{e|d}\big)^2\big]\big)\\ &= \tfrac{99}{200}\bar{a}^2 + \tfrac{1}{8}\,\mathrm{E}[(a^C)^2] + \tfrac{1}{8}\,\mathrm{E}[(a^M)^2] - \tfrac{1}{4}\,\mathrm{E}[a^C a^M].\end{aligned}$$

Using (EC1) we get the required expression for the consumer surplus.

The d-d **Case.** In the d-d case, the total consumer surplus is given as

$$\mathrm{CS}_{d\text{-}d} = \mathrm{CS}^C_{d\text{-}d} + 2\mathrm{CS}^M_{d\text{-}d}.$$

The quantities supplied to the three markets are

$$q^C_{d\text{-}d} = \frac{60}{86}\bar{a} + \frac{2(a^C - a^M)}{5} \qquad q^M_{d|d} = \frac{45}{86}\bar{a} + \frac{(a^C - a^M)}{5}.$$

The consumer surplus is thus,

$$\begin{aligned}\mathrm{CS}_{d\text{-}d} &= \tfrac{1}{2}\big(\mathrm{E}\big[\big(q^C_{d\text{-}d}\big)^2\big] + 2\,\mathrm{E}\big[\big(q^M_{d\text{-}d}\big)^2\big]\big)\\ &= \big[\big(\tfrac{60}{86}\big)^2 + 2\big(\tfrac{45}{86}\big)^2\big]\bar{a}^2 + \tfrac{4}{25}\,\mathrm{E}[(a^C)^2] + \tfrac{2}{25}\,\mathrm{E}[(a^M)^2] - \tfrac{6}{25}\,\mathrm{E}[a^C a^M].\end{aligned}$$

Using (EC1), we get the required expression for the consumer surplus.

Proof for Theorem 4.2. Theorem 4.2 follows from the above computation of consumer surplus and welfare.

EC.3. Proofs for Results in §5

Proof for Theorem 5.1. Theorem 5.1 follows directly from Table 3.

Proof for Theorem 5.2. Theorem 5.2 follows directly from Table 3.

Proof for Theorem 5.3.

Theorem (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.*

Proof. Consider an incumbent firm operating as a monopolist in two markets. It faces an entrant in one of its two markets.

If the incumbent deploys early differentiation and the entrant decides to enter, then the entrants profits are $\Pi^C_{e|e} = \Pi_{e|e} - \bar{a}^2/4$, where Π^C refers to the profits from the competitive market alone. Recall that an early differentiating firm's profits from the monopoly market are always $\bar{a}^2/4$.

If the incumbent deploys delayed differentiation and the entrant decides to enter, the entrant's profits are $\Pi^C_{e|d} = \Pi_{e|d} - \bar{a}^2/4$, where Π^C refers to the profits from the competitive market alone. Recall that an early differentiating firm's profits from the monopoly market are always $\bar{a}^2/4$. Theorem 5.3 now follows from the fact that $\Pi_{e|d} > \Pi_{e|e} \Rightarrow \Pi^C_{e|d} > \Pi^C_{e|e}$, thus the entrant's profits are lower if the incumbent deploys early differentiation. Thus, early differentiation is a better entry-deterrence strategy. □

EC.4. Equilibrium Under Each Supply Chain Configuration (Model of §6)

The additional notation used in this and subsequent sections is summarized in Table EC.2 below. From the distribution of the demand intercepts we know that

$$\begin{gathered} \mathrm{E}[(a^c)^2] = \bar{a}_c^2 + \hat{a}_c \qquad \mathrm{E}[(a^{mi})^2] = \bar{a}_{mi}^2 + \hat{a}_{mi}, \quad \text{where } i \in \{1,2\} \\ \mathrm{E}[a^c a^{mi}] = \rho_i\sqrt{\hat{a}_c\hat{a}_{mi}} + \bar{a}_c\bar{a}_{mi} \qquad \mathrm{E}[a^{mj}a^{mi}] = \rho_m\sqrt{\hat{a}_{mj}\hat{a}_{mi}} + \bar{a}_{mj}\bar{a}_{mi}, \quad \text{where } i,j \in \{1,2\} \text{ and } i \neq j. \end{gathered} \tag{EC16}$$

EC.4.1. The *e*-*e* Case

Lemma EC.4.1. *When the two firms employ early differentiation, the expected sales, quantity of the intermediate goods produced, and the revenues earned by the firms are given as follows:*

$$\mathrm{E}[q^c_{e|e}] = q^c_{e|e} = \tfrac{1}{3}\bar{a}_c; \qquad \mathrm{E}[q^{mi}_{e|e}] = q^{mi}_{e|e} = \tfrac{1}{2}\bar{a}_{mi}; \qquad Q^i_{e|e} = \tfrac{1}{2}\bar{a}_{mi} + \tfrac{1}{3}\bar{a}_c; \qquad \mathrm{E}[\Pi^i_{e|e}] = \tfrac{1}{9}\bar{a}_c^2 + \tfrac{1}{4}\bar{a}_{mi}^2.$$

Proof. The proof follows along the same lines as the proof for Lemma EC.1.1. □

EC.4.2. The *d*-*e* Case

Lemma EC.4.2. *When one of the two firms employs delayed differentiation and the other employs early differentiation, the expected sales, quantity of the intermediate good produced, and the revenues earned by the firms are given as follows:*

$$\begin{gathered} \mathrm{E}[q^c_{d|e}] = \tfrac{3}{10}\bar{a}_c; \qquad \mathrm{E}[q^c_{e|d}] = \tfrac{2}{5}\bar{a}_c; \\ \mathrm{E}[q^{mi}_{d|e}] = \mathrm{E}[q^{mi}_{e|d}] = \tfrac{1}{2}\bar{a}_{mi}; \end{gathered}$$

Table EC.2 Symbols Used in §6 of the Main Paper

Symbol	Meaning
a^c, a^{mi}	Realized value of the demand intercept.
$\bar{a}_x$	Mean of the demand intercept distribution in market x, where $x \in \{c, m1, m2\}$.
$\hat{a}_x$	Variance of the demand intercept distribution in market x, where $x \in \{c, m1, m2\}$.
ρ_i	Correlation between the demand intercepts in the monopoly market of firm i and the competitive market.
ρ_m	Correlation between the demand intercepts in the two monopoly markets.
$q^A_{x\mid y}$	Quantity sold by a firm i employing x, facing a competitor employing y, to market A; where $x, y \in \{e, d\}$, $A \in \{c, m1, m2\}$, $i \in \{1, 2\}$.
$Q^i_{x\mid y}$	Quantity produced by firm i employing x facing a competitor employing y; where $x, y \in \{e, d\}$.

$$Q^i_{d|e} = \tfrac{3}{10}\bar{a}_c + \tfrac{1}{2}\bar{a}_{mi}; \qquad Q^i_{e|d} = \tfrac{2}{5}\bar{a}_c + \tfrac{1}{2}\bar{a}_{mi};$$
$$\mathrm{E}[\Pi^i_{d|e}] = \tfrac{9}{100}\bar{a}_c^2 + \tfrac{1}{4}\bar{a}_{mi}^2 + \tfrac{1}{8}\mathrm{Var}(a_c - a_{mi}); \qquad \mathrm{E}[\Pi^i_{e|d}] = \tfrac{3}{25}\bar{a}_c^2 + \tfrac{1}{4}\bar{a}_{mi}^2.$$

Proof. We consider the problem as a two-stage dynamic game. We first compute the best choices in the distribution stage as a function of the market demands and production quantities. Next, we use this distribution equilibrium to derive the production equilibrium.

Stage 2: Distribution

The Delayed-Differentiating Firm. The firm employing delayed differentiation has a quantity $Q^i_{d|e}$ on hand and chooses quantities $q^c_{d|e}$, $q^{mi}_{d|e}$ to maximize its payoff.

$$\max_{q^c_{d|e},\, q^{mi}_{d|e}} ([a^c - (q^c_{d|e} + q^c_{e|d})]q^c_{d|e} + [a^{mi} - q^{mi}_{d|e}]q^{mi}_{d|e}),$$

where the clearance strategy implies $q^c_{d|e} + q^{mi}_{d|e} = Q^i_{d|e}$, and $q^c_{d|e}, q^{mi}_{d|e} \geq 0$. Parameters of the demand curves (a^C, a^{mi}) are known. The first-order condition for the payoffs gives us the best responses below.

$$\begin{aligned} q^c_{d|e}(a^c, a^{mi}; q^c_{e|d}, Q^i_{d|e}) &= \frac{Q_{d|e}}{2} + \frac{a^c - a^{mi} - q^c_{e|d}}{4}, \\ q^{mi}_{d|e}(a^c, a^{mi}; q^c_{e|d}, Q^i_{d|e}) &= \frac{Q_{d|e}}{2} - \frac{a^c - a^{mi} - q^c_{e|d}}{4}. \end{aligned} \tag{EC17}$$

Note that the second-order condition for the above is trivially satisfied. The conditions

$$\Pr\big(|a_c - a_{mi}| \leq \bar{a}_{mi} + \tfrac{1}{5}\bar{a}_c\big) = 1$$

and

$$\Pr\big(-\tfrac{96}{43}\bar{a}_c - 4\bar{a}_{mi} + \bar{a}_{mj} \leq (3a_c - 4a_{mi} + a_{mj}) \leq \tfrac{144}{43}\bar{a}_c + \tfrac{7}{2}\bar{a}_{mi} + \bar{a}_{mj}\big) = 1$$

for $i, j \in \{1, 2\}$, $i \neq j$ ensure that we do not have corner solutions for equilibrium production levels. Taking expectations, we get

$$\mathrm{E}\big[q^C_{d|e}\big] = \frac{Q^i_{d|e}}{2} + \frac{\bar{a}_c - \bar{a}_{mi}}{4} - \frac{q^C_{e|d}}{4}; \qquad \mathrm{E}\big[q^M_{d|e}\big] = \frac{Q^i_{d|e}}{2} - \frac{\bar{a}_c - \bar{a}_{mi}}{4} - \frac{q^C_{e|d}}{4}. \tag{EC18}$$

Early Differentiating Firm. The other firm employs early differentiation. Thus, there are no choices to be made for this firm at the distribution stage.

Stage 1: Production

Delayed-Differentiating Firm. Given the above allocation decisions, the optimization problem facing the delayed-differentiating firm is

$$\max_{Q^i_{d|e}} \mathrm{E}[\{a^c - (q^c_{d|e}(\cdot) + q^c_{e|d})\}q^c_{d|e}(\cdot) + \{a^{mi} - q^{mi}_{d|e}(\cdot)\}, q^{mi}_{d|e}(\cdot)], \tag{EC19}$$

where $q^{\cdot}_{d|e}(\cdot)$ refers to $q^{\cdot}_{d|e}(a^c, a^{mi}; q^c_{e|d}, Q^i_{d|e})$. From the first-order condition, we get the best response.

$$Q^i_{d|e}\big(q^C_{e|d}\big) = \frac{\bar{a}_c + \bar{a}_{mi}}{2} - \frac{q^C_{e|d}}{2}, \tag{EC20}$$

where $\mathrm{E}[q^C_{d|e}]$ and $\mathrm{E}[q^M_{d|e}]$ are substituted from (EC18). Again the second-order condition is trivially satisfied.

Early Differentiating Firm. For the firm employing early differentiation, the problem is separable in the production quantities for the two markets. The payoff from the competitive market is maximized as

$$\max_{q^c_{e|d}} \mathrm{E}[\{a^c - (q^c_{d|e} + q^c_{e|d})\} q^c_{e|d}].$$

Substituting $q^C_{d|e}$ from (EC17) and differentiating the above we get, the best response of the early differentiating firm for the competitive market production quantities as

$$q^c_{e|d}(Q^i_{d|e}) = \frac{\bar{a}_c}{2} + \frac{\bar{a}_{mi}}{6} - \frac{Q^i_{d|e}}{3}. \tag{EC21}$$

Solving Equations (EC20) and (EC21) gives us the following equilibrium production quantities

$$q^c_{e|d} = \tfrac{2}{5}\bar{a}_c, \tag{EC22}$$

$$Q^i_{d|e} = \tfrac{3}{10}\bar{a}_c + \tfrac{1}{2}\bar{a}_{mi}. \tag{EC23}$$

Firm 2 also produces a quantity $q^{mi}_{e|d}$ for the monopoly market, $q^{mi}_{e|d} = \bar{a}_{mi}/2$. Substituting the equilibrium production and shipping quantities ((EC22), (EC23)) in the expected sales (EC18) and revenue expressions (EC19) and using (EC16) gives us

$$\mathrm{E}[q^c_{d|e}] = \tfrac{3}{10}\bar{a}_c; \qquad \mathrm{E}[q^c_{e|d}] = \tfrac{2}{5}\bar{a}_c;$$
$$\mathrm{E}[q^{mi}_{d|e}] = \mathrm{E}[q^{mi}_{e|d}] = \tfrac{1}{2}\bar{a}_{mi};$$
$$Q^i_{d|e} = \tfrac{3}{10}\bar{a}_c + \tfrac{1}{2}\bar{a}_{mi}; \qquad Q^i_{e|d} = \tfrac{2}{5}\bar{a}_c + \tfrac{1}{2}\bar{a}_{mi};$$
$$\mathrm{E}[\Pi^i_{d|e}] = \tfrac{9}{100}\bar{a}^2_c + \tfrac{1}{4}\bar{a}^2_{mi} + \tfrac{1}{8}\mathrm{Var}(a_c - a_{mi}); \qquad \mathrm{E}[\Pi^i_{e|d}] = \tfrac{3}{25}\bar{a}^2_c + \tfrac{1}{4}\bar{a}^2_{mi}. \quad \square$$

EC.4.3. The *d*-*d* Case

Lemma EC.4.3. *When the two firms employ delayed differentiation; the expected sales, quantity of the intermediate good produced, and the revenues earned by the firms are given as follows:*

$$\mathrm{E}[q^c_{d|d}] = \tfrac{15}{43}\bar{a}_c; \qquad \mathrm{E}[q^{mi}_{d|d}] = \tfrac{1}{43}\bar{a}_c + \tfrac{1}{2}\bar{a}_{mi}; \qquad Q^i_{d|d} = \tfrac{16}{43}\bar{a}_c + \tfrac{1}{2}\bar{a}_{mi};$$
$$\mathrm{E}[\Pi^i_{d|d}] = \tfrac{194}{1{,}849}\bar{a}^2_c + \tfrac{1}{4}\bar{a}^2_{mi} + \tfrac{2}{225}\mathrm{Var}(3a_c - 4a_{mi} + a_{mj}).$$

Proof. We consider the problem as a two-stage dynamic game. We first compute the best choices in distribution stage as a function of the market demands and production quantities. Next, we use the distribution equilibria to derive the production equilibria.

Stage 2: Distribution
We let $\tilde{q}^c_{d|d}$ denote the quantity sold by the competitor and $Q^j_{d|d}$ denote the competitor's production quantity. The firms have a quantity $Q^i_{d|d}$, $Q^j_{d|d}$ on hand and each chooses quantities $q^c_{d|d}$, $q^{mi}_{d|d}$ to maximize the payoff:

$$\max_{q^c_{d|d},\, q^{mi}_{d|d}} ([a^c - (q^c_{d|d} + \tilde{q}^c_{d|d})]q^c_{d|d} + [a^{mi} - q^{mi}_{d|d}]q^{mi}_{d|d}),$$

such that $q^c_{d|d} + q^{mi}_{d|d} = Q^i_{d|d}$, $q^c_{d|d}, q^{mi}_{d|d} \geq 0$. Parameters of the demand curves (a^c, a^{mi}) are known. The first-order condition gives us the best responses as

$$q^c_{d|d}(a^c, a^{mi}; \tilde{q}^c_{d|d}, Q^i_{d|d}) = \frac{Q^i_{d|d}}{2} + \frac{a^c - a^{mi} - \tilde{q}^c_{d|d}}{4},$$
$$q^{mi}_{d|d}(a^c, a^{mi}; \tilde{q}^c_{d|d}, Q^i_{d|d}) = \frac{Q^i_{d|d}}{2} - \frac{a^c - a^{mi} - \tilde{q}^c_{d|d}}{4}.$$

The expressions for $\tilde{q}^c_{d|d}$ and $\tilde{q}^{mi}_{d|d}$ are symmetric. The second-order condition is trivially satisfied. The conditions:

$$\Pr\big(|a_c - a_{mi}| \leq \bar{a}_{mi} + \tfrac{1}{5}\bar{a}_c\big) = 1$$

and

$$\Pr\left(-\tfrac{96}{43}\bar{a}_c - 4\bar{a}_{mi} + \bar{a}_{mj} \le (3a_c - 4a_{mi} + a_{mj}) \le \tfrac{144}{43}\bar{a}_c + \tfrac{7}{2}\bar{a}_{mi} + \bar{a}_{mj}\right) = 1$$

for $i, j \in \{1, 2\}$, $i \neq j$ ensure that we do not have corner solutions for equilibrium production levels. Solving the four equations simultaneously gives us the equilibrium sales by each firm as

$$q^c_{d|d}(a^c, a^{mi}; Q^i_{d|d}, Q^j_{d|d}) = \frac{8Q^i_{d|d} - 2Q^j_{d|d} + 3(a^c - a^{mi})}{15}, \tag{EC24}$$

$$q^{mi}_{d|d}(a^c, a^{mi}; Q^i_{d|d}, Q^j_{d|d}) = \frac{7Q^i_{d|d} + 2Q^j_{d|d} - 3(a^c - a^{mi})}{15}. \tag{EC25}$$

The expected sales are given as

$$\mathrm{E}[q^c_{d|d}] = \frac{8Q^i_{d|d} - 2Q^j_{d|d} + 3(\bar{a}_c - \bar{a}_{mi})}{15} \qquad \mathrm{E}[q^{mi}_{d|d}] = \frac{7Q^i_{d|d} + 2Q^j_{d|d} - 3(\bar{a}_c - \bar{a}_{mi})}{15}. \tag{EC26}$$

Stage 1: Production
Given the above allocation decisions, the optimization problem facing the delayed-differentiating firm is

$$\max_{Q^i_{d|d}} \mathrm{E}[\{a^c - (q^c_{d|d}(\cdot) + \tilde{q}^c_{d|d}(\cdot))\}q^c_{d|d}(\cdot) + \{a^{mi} - q^{mi}_{d|d}(\cdot)\}q^{mi}_{d|d}(\cdot)], \tag{EC27}$$

where $q^{\cdot}_{d|d}(\cdot)$ refers to $q^{\cdot}_{d|d}(a^c, a^{mi}; Q^i_{d|d}, Q^j_{d|d})$. From the first-order condition, we get the best response in production quantities.

$$Q^i_{d|d}(Q^j_{d|d}) = \tfrac{1}{194}[96\bar{a}_c + 97\bar{a}_{mi} + 32\bar{a}_{mj} - 64Q^j_{d|d}], \tag{EC28}$$

where $\mathrm{E}[q^c_{d|d}]$ and $\mathrm{E}[q^{mi}_{d|d}]$ are substituted from (EC26). Again the second-order condition is trivially satisfied. $Q^j_{d|d}(Q^i_{d|d})$ is symmetrically defined.

Solving the equations in (EC28) gives us the equilibrium production levels as

$$Q^j_{d|d} = Q^i_{d|d} = \tfrac{16}{43}\bar{a}_c + \tfrac{1}{2}\bar{a}_{mi}.$$

Substituting the above production level in the expressions for revenue (EC27) and expected sales (EC26) and using (EC16) gives us the equilibrium sales and the revenues.

$$\mathrm{E}[q^c_{d|d}] = \tfrac{15}{43}\bar{a}_c; \qquad \mathrm{E}[q^{mi}_{d|d}] = \tfrac{1}{43}\bar{a}_c + \tfrac{1}{2}\bar{a}_{mi}; \qquad Q^i_{d|d} = \tfrac{16}{43}\bar{a}_c + \tfrac{1}{2}\bar{a}_{mi};$$
$$\mathrm{E}[\Pi^i_{d|d}] = \tfrac{194}{1{,}849}\bar{a}_c^2 + \tfrac{1}{4}\bar{a}_{mi}^2 + \tfrac{2}{225}\mathrm{Var}(3a_c - 4a_{mi} + a_{mj}). \quad \square$$

Note that Lemmas EC.4.1, EC.4.2, and EC.4.3 correspond to Lemmas EC.1.1, EC.1.2, and EC.1.3, if we set $\bar{a}_c = \bar{a}_{mi} = \bar{a}$, $\hat{a}_c = \hat{a}_{mi} = \hat{a}$, $\rho_i = \rho$, and $\rho_m = 1$.

EC.5. Proofs for Results in §6

Proof for Table 5. Table 5 follows directly from Lemmas EC.4.1, EC.4.2, and EC.4.3.

Proof for Theorem 6.1.

(1) The best responses follow directly by comparing the profit expressions in Table 5: $\mathrm{BR}_i(e)$ is given by comparing $\Pi^i_{d|e}$ with $\Pi^i_{e|e}$ (Row 1 and 2 of Table 5). $\mathrm{BR}_i(d)$ is given by comparing $\Pi^i_{d|d}$ with $\Pi^i_{e|d}$ (Row 3 and 4 of Table 5).

(2) The equilibrium choices follow from the best responses. Feasible values of ρ_m i.e $\rho_m \in [-1, 1]$, imply that the cell corresponding to the middle column and middle row of Table 6 is infeasible.

Proof for Table 7 (Comparative Statics). Table 7 is reproduced as Table EC.3 in this supplement.

Row 1. $\mathrm{BR}_i(e)$ depends upon the difference $\mathrm{E}[\Pi^i_{e|e}] - \mathrm{E}[\Pi^i_{d|e}]$, or the relative advantage of e over d when the competitor employs e. All entries in Row 1 are obtained by looking at the sign of $\partial(\mathrm{E}[\Pi^i_{e|e}] - \mathrm{E}[\Pi^i_{d|e}])/\partial\cdot$, where $\cdot$ corresponds to the parameter of interest in the corresponding column. From Lemmas EC.4.1 and EC.4.2,

$$\mathrm{E}[\Pi^i_{e|e}] - \mathrm{E}[\Pi^i_{d|e}] = \tfrac{19}{900}\bar{a}_c^2 - \tfrac{1}{8}\hat{a}_c - \tfrac{1}{8}\hat{a}_{mi} + \tfrac{1}{4}\rho_i\sqrt{\hat{a}_c\hat{a}_{mi}}. \tag{EC29}$$

Table EC.3 Effect of Altering Demand Parameters on Best-Response Choices

	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)
$\text{BR}_i(e)$	$\to e$	0	$\to d$ iff $T_i > 0$	$\to d$ iff $M_i > 0$	$\to d$	0	$\to e$ iff $P_i < 0$	$\to e$ iff $M_i < 0$
$\text{BR}_j(e)$	$\to e$	0	$\to d$ iff $T_j > 0$	0	0	0	$\to e$ iff $P_j < 0$	0
$\text{BR}_i(d)$	$\to e$	0	$\to d$ iff $U_i > 0$	$\to d$ iff $N_i > 0$	$\to d$	$\to d$	$\to e$ iff $R_i < 0$	$\to e$ iff $N_i < 0$
$\text{BR}_j(d)$	$\to e$	0	$\to d$ iff $U_j > 0$	$\to d$ iff $O_i > 0$	$\to e$	$\to d$	$\to e$ iff $R_j < 0$	$\to e$ iff $O_i < 0$

Notes. Each column illustrates the effect of increasing (denoted by the symbol "$\uparrow$") or decreasing (denoted by "$\downarrow$") the value of a parameter. The symbol "$\to e[d]$" denotes an increasing tendency to adopt early [delayed] differentiation.

$\gamma_c = \hat{a}_c/\bar{a}_c^2$, $\gamma_{mi} = \hat{a}_{mi}/\bar{a}_{mi}^2$, $T_i = 1-\rho_i\sqrt{\hat{a}_{mi}/\hat{a}_c}$, $U_i = 3-4\rho_i\sqrt{\hat{a}_{mi}/\hat{a}_c}+\rho_j\sqrt{\hat{a}_{mj}/\hat{a}_c}$, $M_i = 1-\rho_i\sqrt{\hat{a}_c/\hat{a}_{mi}}$, $N_i = 4-\rho_m\sqrt{\hat{a}_{mj}/\hat{a}_{mi}}-3\rho_i\sqrt{\hat{a}_c/\hat{a}_{mi}}$, $O_i = 1-4\rho_m\sqrt{\hat{a}_{mj}/\hat{a}_{mi}}+3\rho_i\sqrt{\hat{a}_c/\hat{a}_{mi}}$, $P_i = 1-(38/225\gamma_c)-\rho_i\sqrt{\hat{a}_{mi}/\hat{a}_c}$, $R_i = 3-4\rho_i\sqrt{\hat{a}_{mi}/\hat{a}_c}+\rho_j\sqrt{\hat{a}_{mj}/\hat{a}_c}-(2{,}091/3{,}698\gamma_c)$.

Column 1: From (EC29), $\partial(\text{E}[\Pi^i_{e|e}]-\text{E}[\Pi^i_{d|e}])/\partial\bar{a}_c = (19/450)\bar{a}_c > 0$. Thus, relative advantage of early differentiation increases with an increase in $\bar{a}_c$.

Column 2: From (EC29), $\partial(\text{E}[\Pi^i_{e|e}]-\text{E}[\Pi^i_{d|e}])/\partial\bar{a}_{mi} = 0$. Thus, relative advantage of early differentiation does not change with an increase in $\bar{a}_{mi}$.

Column 3: From (EC29), the relative advantage of e increases iff

$$\frac{\partial(\text{E}[\Pi^i_{e|e}]-\text{E}[\Pi^i_{d|e}])}{\partial\hat{a}_c} = \frac{1}{8}\left(-1+\rho_i\sqrt{\frac{\hat{a}_{mi}}{\hat{a}_c}}\right) > 0 \equiv T_i = 1-\rho_i\sqrt{\frac{\hat{a}_{mi}}{\hat{a}_c}} < 0.$$

Column 4: From (EC29), the relative advantage of e increases iff

$$\frac{\partial(\text{E}[\Pi^i_{e|e}]-\text{E}[\Pi^i_{d|e}])}{\partial\hat{a}_{mi}} = \frac{1}{8}\left(-1+\rho_i\sqrt{\frac{\hat{a}_c}{\hat{a}_{mi}}}\right) > 0 \equiv M_i = 1-\rho_i\sqrt{\frac{\hat{a}_c}{\hat{a}_{mi}}} < 0.$$

Column 5: From (EC29), the relative advantage of d increases with a decrease in ρ_i iff

$$\frac{\partial(\text{E}[\Pi^i_{e|e}]-\text{E}[\Pi^i_{d|e}])}{\partial\rho_i} = \tfrac{1}{4}\sqrt{\hat{a}_c\hat{a}_{mi}} > 0,$$

which is always true.

Column 6: From (EC29), $\partial(\text{E}[\Pi^i_{e|e}]-\text{E}[\Pi^i_{d|e}])/\partial\rho_m = 0$, thus a change in ρ_m has no impact.

Column 7: In (EC29), substitute $\bar{a}_c = \sqrt{\hat{a}_c/\gamma_c}$. The relative advantage of e increases iff

$$\frac{\partial(\text{E}[\Pi^i_{e|e}]-\text{E}[\Pi^i_{d|e}])}{\partial\bar{a}_c} = \frac{38}{225}\gamma_c+\rho_i\sqrt{\frac{\hat{a}_{mi}}{\hat{a}_c}}-1 > 0 \equiv P_i = 1-\frac{38}{225}\gamma_c-\rho_i\sqrt{\frac{\hat{a}_{mi}}{\hat{a}_c}} < 0.$$

Column 8: The proof is exactly the same as Column 4.

Row 2. $\text{BR}_j(e)$ depends on the difference $\text{E}[\Pi^j_{e|e}]-\text{E}[\Pi^j_{d|e}]$ or the relative advantage of early differentiation over delayed differentiation, when the competitor employs early differentiation. All entries in Row 2 are obtained by looking at the sign of $\partial(\text{E}[\Pi^j_{e|e}]-\text{E}[\Pi^j_{d|e}])/\partial\cdot$, where $\cdot$ corresponds to the parameter in the corresponding column.

The proofs for Columns 1, 2, 3, 6, and 7 are analogous to the proofs for the respective columns in Row 1. From Lemmas EC.4.1 and EC.4.2,

$$\text{E}[\Pi^j_{e|e}]-\text{E}[\Pi^j_{d|e}] = \tfrac{19}{900}\bar{a}_c^2-\tfrac{1}{8}\hat{a}_c-\tfrac{1}{8}\hat{a}_{mj}+\tfrac{1}{4}\rho_j\sqrt{\hat{a}_c\hat{a}_{mj}}. \tag{EC30}$$

Column 4: From (EC30), $\partial(\text{E}[\Pi^j_{e|e}]-\text{E}[\Pi^j_{d|e}])/\partial\hat{a}_{mi} = 0$.

Column 5: From (EC30), $\partial(\text{E}[\Pi^j_{e|e}]-\text{E}[\Pi^j_{d|e}])/\partial\rho_i = 0$.

Column 8: The proof is exactly the same as that for Column 4.

Row 3. $\mathrm{BR}_i(d)$ depends on the difference $\mathrm{E}[\Pi^i_{e|d}] - \mathrm{E}[\Pi^i_{d|d}]$, or the relative advantage of e over d when the competitor employs d. All entries in Row 1 are obtained by looking at the sign of $\partial(\mathrm{E}[\Pi^i_{e|d}] - \mathrm{E}[\Pi^i_{d|d}])/\partial\cdot$, where $\cdot$ corresponds to the parameter of interest in the corresponding column. From Lemmas EC.4.2 and EC.6.3, we get

$$\mathrm{E}[\Pi^i_{e|d}] - \mathrm{E}[\Pi^i_{d|d}] = \tfrac{697}{46{,}225}\bar{a}_c^2 - \tfrac{2}{25}\hat{a}_c - \tfrac{32}{225}\hat{a}_{mi} - \tfrac{2}{225}\hat{a}_{mj} - \tfrac{16}{75}\rho_i\sqrt{\hat{a}_c\hat{a}_{mi}} - \tfrac{16}{225}\rho_m\sqrt{\hat{a}_{mi}\hat{a}_{mj}} + \tfrac{4}{75}\rho_j\sqrt{\hat{a}_c\hat{a}_{mj}}. \tag{EC31}$$

Column 1: From (EC31), $\partial(\mathrm{E}[\Pi^i_{e|d}] - \mathrm{E}[\Pi^i_{d|d}])/\partial\bar{a}_c = (1{,}394/46{,}225)\bar{a}_c > 0$. Thus, the relative advantage of early differentiation increases with an increase in $\bar{a}_c$.

Column 2: From (EC31), $\partial(\mathrm{E}[\Pi^i_{e|d}] - \mathrm{E}[\Pi^i_{d|d}])/\partial\bar{a}_{mi} = 0$. Thus, the relative advantage of early differentiation does not change with an increase in $\bar{a}_{mi}$.

Column 3: From (EC31), the relative advantage of e increases iff

$$\frac{\partial(\mathrm{E}[\Pi^i_{e|d}] - \mathrm{E}[\Pi^i_{d|d}])}{\partial\hat{a}_c} = \frac{6}{225}\left(-3 + 4\rho_i\sqrt{\frac{\hat{a}_{mi}}{\hat{a}_c}} - \rho_j\sqrt{\frac{\hat{a}_{mj}}{\hat{a}_c}}\right) > 0$$

$$\equiv U_i = 3 - 4\rho_i\sqrt{\frac{\hat{a}_{mi}}{\hat{a}_c}} + \rho_j\sqrt{\frac{\hat{a}_{mj}}{\hat{a}_c}} < 0.$$

Column 4: From (EC31), the relative advantage of e increases iff

$$\frac{\partial(\mathrm{E}[\Pi^i_{e|d}] - \mathrm{E}[\Pi^i_{d|d}])}{\partial\hat{a}_{mi}} = \frac{8}{225}\left(-4 + 3\rho_i\sqrt{\frac{\hat{a}_c}{\hat{a}_{mi}}} + \rho_m\sqrt{\frac{\hat{a}_{mj}}{\hat{a}_{mi}}}\right) > 0$$

$$\equiv N_i = 4 - 3\rho_i\sqrt{\frac{\hat{a}_c}{\hat{a}_{mi}}} - \rho_m\sqrt{\frac{\hat{a}_{mj}}{\hat{a}_{mi}}} < 0.$$

Column 5: From (EC31), the relative advantage of d increases with a decrease in ρ_i iff $\partial(\mathrm{E}[\Pi^i_{e|d}] - \mathrm{E}[\Pi^i_{d|d}])/\partial\rho_i = (16/75)\sqrt{\hat{a}_c\hat{a}_{mi}} > 0$, which is always true.

Column 6: From (EC31), the relative advantage of d increases with a decrease in ρ_m iff $\partial(\mathrm{E}[\Pi^i_{e|d}] - \mathrm{E}[\Pi^i_{d|d}])/\partial\rho_m = (16/225)\sqrt{\hat{a}_{mj}\hat{a}_{mi}} > 0$, which is always true.

Column 7: In (EC31), substitute $\bar{a}_c = \sqrt{\hat{a}_c/\gamma_c}$. The relative advantage of e increases iff

$$\frac{\partial(\mathrm{E}[\Pi^i_{e|d}] - \mathrm{E}[\Pi^i_{d|d}])}{\partial\bar{a}_c} = \frac{6}{225}\left(\frac{2{,}091}{3{,}698\gamma_c} - 3 + 4\rho_i\sqrt{\frac{\hat{a}_{mi}}{\hat{a}_c}} - \rho_j\sqrt{\frac{\hat{a}_{mj}}{\hat{a}_c}}\right) > 0$$

$$\equiv R_i = -\frac{2{,}091}{3{,}698\gamma_c} + 3 - 4\rho_i\sqrt{\frac{\hat{a}_{mi}}{\hat{a}_c}} + \rho_j\sqrt{\frac{\hat{a}_{mj}}{\hat{a}_c}} < 0.$$

Column 8: The proof is exactly the same as that for Column 4.

Row 4: $\mathrm{BR}_j(d)$ depends on the difference $\mathrm{E}[\Pi^j_{e|d}] - \mathrm{E}[\Pi^j_{d|d}]$ or the relative advantage of e over d when the competitor employs d. All entries in Row 4 are obtained by looking at the sign of $\partial(\mathrm{E}[\Pi^j_{e|d}] - \mathrm{E}[\Pi^j_{d|d}])/\partial\cdot$, where $\cdot$ corresponds to the parameter in the corresponding column.

The proofs for Columns 1, 2, 3, 6, and 7 are analogous to the proofs for the respective columns in Row 1. From Lemmas EC.4.2 and EC.6.3, we get

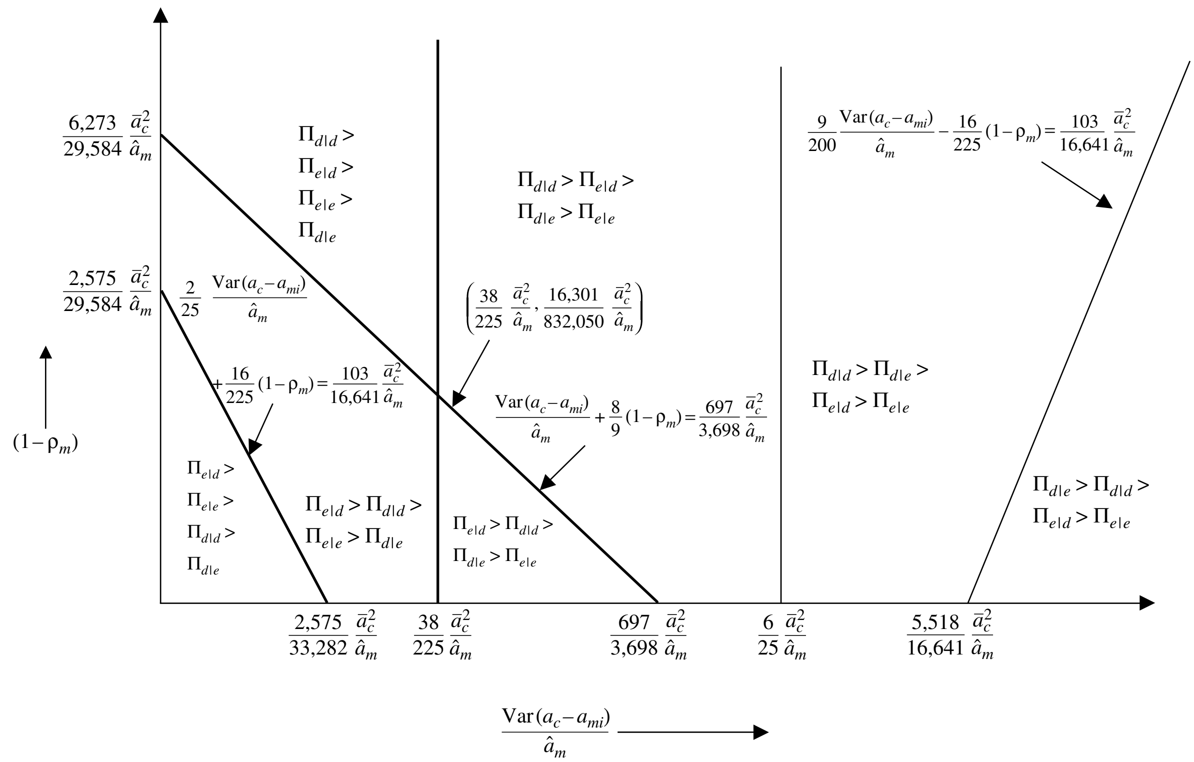
$$\mathrm{E}[\Pi^j_{e|d}] - \mathrm{E}[\Pi^j_{d|d}] = \tfrac{697}{46{,}225}\bar{a}_c^2 - \tfrac{2}{25}\hat{a}_c - \tfrac{32}{225}\hat{a}_{mj} - \tfrac{2}{225}\hat{a}_{mi} - \tfrac{16}{75}\rho_j\sqrt{\hat{a}_c\hat{a}_{mj}} - \tfrac{16}{225}\rho_m\sqrt{\hat{a}_{mi}\hat{a}_{mj}} + \tfrac{4}{75}\rho_i\sqrt{\hat{a}_c\hat{a}_{mi}}. \tag{EC32}$$

Column 4: The relative advantage of e increases iff

$$\frac{\partial(\mathrm{E}[\Pi^j_{e|d}] - \mathrm{E}[\Pi^j_{d|d}])}{\partial\hat{a}_{mi}} = \frac{2}{225}\left(-1 + 4\rho_m\sqrt{\frac{\hat{a}_{mj}}{\hat{a}_{mi}}} - 3\rho_i\sqrt{\frac{\hat{a}_c}{\hat{a}_{mi}}}\right) > 0$$

$$\equiv O_i = 1 - 4\rho_m\sqrt{\frac{\hat{a}_{mj}}{\hat{a}_{mi}}} + 3\rho_i\sqrt{\frac{\hat{a}_c}{\hat{a}_{mi}}} < 0.$$

Figure EC.1 Profit Comparisons



Column 5: The relative advantage of e increases if $\partial(\mathrm{E}[\Pi^j_{e|e}] - \mathrm{E}[\Pi^j_{d|e}])/\partial\rho_i = (48/225)\sqrt{\hat{a}_c\hat{a}_{mi}} > 0$, which is always true.

Column 8: The proof is exactly the same as that for Column 4.

Proof for Figure 5. The proof for Figure 5 follows 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 Lemmas EC.4.1, EC.4.2, and EC.4.3. A more detailed version of Figure 5 is provided as Figure EC.1 in this document.

EC.6. Proofs for Results in §7

EC.6.1. Proofs for Results in §7.1 (Holdback Strategies)

Proof for Table 8. We prove individual rows of Table 8 (reproduced in this supplement as Table EC.4) in the following three lemmas.

EC.6.1.1. The *e-e* Case

Lemma EC.6.1. *When the two firms employ early differentiation, the quantity sold under low and high demand, the quantity salvaged, and the quantity of the intermediate good produced are given by Row* 1 *of Table* EC.4.

Proof. We consider the problem as a two-stage dynamic game. We first compute the best choices in distribution stage as a function of the market demand (low or high demand) and production quantities. Next, we use the distribution equilibria to derive the production equilibria. We let $\tilde{\bullet}$ denote the variables for the competitor.

Under the *e-e* case, the decisions of the monopoly and the competitive market are separable. Further, because the monopoly market has no uncertainty, both firms produce and sell a quantity $a/2$ in their monopoly markets and earn a profit $a^2/4$ from this market. The firms produce a quantity differentiated for the competitive market ($Q^C_{e|e}$) at the production stage and may salvage some of it (under low demand) in the distribution stage.

Table EC.4 Quantities Produced, Sold and Salvaged in Equilibrium, Under Holdback

	Low demand			High demand		
Setting	q^C	q^M	q^s	q^C	q^M	Q
$e \mid e$	$\frac{a_l+s}{3}$	$\frac{a}{2}$	$\frac{a_hp-a_lp-s}{3p}$	$\frac{(a_hp-(1-p)s)}{3p}$	$\frac{a}{2}$	$\frac{a_h+s}{3}-\frac{s}{3p}, \frac{a}{2}$
$d \mid e$	$\frac{a_l+s}{3}$	$\frac{a+s}{2}$	$\frac{9a_hp-10a_lp-(24+p)s}{30p}$	$\frac{3(a_hp-(1-p)s)}{10p}$	$\frac{a}{2}-\frac{(1-p)s}{2p}$	$\frac{5a+3a_h}{10}-\frac{8s(1-p)}{10p}$
$e \mid d$	$\frac{a_l+s}{3}$	$\frac{a}{2}$	$\frac{6a_hp-5a_lp-(6-p)s}{15p}$	$\frac{2(a_hp-(1-p)s)}{5p}$	$\frac{a}{2}$	$\frac{2(a_hp-(1-p)s)}{5p}, \frac{a}{2}$
$d \mid d$	$\frac{a_l+s}{3}$	$\frac{a+s}{2}$	$\frac{96a_hp-86a_lp-5(45-2p)s}{258p}$	$\frac{15(a_hp-(1-p)s)}{43p}$	$\frac{a}{2}+\frac{2ap-45(1-p)s}{86p}$	$\frac{a}{2}+\frac{32a_hp-75s(1-p)}{86p}$

Stage 2: Distribution

Low Demand. Under low demand, we assume that the firms chose to salvage a positive quantity of the intermediate good destined for the competitive market. The firms have quantities $Q^C_{e\mid e}$ and $\tilde{Q}^C_{e\mid e}$ on hand and they maximize the payoff:

$$\max_{q^C_{e\mid e}}\left(\left[a_l-\left(q^C_{e\mid e}+\tilde{q}^C_{e\mid e}\right)\right]q^C_{e\mid e}-s\left(Q^C_{e\mid e}-q^C_{e\mid e}\right)\right), \tag{EC33}$$

subject to

$$q^C_{e\mid e} \le Q^C_{e\mid e}.$$

Similarly, the other firm chooses quantities $\tilde{q}^C_{e\mid e}$ to maximize the payoff:

$$\max_{\tilde{q}^C_{e\mid e}}\left(\left[a_l-\left(q^C_{e\mid e}+\tilde{q}^C_{e\mid e}\right)\right]\tilde{q}^C_{e\mid e}-s\left(\tilde{Q}^C_{e\mid e}-\tilde{q}^C_{e\mid e}\right)\right), \tag{EC34}$$

subject to

$$\tilde{q}^C_{e\mid e} \le \tilde{Q}^C_{e\mid e}.$$

Solving the best responses obtained from the two objective functions obtained above we get

$$q^C_{e\mid e}=\tilde{q}^C_{e\mid e}=\frac{a_l+s}{3}. \tag{EC35}$$

The quantity salvaged, $q^s_{e\mid e}$ is given as $Q^C_{e\mid e}-q^C_{e\mid e}$.

Substituting the sales from above (EC35) in Equations (EC33) and (EC34) gives us the profits under low demand as function of the production quantities $Q^C_{e\mid e}$ and $\tilde{Q}^C_{e\mid e}$ $(\Pi^l_{e\mid e}(Q^C_{e\mid e}), \tilde{\Pi}^l_{e\mid e}(\tilde{Q}^C_{e\mid e}))$.

High Demand. Under high demand, we assume that the firms do not salvage; and early differentiating firms have no decisions to make at the distribution stage, thus $q^C_{e\mid e}=\tilde{q}^C_{e\mid e}=Q^C_{e\mid e}=\tilde{Q}^C_{e\mid e}$. The profits $\Pi^h_{e\mid e}$ and $\tilde{\Pi}^h_{e\mid e}$ are obtained by substituting this in Equations (EC33) and (EC34) (and replacing a_l by a_h).

Stage 1: Production

Given the above allocation decisions, the optimization problem facing the delayed-differentiating firm is

$$\max_{Q^C_{e\mid e}}\left\{p\Pi^h_{e\mid e}(\cdot)+(1-p)\Pi^l_{e\mid e}(\cdot)\right\}. \tag{EC36}$$

The other firm faces a symmetrical problem. Solving the two first-order conditions simultaneously, we get the optimal production quantities as

$$Q^C_{e\mid e}=\tilde{Q}^C_{e\mid e}=\frac{a_h+s}{3}-\frac{s}{3p}. \tag{EC37}$$

In addition, the firms also produce a quantity $a/2$ destined for the monopoly market and earn a profit $a^2/4$ from the monopoly market. The profits are obtained by substituting the obtained quantities ((EC35) and (EC37)) in (EC36) and adding the profit from the monopoly market ($a^2/4$). □

EC.6.1.2. The *d-e* Case

Lemma EC.6.2. *When one of the two firms employs early differentiation and the other employs delayed differentiation, the sales under low and high demand, the quantity salvaged, and the quantity of the intermediate good produced are given by Rows* 2 *and* 3 *of Table* EC.4.

Proof. We consider the problem as a two-stage dynamic game. We first compute the best choices in distribution stage as a function of the market demand (low or high demand) and production quantities. Next, we use the distribution equilibria to derive the production equilibria.

Under the *d-e* case, the decisions of the monopoly and the competitive market are separable for the early differentiating firm. Further, because the monopoly market has no uncertainty, the early differentiating firm produces and sells a quantity $a/2$ in its monopoly markets and earns a profit $a^2/4$ from this market. The early differentiating firm also produces a quantity differentiated for the competitive market ($Q^C_{e|d}$) at the production stage and may salvage some of it (under low demand) at the distribution stage. The delayed-differentiating firm produces a quantity $Q_{d|e}$, which may be sold in the monopoly market ($q^M_{d|e}$), or sold in the competitive market ($q^C_{d|e}$), or salvaged ($Q_{d|e} - q^C_{d|e} - q^M_{d|e}$).

Stage 2: Distribution

Low Demand. Under low demand, we assume that the firms chose to salvage a positive quantity of the intermediate good. The firms have quantities $Q^C_{e|d}$ and $Q_{d|e}$ on hand and they maximize the payoffs:

$$\max_{q^C_{d|e},\, q^M_{d|e}} \left(\left[a_l - \left(q^C_{d|e} + q^C_{e|d}\right)\right]q^C_{d|e} + \left[a - q^M_{d|e}\right]q^M_{d|e} - s\left(Q_{d|e} - q^C_{d|e} - q^M_{d|e}\right)\right), \tag{EC38}$$

subject to

$$q^C_{d|e} + q^M_{d|e} \le Q_{d|e}.$$

The early differentiating firm chooses quantities $q^C_{e|d}$ to maximize the payoff:

$$\max_{q^C_{e|d}} \left(\left[a_l - \left(q^C_{e|d} + q^C_{d|e}\right)\right]q^C_{e|d} - s\left(Q^C_{e|d} - q^C_{e|d}\right)\right), \tag{EC39}$$

subject to

$$q^C_{e|d} \le Q^C_{e|d}.$$

Solving the best responses obtained from the two objective functions above we get

$$\begin{aligned} q^C_{e|d} = q^C_{d|e} &= \frac{a_l + s}{3} \\ q^M_{d|e} &= \frac{a+s}{2}. \end{aligned} \tag{EC40}$$

The condition $s(1 + 24/p) < 9a_h - 10a_l$ ensures that under equilibrium production levels, the quantity salvaged is always positive. Substituting the sales from above (EC40) in Equations (EC38) and (EC39) gives us the profits under low demand as function of the production quantities $Q_{d|e}$ and $Q^C_{e|d}$ ($\Pi^l_{d|e}(Q_{d|e})$, $\Pi^l_{e|d}(Q^C_{e|d})$).

High Demand. Under high demand, we assume that the firms do not salvage. For the early differentiating there are no decisions to be made at this stage ($q^C_{e|d} = Q^C_{e|d}$). For the delayed-differentiating firm, the quantities sold as a function of the production are given by Equation (EC41). The ensuing profits (as a function of the quantities produced) are obtained by substituting (EC41) in (EC38) and (EC39) (and replacing a_l by a_h). We denote these profits as $\Pi^h_{d|e}$ and $\Pi^h_{e|d}$.

$$\begin{aligned} q^C_{d|e} &= \frac{Q_{d|e}}{2} + \frac{a_h - a - q^C_{e|d}}{4} \\ q^M_{d|e} &= \frac{Q_{d|e}}{2} - \frac{a_h - a - q^C_{e|d}}{4}. \end{aligned} \tag{EC41}$$

Stage 1: Production
Given the above allocation decisions, the optimization problem facing the delayed differentiating firm is

$$\max_{Q_{d|e}} \{p\Pi^h_{d|e}(\cdot) + (1-p)\Pi^l_{d|e}(\cdot)\}. \tag{EC42}$$

The other firm faces the maximization problem:

$$\max_{Q^C_{e|d}} \{p\Pi^h_{e|d}(\cdot) + (1-p)\Pi^l_{e|d}(\cdot)\}.$$

Solving the two first-order conditions simultaneously, we get the optimal production quantities as

$$\begin{aligned} Q_{d|e} &= \frac{5a+3a_h}{10} - \frac{8s(1-p)}{10p} \\ Q_{e|d} &= \frac{2(a_h p - (1-p)s)}{5p}. \end{aligned} \tag{EC43}$$

In addition, the early differentiating firm produces a quantity $a/2$ for the monopoly market and earns an additional profit of $a^2/4$.

Substituting the above production quantities (EC43) in the expressions from the distribution stage (EC41) gives us the quantities shipped to the monopoly and competitive market and the quantities salvaged. The profits are obtained by substituting the obtained quantities ((EC41) and (EC43)) in (EC42). For the early differentiating firm, we add the further term $a^2/4$. □

EC.6.1.3. The d-d Case

Lemma EC.6.3. *When the two firms employ delayed differentiation, the sales under high and low demand, the quantity salvaged, and the quantity of the intermediate good produced are given by Row* 4 *of Table* EC.4.

Proof. We consider the problem as a two-stage dynamic game. We first compute the best choices in distribution stage as a function of the market demand (low or high demand) and production quantities. Next, we use the distribution equilibria to derive the production equilibria. We let $\tilde{\bullet}$ denote the variables for the competitor.

Stage 2: Distribution

Low Demand. Under low demand, we assume that the firms chose to salvage a positive quantity of the intermediate good. The firms have quantities $Q_{d|d}$ and $\tilde{Q}_{d|d}$ on hand and they maximize the payoffs:

$$\max_{q^C_{d|d},\, q^M_{d|d}} \left([a_l - (q^c_{d|d} + \tilde{q}^c_{d|d})]q^c_{d|d} + [a - q^M_{d|d}]q^M_{d|d} - s(Q_{d|d} - q^C_{d|d} - q^M_{d|d})\right), \tag{EC44}$$

subject to

$$q^C_{d|d} + q^M_{d|d} \le Q_{d|d}.$$

Similarly, the other firm chooses quantities $\tilde{q}^c_{d|d}$, $\tilde{q}^M_{d|d}$ to maximize the payoff:

$$\max_{\tilde{q}^C_{d|d},\, \tilde{q}^M_{d|d}} \left([a_l - (q^c_{d|d} + \tilde{q}^c_{d|d})]\tilde{q}^c_{d|d} + [a - \tilde{q}^M_{d|d}]\tilde{q}^M_{d|d} - s(\tilde{Q}_{d|d} - \tilde{q}^C_{d|d} - \tilde{q}^M_{d|d})\right), \tag{EC45}$$

subject to

$$\tilde{q}^C_{d|d} + \tilde{q}^M_{d|d} \le \tilde{Q}_{d|d}.$$

Solving the best responses obtained from the two objective functions obtained above we get

$$\begin{aligned} q^C &= \tilde{q}^C = \frac{a_l + s}{3} \\ q^M &= \tilde{q}^M = \frac{a+s}{2}. \end{aligned} \tag{EC46}$$

The condition $s(1+(24/p)) < 9a_h - 10a_l$ ensures that under equilibrium production levels, the quantity salvaged is always positive. Substituting the sales from above in Equations (EC44) and (EC45) gives us the profits under low demand as function of the production quantities $Q_{d|d}$ and $\tilde{Q}_{d|d}$ ($\Pi^l_{d|d}(Q_{d|d})$, $\tilde{\Pi}^l_{d|d}(\tilde{Q}_{d|d})$).

High Demand. Under high demand, we assume that the firms do not salvage; the quantities sold as a function of the production are given by (EC47). The ensuing profits (as a function of quantity produced) are obtained by substituting (EC47) in Equations (EC44) and (EC45) (and replacing a_l by a_h).

$$q^C_{d|d}(Q_{d|d}, \tilde{Q}_{d|d}) = \frac{8Q_{d|d} - 2\tilde{Q}_{d|d} + 3(a_h - a)}{15}$$
$$q^M_{d|d}(Q_{d|d}, \tilde{Q}_{d|d}) = \frac{7Q_{d|d} + 2\tilde{Q}_{d|d} - 3(a_h - a)}{15}. \tag{EC47}$$

The expressions for the other firm are symmetrical.

Stage 1: Production
Given the above allocation decisions, the optimization problem facing the delayed differentiating firm is

$$\max_{Q_{d|d}} \{p\Pi^h_{d|d}(\cdot) + (1-p)\Pi^l_{d|d}(\cdot)\}. \tag{EC48}$$

The other firm faces a symmetrical problem. Solving the two first-order conditions simultaneously, we get the optimal production quantities as

$$Q_{d|d} = \tilde{Q}_{d|d} = \frac{a}{2} + \frac{32a_h p - 75s(1-p)}{86p}. \tag{EC49}$$

Substituting the above production quantity ((EC49)) in the expressions from the shipping stage ((EC46), (EC47)) gives us the quantities shipped to the monopoly and competitive market and the quantities salvaged. The profits are obtained by substituting the obtained quantities ((EC46), (EC47), and (EC49)) in (EC48). ☐

Proof for Figure 6. Figure 6 is obtained by comparing the profit expressions obtained by substituting the quantities from Table EC.4 (Table 8 in the main paper) in the objective functions provided in Lemmas EC.6.1, EC.6.2, and EC.6.3.

EC.6.2. Proof for Results in §7.2 (Alternative Market Structure)

EC.6.2.1. The *e-e* case

Lemma EC.6.4. *When the two firms employ early differentiation, the expected sales, quantity of the intermediate goods produced, and the revenues earned by the firms are given as follows*:

$$E[q^i_{e|e}] = q^i_{e|e} = \frac{\bar{a}_i}{3}; \qquad Q_{e|e} = \frac{\bar{a}_i + \bar{a}_j}{3}; \qquad E[\Pi_{e|e}] = \frac{\bar{a}_i^2 + \bar{a}_j^2}{9}.$$

Proof. There are no decisions to be made at the shipping stage (both firms employ early differentiation) and the decisions at the production stage for each market are separable from those for the other market (the firms produce customized goods). Thus, as before, the *e-e* case corresponds to the traditional Cournot setting in each of the two markets. ☐

EC.6.2.2. The *d-e* Case

Lemma EC.6.5. *When one of the two firms employs delayed differentiation and the other employs early differentiation, the expected sales, quantity of the intermediate good produced, and the revenues earned by the firms are given as follows*:

$$E[q^i_{d|e}] = \frac{7\bar{a}_i + \bar{a}_j}{24}; \qquad E[q^i_{e|d}] = \frac{5\bar{a}_i - \bar{a}_j}{12};$$
$$Q_{d|e} = Q_{e|d} = \frac{\bar{a}_i + \bar{a}_j}{3};$$
$$E[\Pi_{d|e}] = \frac{\bar{a}_i^2 + \bar{a}_j^2}{9} - \frac{7(\bar{a}_i - \bar{a}_j)^2}{288} + \frac{\mathrm{Var}(a_i - a_j)}{8};$$
$$E[\Pi_{e|d}] = \frac{\bar{a}_i^2 + \bar{a}_j^2}{9} + \frac{(\bar{a}_i - \bar{a}_j)^2}{144}.$$

Proof. We consider the problem as a two-stage dynamic game. We first compute the best choices in the distribution stage as a function of the market demand and the production quantities. Next, we use this distribution equilibrium to derive the production equilibrium.

Stage 2: Distribution

The Delayed-Differentiating Firm. The firm employing delayed differentiation has a quantity $Q_{d|e}$ on hand and chooses quantities $q^C_{d|e}$, $q^M_{d|e}$ to maximize its payoff.

$$\max_{q^i_{d|e},\, q^j_{d|e}} ([a^i - (q^i_{d|e} + q^i_{e|d})]q^i_{d|e} + [a^j - (q^j_{d|e} + q^j_{e|d})]q^j_{d|e}),$$

where the clearance strategy implies $q^i_{d|e} + q^j_{d|e} = Q_{d|e}$, and $q^i_{d|e}, q^j_{d|e} \geq 0$. Parameters of the demand curves (a^C, a^M) are known. The first-order condition for the payoffs gives us the best response below.

$$q^i_{d|e}(a^i, a^j; q^i_{e|d}, q^j_{e|d}, Q_{d|e}) = \frac{a_i - a_j + 2Q_{d|e} - q^i_{e|d} + q^j_{e|d}}{4}$$

$$q^j_{d|e}(a^i, a^j; q^i_{e|d}, q^j_{e|d}, Q_{d|e}) = Q - q^i_{d|e}(a^i, a^j; q^i_{e|d}, q^j_{e|d}, Q_{d|e}).$$

Note that the second-order condition for the above is trivially satisfied.

Early Differentiating Firm. The other firm employs early differentiation. Thus, there are no choices to be made for this firm at the distribution stage.

Stage 1: Production

Delayed-Differentiating Firm. Given the above allocation decisions, the optimization problem facing the delayed differentiating firm is

$$\max_{Q_{d|e}} \mathrm{E}[\{a^i - (q^i_{d|e}(\cdot) + q^i_{e|d})\}q^i_{d|e}(\cdot) + \{a^j - (q^j_{d|e}(\cdot) + q^j_{e|d})\}q^j_{d|e}(\cdot)],$$

where $q^{\cdot}_{d|e}(\cdot)$ refers to $q^{\cdot}_{d|e}(a^i, a^j; q^i_{e|d}, q^j_{e|d}, Q_{d|e})$.

Early Differentiating Firm. The firm employing early differentiation, faces the following optimization problem

$$\max_{q^i_{e|d},\, q^j_{e|d}} \mathrm{E}[[a^i - (q^i_{d|e} + q^i_{e|d})]q^i_{e|d} + [a^j - (q^j_{d|e} + q^j_{e|d})]q^j_{e|d}].$$

Taking expectations and simultaneously solving the first-order conditions for the two optimization problems above gives us following equilibrium production quantities:

$$Q_{d|e} = \frac{\bar{a}_i + \bar{a}_j}{3}$$

$$q^i_{e|d} = \frac{5\bar{a}_i - \bar{a}_j}{12}, \qquad q^j_{e|d} = \frac{5\bar{a}_j - \bar{a}_i}{12}.$$

Substituting the above two equations in the objective functions gives us the equilibrium profits

$$\mathrm{E}[\Pi_{d|e}] = \frac{\bar{a}_i^2 + \bar{a}_j^2}{9} - \frac{7(\bar{a}_i - \bar{a}_j)^2}{288} + \frac{\mathrm{Var}(a_i - a_j)}{8};$$

$$\mathrm{E}[\Pi_{e|d}] = \frac{\bar{a}_i^2 + \bar{a}_j^2}{9} + \frac{(\bar{a}_i - \bar{a}_j)^2}{144}. \quad \square$$

EC.6.2.3. The *d*-*d* Case

Lemma EC.6.6. *When the two firms employ delayed differentiation, the expected sales, quantity of the intermediate good produced, and the revenues earned by the firms are given as follows*:

$$\mathrm{E}[q^i_{d|d}] = \frac{\bar{a}_i}{3}; \qquad Q_{d|d} = \frac{\bar{a}_i + \bar{a}_j}{3}; \qquad \mathrm{E}[\Pi_{d|d}] = \frac{\bar{a}_i^2 + \bar{a}_j^2}{9} + \frac{\mathrm{Var}(a_i - a_j)}{18}.$$

Proof. We consider the problem as a two-stage dynamic game. We first compute the best choices in distribution stage as a function of the market demand and production quantities. Next, we use the distribution equilibria to derive the production equilibria.

Stage 2: Distribution
We let $\tilde{q}^i_{d|d}$ denote the quantity sold by the competitor in market i and $\tilde{Q}_{d|d}$ denote the competitor's production quantity. The firms have a quantity $Q_{d|d}$ on hand and face the optimization problem

$$\max_{q^i_{d|d},\, q^j_{d|d}} ([a^i - (q^i_{d|d} + \tilde{q}^i_{d|d})]q^i_{d|d} + [a^j - (q^j_{d|d} + \tilde{q}^j_{d|d})]q^j_{d|d}),$$

such that $q^i_{d|d} + q^j_{d|d} = Q_{d|d}, q^i_{d|d}, q^j_{d|d} \geq 0$. Parameters of the demand curves (a^i, a^j) are known. The other firm faces a symmetric optimization problem.

Simultaneously solving the first-order conditions for the two firms optimization problem gives us

$$q^i_{d|d}(a^i, a^j, Q_{d|d}) = \frac{a_i - a_j + 3Q_{d|d}}{6}.$$

The expressions for $\tilde{q}^i_{d|d}$ is symmetric. The second-order condition is trivially satisfied.

Stage 1: Production
Given the above allocation decisions, the optimization problem facing the delayed-differentiating firm is

$$\max_{Q_{d|d}} \mathrm{E}[\{a^i - (q^i_{d|d}(\cdot) + \tilde{q}^i_{d|d}(\cdot))\}q^i_{d|d}(\cdot) + \{a^j - (q^j_{d|d}(\cdot) + \tilde{q}^j_{d|d}(\cdot))\}q^j_{d|d}(\cdot)],$$

where $q^{\cdot}_{d|d}(\cdot)$ refers to $q^{\cdot}_{d|d}(a^i, a^j; Q_{d|d})$.[EC4] The other firm faces a symmetric decision problem.

Solving the equations in (EC15) gives us the equilibrium production levels as

$$\tilde{Q}_{d|d} = Q_{d|d} = \frac{\bar{a}_i + \bar{a}_j}{3}.$$

Substituting the above production level in the objective function and the distribution decisions we get the required results. □

Proof for Table 9. Table 9 follows directly from Lemmas EC.6.4, EC.6.5, and EC.6.6.

Proof for Theorem 7.1. Theorem 7.1 follows directly by comparing the profits in Lemmas EC.6.4, EC.6.5, and EC.6.6.

EC.7. Proof for Results in Part 1

Theorem (Equilibrium Characterization Under Endogenous Reconfiguration Costs).

(1) *Delayed differentiation is a* dominated *strategy for high enough values of the demand correlation and low coefficients of variation, specified mathematically by the condition* $\rho \gtrsim 1 - (0.091/\gamma^2)$. *The precise technical result (derived below) is that the optimal* $\theta_i > 0$ *iff* $\rho > 1 - (1/\gamma^2)g(\theta_j)$, *where the polynomial* $g(\theta_j) \in [3{,}209{,}625/35{,}142{,}094, 12/125] \equiv [0.091, 0.096]$. *A symmetrical condition applies for* θ_j. *Thus the equilibrium (fixed point)* (θ_i^*, θ_j^*) *derived from the optimal-reaction functions is bounded away from* $(0, 0)$ *when* $\rho \gtrsim 1 - 0.091/\gamma^2$.

(2) *The equilibrium choices of* θ_i *and* θ_j *increase with* ρ *and decrease with* γ.

Proof. When firms may choose from a continuum of configuration choices, the firms essentially solve a three-stage game. In the first stage, the firms choose the quantity of intermediate good they reconfigure from the competitive market to the monopoly market, as a function of the on-hand quantities of intermediate goods and the employed configuration (parametrized by θ). Then, the firms choose the quantity of intermediate goods to produce as a function of θ. Finally, firms choose θ.

In the distribution stage, the firms choose q_i^r to maximize the payoff in

$$\max_{q_i^r} \Big\{\big[a^C - (Q_i^C - q_i^r) - (Q_j^C - q_j^r)\big](Q_i^C - q_i^r) + \big[a^M - (Q_i^M + q_i^r)\big](Q_i^M + q_i^r) - \theta_i (q_i^r)^2\Big\}. \tag{EC50}$$

[EC4] Note that the allocation to each market does not depend on the competition's production, reflecting the fact that neither firm has any strategic advantage.

The other firm maximizes a similar expression. Solving the first-order conditions simultaneously gives us

$$q_i^r = \frac{7Q_i^C + 2Q_j^C - 8Q_i^M + 2Q_j^M + 4\theta_j Q_i^C + 2\theta_j Q_j^C - 4\theta_j Q_i^M + (a^M - a^C)(3 + 2\theta_j)}{15 + 8\theta_j + 4\theta_i(2 + \theta_i)}.$$

Substituting q_i^r and q_j^r in the profit expressions of (EC50), taking the expectation using (EC1), and then differentiating with respect to $Q_\cdot^C$ and $Q_\cdot^M$ gives us four simultaneous first-order conditions to solve. Substituting the obtained solutions for $Q_\cdot^C$ and $Q_\cdot^M$ back into the expressions of (EC50), gives us the profits as a function of the θ denoted as $\Pi_i(\theta_i, \theta_j)$.

(1) To prove that delayed differentiation ($\theta_i = 0$) is a dominated strategy we show that

$$\left.\frac{\partial(\Pi_i(\theta_i, \theta_j))}{\partial \theta_i}\right|_{\theta_i = 0} > 0 \quad \forall \theta_j. \tag{EC51}$$

In other words, the firm can always find a profitable deviation from $\theta_i = 0$, for all values of θ_j. The denominator of the expression in (EC51) is always positive and the numerator is given as $\bar{a}^2 g_1(\theta_j) + \hat{a}(-1+\rho) g_2(\theta_j)$, where

$$g_1(\theta_j) = (15 + 8\theta_j)^3(1{,}446{,}471 + 5{,}010{,}460\theta_j + 7{,}180{,}476\theta_j^2 + 5{,}456{,}544\theta_j^3 + 2{,}321{,}024\theta_j^4 + 524{,}288\theta_j^5 + 49{,}152\theta_j^6)$$

$$g_2(\theta_j) = 2(3 + 2\theta_j)^2(17 + 8\theta_j)(559 + 600\theta_j + 160\theta_j^2)^3.$$

This leads to the condition $\rho > 1 - (1/\gamma^2)(g_1(\theta_j)/g_2(\theta_j))$. The polynomial $g(\theta_j) = (g_1(\theta_j)/g_2(\theta_j)) \in [0.091, 0.096]$. The result now follows.

(2) To prove statement 2 of Theorem 7.1 we need to show $(\partial^2 \Pi_i(\theta_i, \theta_j)/\partial\rho\partial\theta_i) > 0$ and $(\partial^2 \Pi_i(\theta_i, \theta_j)/\partial\gamma\partial\theta_i) < 0$ (standard comparative statics analysis)

$$\frac{\partial^2 \Pi_i(\theta_i, \theta_j)}{\partial\rho\,\partial\theta_i} = \frac{(2(3 + 2\theta_j)^2(17 + 8\theta_j + 4\theta_i(2 + \theta_j)))\hat{a}}{(15 + 8\theta_j + 4\theta_i(2 + \theta_j))^3} > 0,$$

$$\frac{\partial^2 \Pi_i(\theta_i, \theta_j)}{\partial\gamma\,\partial\theta_i} = \frac{(2(3 + 2\theta_j)^2(17 + 8\theta_j + 4\theta_i(2 + \theta_j)))\bar{a}^2(-1+\rho)}{(15 + 8\theta_j + 4\theta_i(2 + \theta_j))^3} < 0.$$

The results now follow. □