The Value of Fast Fashion: Rapid Production, Enhanced Design, and Strategic Consumer Behavior

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Abstract

A fast fashion system combines rapid production capabilities with enhanced product design capabilities, to both design “hot” products that capture the latest consumer trends and exploit minimal production leadtimes to match supply with uncertain demand. We develop a model of such a system, and compare its performance to three alternative systems: rapid production-only systems, enhanced design-only systems, and traditional systems (which lack both enhanced design and rapid production capabilities). In particular, we focus on the impact of each of the four systems on “strategic” or forward-looking customer purchasing behavior, i.e., the intentional delay in purchasing an item at the full price to obtain it during an end-of-season clearance. We find that enhanced design helps to mitigate strategic behavior by offering consumers a product they value more, making them less willing to risk waiting for a clearance sale and possibly experiencing a stock-out. Rapid production, on the other hand, mitigates strategic behavior by reducing the chance of a clearance sale via better matching of inventory to product demand. Most importantly, we find that these two practices are typically complementary. Hence, when both rapid production and enhanced design are combined in a fast fashion system, the firm enjoys a greater incremental increase in profit than the sum of the increases resulting from employing either system in isolation, roughly by a factor of two in our numerical experiments. Furthermore, the magnitude of this complementarity is increasing in the severity of strategic consumer behavior—that is, the more “strategic” the population, the more dramatic the complementarity. We conclude that fast fashion systems can be of significant value, particularly when consumers exhibit strategic behavior.

1 Introduction

Firms in the fashion apparel industry—such as Zara, H&M, and Benetton—have increasingly embraced the philosophy of “fast fashion” retailing (Passariello 2008, Rohwedder and Johnson 2008). Generally speaking, a fast fashion system combines at least two components:

1. Short production and distribution leadtimes, enabling a close matching of supply with uncertain demand.
2. Highly fashionable (“trendy”) product design.

Short leadtimes are enabled through a combination of localized production, sophisticated information systems that facilitate frequent inventory monitoring and replenishment, and expedited distribution methods. For example, Zara, primarily a European retailer, produces the majority of its designs in costly European and North African factories (rather than outsourcing to less expensive Asian facilities), and continuously monitors inventory levels in stores to effectively match supply and demand (Ghemawat and Nueno 2003, Ferdows et al. 2004). The second component (trendy product design) is made possible by carefully monitoring consumer and industry tastes for unexpected fads and reducing design leadtimes. Benetton, for example, employs a network of “trend-spotters” and designers throughout Europe and Asia, and also pays close attention to seasonal fashion shows in Europe (Meichtry 2007).¹

From an operational perspective, production and distribution leadtime reduction strategies have been relatively well studied, and are known to yield significant value to firms by better matching supply and demand (see the literature on quick response, e.g., Fisher and Raman 1996, Eppen and Iyer 1997, Caro and Martínez-de-Albéniz 2007, Caro and Gallien 2008) and by influencing consumer purchasing behavior by reducing the frequency and severity of season-ending clearance sales (Cachon and Swinney 2009). However, the second component of fast fashion systems—creating trendy, highly fashionable products—has received far less attention. Indeed, despite the intense recent interest in leadtime reduction, Meichtry (2007) describes how some firms are attempting to focus on design and develop trendier products without reducing their production leadtimes, due to the difficulties (both logistical and cultural) that can accompany drastically redesigning the supply network.

In this paper, we develop a framework that allows us to address the value of this strategy, which we call *enhanced design*, and subsequently to consider the impact of combining both production leadtime reduction and enhanced design in a fast fashion system. We postulate that, all else being equal, enhanced design capabilities result in products that are of greater value to consumers and hence elicit a greater willingness-to-pay. Consequently, firms may exploit this greater willingness-to-pay by charging higher prices on “trendy” products than on more conservative prod-

¹There are other aspects of fast fashion systems that we do not consider, notably frequent changes in product assortment.
ucts. Enhanced design capabilities are costly, however: there are typically fixed costs (a large design staff, trend-spotters, rapid prototyping capabilities, etc.) and there may be greater variable costs (e.g., because of more labor-intensive production processes or costly local labor). Thus, as with any operational strategy, firms considering enhanced design must trade off the benefits of the strategy (greater consumer willingness-to-pay) with the costs (fixed and variable).

A central issue that we address is the impact of enhanced design and rapid production on consumer purchasing behavior. Particularly in the fashion apparel industry, the propensity of consumers to anticipate future markdowns and intentionally delay purchasing until a sale occurs is a well documented and widespread problem (Rozhon 2004). This behavior erodes retailer margins and can drastically reduce profitability. Fast fashion systems have frequently been cited as an effective tool for retailers to combat such “strategic” customer behavior (see, e.g., Ghemawat and Nueno 2003). Such systems, we demonstrate, decrease consumer incentives to wait for markdowns in two ways. The rapid production component of fast fashion reduces the chance that a markdown will occur (because rapid production more closely matches supply and demand and hence decreases the probability of excess inventory necessitating markdowns–see Cachon and Swinney 2009). Enhanced product design, on the other hand, gives customers a trendier product that they value more, making them less willing to risk waiting for a sale if there is any chance that the item will stock out. Thus, while rapid production decreases the expected future utility of waiting for a price reduction, enhanced design increases the immediate utility of buying the product at the full price.

Because both components of fast fashion independently serve to reduce consumer incentives to strategically wait for markdowns, this logic may lead one to conclude that these two practices are substitutes—implementing one practice diminishes the marginal worth of the other. If true, this fact would have important consequences for the profitability of fast fashion systems versus alternative systems (e.g., a system with only rapid production or enhanced design, but not both), and may imply that the efforts of firms described by Meichtry (2007) to focus on implementing only one aspect of fast fashion are prudent. Consequently, a primary goal of our analysis is to consider precisely this question: are rapid production and enhanced product design substitutes?

We find that, while it is possible for these two practices to be substitutes, the opposite result is much more likely—under fairly general conditions, the two practices are complements. That is, pos-
sessing rapid production increases the total incremental value of enhanced design capabilities, and possessing enhanced design increases the incremental value of rapid production capabilities. Thus, when employing both strategies in a fast fashion system, the firm typically enjoys a superadditive increase in profit relative to employing the strategies in isolation. Furthermore, via numerical experiments we show that the magnitude of this complementarity effect is generally increasing in the severity of strategic behavior exhibited by the customer population; that is, the more strategic the consumer base, the more dramatic the superadditivity effect. These results help to demonstrate that, while it may be tempting for retailers to only invest in one aspect of fast fashion (either rapid production or enhanced design), there is less value in doing so than in pursuing both strategies together—potentially far less value, if consumers are highly strategic.

The remainder of this paper is organized as follows. §2 reviews the relevant literature, while §3 describes a basic model and analyzes a system with neither rapid production nor enhanced design. §§4–5 discuss the impact of employing rapid production and enhanced design in isolation, and §§6–7 consider the combination of both components in a fast fashion system. §8 reports the results of an extensive numerical study, and §9 concludes the paper with a discussion of the results.

2 Literature Review

There are two primary streams of research that relate to our analysis: the literature on operational flexibility with non-strategic customers (in particular, quick response and postponement practices) and the literature on strategic consumer purchasing behavior. Quick response has received a large amount of attention—see, e.g., Fisher and Raman (1996), Eppen and Iyer (1997), Iyer and Bergen (1997), Fisher et al. (2001), and the Sport Obermeyer case study by Hammond and Raman (1994). Each of these works describes the benefit of reducing supply-demand mismatches by providing the firm with an option to procure inventory after learning updated demand information. More recent works, such as Li and Ha (2008) and Caro and Martínez-de-Albéniz (2007), address the impact of competition on quick response inventory practices. Postponement—the practice of delaying final assembly—also seeks to provide higher product availability with a lower inventory investment; see Lee and Tang (1997), Feitzinger and Lee (1997), Goyal and Netessine (2007), and Anand and Girotra (2007). The distinction between postponement and enhanced design is one of degree.
Postponement creates variants from a base model (e.g., different color panels for the same phone) whereas enhanced design creates significantly different product variants from component inventory (e.g., a skirt or dress slacks from the same material). Neither the papers on quick response nor postponement analytically address the impact of rapid production or enhanced design on strategic consumer behavior.

The issue of strategic (or rational) customer purchasing behavior dates to Coase (1972) and the theory of durable goods pricing in monopolies. The Coase Conjecture, which was described informally by Coase (1972) and formalized by Stokey (1981) and Bulow (1982), states that in the face of infinitely patient consumers, a monopolist can charge a price no higher than marginal cost, as consumers will patiently wait as long as possible for the price to be reduced to its lowest level.

More recently, a stream of research has emerged that explores the role of supply and demand mismatch in influencing strategic consumer purchasing behavior. Liu and van Ryzin (2008) show that a firm may wish to understock to generate shortages when prices decline over time and consumers may strategically wait for the sale. Aviv and Pazgal (2008) examine the value of dynamic and static pricing schemes in a revenue management setting with stochastically arriving strategic customers. Yin et al. (2009) consider the impact of in-store display formats (e.g., displaying all units or displaying one unit to limit consumer information about inventory availability) on the consumer incentive to strategically delay purchasing. Su and Zhang (2008) show that when the sale price is exogenously set, the firm reduces inventory and sets a lower full price in order to induce strategic consumers to purchase at the full price. Other aspects of the strategic consumer purchasing problem that have been addressed include: availability guarantees in Su and Zhang (2009), product returns in Su (2009), and consumer stockpiling in Su (2007). While many of these papers consider the inventory decision of the firm, none address the interaction of rapid production, enhanced design, or fast fashion systems with consumer purchasing.

Cachon and Swinney (2009) and Swinney (2009) do address the impact of quick response on strategic consumer purchasing. Cachon and Swinney (2009) show that the presence of strategic consumers can enhance the value of quick response beyond just matching supply with demand - adopting quick response reduces the likelihood of deep discounts, which makes strategic consumers more willing to purchase at the regular price. In Swinney (2009), the impact of quick response in markets where consumers learn about product value over time is explored, and it is shown that
quick response may decrease or increase the firm’s profit, depending on characteristics of the selling environment (e.g., whether consumer returns are allowed or whether the firm prices dynamically). Unlike the present analysis, these papers do not address the impact of enhanced design on consumer purchasing behavior nor the interaction between enhanced design and rapid production to generate a fast fashion retail system.

3 The Traditional System

To stimulate our analysis of the incremental value of the components of a fast fashion system, we analyze a total of four potential operational systems. A traditional system, abbreviated T, represents a typical retailer with long design leadtimes and standard product design abilities. As we will reveal below, this system most closely resembles a newsvendor model. A rapid production system, abbreviated P, does not employ enhanced design capabilities, but does yield significantly reduced production leadtimes. This system most closely resembles a quick response model. An enhanced design system, abbreviated D, employs enhanced design capabilities (and hence greater consumer willingness-to-pay) but maintains long production leadtimes—this system resembles the efforts described by Meichtry (2007) to focus on product design while avoiding the kind of radical supply chain overall necessary to achieve leadtime reduction. Finally, a fast fashion system, abbreviated F, employs both rapid production and enhanced design capabilities. The fast fashion system resembles the mode of operations increasingly found in retailers such as Zara, Benetton, and H&M. The characteristics of these systems are summarized in Table 1.

One could argue that short production leadtimes should increase the efficacy of creating trendy products by allowing designs to be finalized closer to the selling season. For example, many traditional fashion retailers (such as Gap) have average design and production leadtimes on the order of six to twelve months. If these firms intensified their product design efforts without reducing production leadtimes, while they may be able to generate better products overall, they would still
have to make final design decisions months in advance of the selling season (and consequently well in advance of the revelation of any unexpected trends). On the other hand, a fast fashion firm has dramatically shorter design-to-shelf leadtimes—in some cases, on the order of weeks—and so such firms can observe and replicate trends practically in real time. Thus, enhanced design efforts presumably result in an even greater increase in consumer willingness-to-pay if the firm simultaneously achieves leadtime reduction. We take a conservative approach on this issue: we assume that adopting enhanced design capabilities results in an identical increase in consumer willingness-to-pay regardless of the production leadtime of the firm. In other words, we do not assume, ex ante, that any complementarity exists between enhanced design efforts and rapid production capabilities—we discuss the impact of this assumption in the conclusion of the paper.

In each possible system depicted in Table 1, we analyze a game between a firm and its consumers. The firm chooses the selling price and the inventory level, while consumers choose whether to buy at the full price or wait for a potential clearance sale (running the risk that the product might run out). In this section, we introduce the basic model and analyze the case of the traditional system—that is, a system possessing neither rapid production nor enhanced design. As such, inventory decisions are finalized in advance of learning total market size and product design efforts result in (relatively) low consumer valuations. This model will serve as a base case, upon which we will expand to analyze the three alternative systems. We first describe the details of the model, then proceed with the analysis.

3.1 The Model

A single firm sells a single product over a finite season. The market is characterized by demand uncertainty: consequently, the total number of consumers in the market is stochastic and denoted by the continuous random variable $N$ with distribution $F(\cdot)$ and mean $\mu$. We assume that consumers have homogenous value $v$ for the product.

The product is sold over a single season. Prior to the start of the selling season (and prior to learning market size), the firm makes an inventory procurement $q$ at unit cost $c$, and sets a selling price, $p$, to maximize expected profit. At the end of the season, all remaining inventory is cleared at an exogenous salvage or “sale” price $s$, where $s < c$.\footnote{Su and Zhang (2008) also assume that the clearance price $s$ is exogenous and common knowledge (e.g., it may be}
Customers are strategic to the extent that they are forward-looking: they recognize that the product will eventually be reduced in price (to \( s \), the salvage price) and consider delaying their purchase until the price is lowered. Customers discount future consumption at a rate \( \delta \in [0, 1] \). By delaying a purchase until the clearance sale, customers lose out on some consumptive value, and hence their future utility is reduced to reflect this loss. In addition, \( \delta \) may be thought of as the level of strategic behavior or patience of the customer population (higher \( \delta \) implies more patient or strategic consumers) or as a proxy for the durability of the good (higher \( \delta \) implies a more durable good with greater future value).

All consumers arrive at the firm at the start of the selling season. After observing the selling price \( p \), each consumer individually chooses to either purchase the product immediately at price \( p \) or delay her purchase until the clearance sale. When making this decision, consumers take into account their surplus from an immediate purchase (a function of valuation and price) and their expected surplus from a delayed purchase, which incorporates the clearance price \( s \), the discount factor \( \delta \), and the perceived probability of obtaining a unit, which we label \( \phi \). The surplus of an immediate purchase at price \( p \) is

\[
v - p,
\]

while the expected surplus of a delayed purchase at the clearance price is

\[
\delta \phi (v - s).
\]

Consumers subsequently choose to purchase at the price that yields greater expected surplus, and we assume that if consumers are indifferent between the two actions, then they purchase at the full price \( p \). The sequence of events is depicted in Figure 1.

Strategic consumers who choose to delay their purchase are “first in line” in the salvage market—that is, while the firm may dispose of an infinite amount of inventory on the salvage market (implying infinite demand), strategic customers are allocated remaining inventory first, followed by demand from the salvage market. Such an assumption is reasonable: customers who considered a
purchase at the full price and chose to strategically delay until a sale are likely to monitor prices frequently and move quickly once a sale occurs.\(^3\)

Finally, we note here that we do not consider any fixed costs resulting from the implementation of any system (though we will account for increases in variable costs resulting from rapid production or enhanced design). Indeed, fixed costs can be significant, particularly in the form of physical infrastructure (factory, warehouse, and distribution systems) and information systems. Directionally, the impact of such fixed costs are clear. For expository clarity, we omit these costs from our discussion, with the understanding that evaluating fixed costs is an important component of understanding the value of any system.

### 3.2 Equilibrium Inventory and Pricing

To explore the value of the traditional system (and each of the subsequent systems), we analyze a game between the forward-looking customer population and the firm: consumers choose *when to buy* the product (at the full price or at the discounted price) and the firm chooses *how much inventory* to stock and *what price* to charge. Hence, it will be necessary to define the equilibrium concept that we employ. We assume that consumers do *not* directly observe the total inventory of the firm before making their decisions,\(^4\) and consequently the firm cannot credibly convey inventory

\(^3\)This allocation rule is also adopted by Su and Zhang (2008). A more general allocation mechanism in the salvage stage—e.g., random arrivals of strategic customers and customers from the exogenous salvage market, discussed in Cachon and Swinney (2009)—merely reduces the probability that a consumer receives a unit at the salvage price and is unlikely to qualitatively change the results.

\(^4\)Consumers may be incapable of directly observing inventory in a variety of situations, including: if the firm is an online retailer; if the firm stocks a particular retail location from a centralized warehouse; or if the firm displays
information to consumers (i.e., the firm is not a leader in a sequential game). Thus, we seek Nash equilibria in a simultaneous decision game between an infinite number of players: the firm and a continuum of (identical) consumers.

We note that because consumers are homogeneous, there are two potential equilibrium candidates: either all consumers purchase at price $p$ or all consumers purchase at price $s$. However, all consumers purchasing at price $s$ is not supportable as an equilibrium due to the fact that $s < c$–the firm would be better off not producing any inventory, resulting in market failure (zero production and zero social welfare). Thus, we are left to derive an equilibrium in which all consumers purchase early. In such an equilibrium, the firm’s expected profit as a function of the price $p$ and quantity $q$ is

$$\pi_T(q, p) = E((p - s) \min(q, N) - (c - s) q),$$

where the expectation operator $E$ is taken over market size, $N$. We introduce the following notation, which we will use throughout the analysis: let $(x)^+ = \max(x, 0)$, let $L(q) = E(N - q)^+$ be the expected lost sales (excess demand above $q$) and let $I(q) = E(q - N)^+$ be the expected leftover inventory (excess inventory above $N$ that is cleared at the sale price $s$). Then, the firm’s profit function may be written

$$\pi_T(q, p) = (p - c) \mu - (p - c) L(q) - (c - s) I(q). \quad (1)$$

Our model of the traditional system is similar to the model analyzed by Su and Zhang (2008), with two differences: consumers discount future consumption by an arbitrary amount, and product-consumer mismatches are incurred (via the mismatch cost) in addition to supply-demand mismatches. These differences result in slightly more complicated expressions for equilibrium price and inventory levels than those derived in Su and Zhang (2008), but nevertheless the equilibrium analysis is qualitatively similar to our own: in equilibrium, all consumers choose to purchase early at the higher price, while the firm sets a lower price and a lower inventory level than it would with non-strategic customers (i.e., if $\delta = 0$) in order to induce consumers to buy at the full price. The following lemma summarizes the equilibrium.

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*a limited amount of inventory on the store floor.*
Lemma 1 In a traditional system, an equilibrium with non-zero production exists and is unique. In equilibrium, all consumers purchase early. The equilibrium full price is

\[ p^*_T = \frac{A + \sqrt{A^2 - 4B}}{2}, \]

where \( A = v (1 - \delta) + (1 + \delta) s \) and \( B = sv - \delta c (v - s) \).

Proof. The profit function in (1) is the familiar newsvendor formula yielding an optimal inventory level (given a price \( p \)) satisfying \( F(q) = (p - c) / (p - s) \). This equilibrium is viable if consumers have incentive to purchase early,

\[ v - p \geq \delta \phi (v - s), \tag{2} \]

if the firm chooses the optimal inventory level, \( F(q^*_T) = (p - c) / (p - s) \), and if expectations of consumers are rational, \( \phi = F(q^*_T) \). When choosing the price \( p \), the firm maximizes its profit by selecting the highest price that satisfies (2), which implies the optimal pricing policy is to set a full price equal to \( p^*_T = v - \delta \phi (v - s) \). Combining this expression with the \( \phi = F(q^*_T) \) requirement yields

\[ p^*_T = v - \delta \frac{p^*_T - c}{p^*_T - s} (v - s). \]

Simplifying this expression, and defining \( A \) and \( B \) as above, yields

\[ p^*_T = \frac{A \pm \sqrt{A^2 - 4B}}{2}. \]

The lower candidate equilibrium sale price results in \( p^*_T < c \), and hence is unsupportable; thus, a unique equilibrium exists which satisfies the conditions in the lemma. □

It is clear that the equilibrium price \( p^*_T \) is increasing in product value, marginal production cost and salvage value (\( v, c, \) and \( s \)), and decreasing in the consumer discount factor (\( \delta \)). Here, we note our first intuitive result: the greater the severity of strategic customer behavior (i.e., the less consumers discount future consumption and the greater \( \delta \)), the lower the firm must set the selling price in order to induce consumers to purchase at the full price. In particular, when \( \delta = 0 \), consumers are completely myopic; in this case, \( p^*_T = v \), i.e., the firm extracts all surplus from consumers. For any greater \( \delta \), \( p^*_T < v \), and the firm leaves some surplus with consumers in order
to discourage customers from strategically waiting for the sale.

4 Rapid Production

In the rapid production system, the design abilities are standard while the production phase is fast—hence, while the product design process results in lower value products for consumers, the inventory may be procured after learning total market size ($N$). To model rapid production, we adopt the quick response framework (see, e.g., Cachon and Swinney 2009, Fisher and Raman 1996, and Eppen and Iyer 1997). Following this literature, we assume that the firm can procure inventory both before and after receiving a forecast update prior to the start of the selling season. The forecast update is perfectly informative (i.e., reveals the actual demand level) and production is fast enough that all units arrive before the start of the selling season. Inventory procured prior to learning demand information is obtained for a low cost ($c$, just as in the traditional system in the preceding section), while additional inventory procured after learning the realized value of market size incurs an additional cost $c_P \geq 0$ due to expedited manufacturing and shipping expenses. The sequence of events is depicted in Figure 2.

When making the inventory procurement following the realization of demand information, it is easy to see that as long as the margin on each unit ($p - c - c_P$) is positive, the optimal action of the firm is to produce precisely enough inventory to cover all full price demand. The following lemma uses this fact to derive the equilibrium to the game between forward-looking consumers and a firm.
with rapid production capabilities.

**Lemma 2** In a rapid production system, an equilibrium with non-zero production exists and is unique. In equilibrium, all consumers purchase early. The equilibrium full price is

\[ p^*_P = v - \delta \frac{c_P}{c + c_P - s} (v - s), \]  

(3)

if \( p^*_P \geq c + c_p \), while if \( p^*_P < c + c_p \), the equilibrium is identical to the traditional system.

**Proof.** By the same logic from Lemma 1, the only possible candidate equilibrium is one in which all consumers attempt to purchase at the full price. Suppose \( p \geq c + c_p \). In such an equilibrium, the firm’s expected profit with rapid production as a function of the initial inventory procurement \( q \) and price \( p \) is

\[ \pi_P (q, p) = (p - c) \mu - c_P L(q) - (c - s) I(q). \]

This function is concave in \( q \), and the unique optimal inventory level is given by

\[ q^*_P = F^{-1} \left( \frac{c_P}{c + c_P - s} \right). \]

Note that this quantity is independent of the selling price. Recall that consumers purchase early if

\[ v - p \geq \delta \phi (v - s). \]  

(4)

If the firm behaves optimally and if consumer expectations are rational, then \( \phi = F(q^*_P) = c_P / (c + c_P - s) \). Hence, the maximum price that induces consumers to purchase prior to the sale by making (4) hold with equality is given by (3). Alternatively, if \( p < c + c_p \), the firm will never use the option to procure additional inventory, meaning the profit function and equilibrium analysis reduce to that analyzed in Lemma 1. 

How does the equilibrium price in the rapid production system compare to that in the traditional system? Because, in the second procurement opportunity, the firm produces precisely enough inventory to cover all demand, sales only occur at the salvage price if the firm procures more inventory than the total demand during the initial (low-cost) purchase opportunity. Intuitively, by having the option to procure additional inventory at a later date, we expect that the firm will
procure less inventory in the initial buy than in the traditional system. By virtue of procuring less inventory in the initial buy, the probability of remaining inventory during the salvage season is reduced, resulting in (from the consumer’s point of view) a lower probability of successfully obtaining a unit at the sale price and hence, decreased incentives to wait for the discounted price. In turn, this should allow the firm to charge a higher full price while maintaining an equilibrium in which (as we saw in the traditional system) all consumers attempt to purchase at the full price. Indeed, this intuition turns out to be correct, provided the extra cost of rapid production ($c_P$) is not too high, as the following lemma summarizes:

**Lemma 3** The equilibrium price is greater in the rapid production system than in the traditional system ($p^*_P > p^*_T$) if and only if $c_P < p^*_T - c$.

**Proof.** By observing the expressions for the equilibrium prices, note that the price is higher in the $P$ system than the $T$ system if and only if the probability that a customer obtains a unit at the sale price ($\phi$) is lower in the $P$ system. This happens if

$$\frac{c_P}{c + c_P - s} < \frac{p^*_T - c}{p^*_T - s}.$$  

Rearranging the terms, this reduces to $c_P < p^*_T - c$.  

Note that the lemma shows $p^*_P - c - c_P > 0$ implies $p^*_P > p^*_T$. Thus, any rapid production system that yields a positive margin on a unit in the second procurement also yields an equilibrium price increase. Rapid production clearly provides value by matching supply with demand (eliminating lost sales)–Lemma 3 demonstrates that when the cost of rapid production is not too high, value is also added by reducing consumer incentives to wait for the sale and subsequently increasing the equilibrium selling price. Thus, when $c_P < p^*_T - c$, a rapid production system yields higher profit to the firm than a traditional system.

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5 This is a similar, but complementary, result to that derived in Cachon and Swinney (2009). In that paper, rapid production (referred to as quick response) provides value by influencing the firm’s dynamic sale pricing decisions during the selling season; here, the sale price is exogenously fixed, and rapid production provides value by influencing the firm’s initial pricing decision at the start of the season.
5 Enhanced Design

In the enhanced design system, the production leadtimes are long but the firm invests in improved design efforts that result in greater value to consumers. Thus, we assume that enhanced design results in a marginal increase of \( m \geq 0 \) to consumer value, that is, consumers possess valuations equal to \( v + m \) for products resulting from enhanced design efforts.

As discussed above, enhanced design may well comprise additional fixed costs as well as additional variable costs. As with the rapid production system, we will effectively ignore fixed costs, as they have a clear directional impact on firm profit. We will, however, incorporate (potential) changes in variable costs: when operating with enhanced design capabilities, every unit produced incurs an additional cost \( c_D \geq 0 \). The sequence of events is identical to that depicted in Figure 1.

Due to the similarity in the sequence of events, the analysis of the enhanced design system is comparable to that of the traditional system. Indeed, the two systems are identical save for the fact that in the enhanced design system, consumer valuations are equal to \( v + m \) and an additional cost of \( c_D \) is incurred on every unit. Thus, the following lemma follows immediately from Lemma 1 by incorporating these facts.

**Lemma 4** In an enhanced design system, an equilibrium with non-zero production exists and is unique. In equilibrium, all consumers purchase early. The equilibrium full price is

\[
p_D^* = \frac{C + \sqrt{C^2 - 4D}}{2},
\]

where \( C = (v + m)(1 - \delta) + (1 + \delta)s \) and \( D = s(v + m) - \delta(c + c_D)(v + m - s) \).

Note that \( p_D^* \) is increasing in \( m \) and \( c_D \) while the behavior of \( p_T^* \) as a function of the other parameters is identical to the behavior of \( p_T^* \). Hence, because the traditional system is equivalent to the enhanced design system with \( m = c_D = 0 \), it follows that \( p_D^* > p_T^* \), which we formally state in the following lemma:

**Lemma 5** The equilibrium price is greater in the enhanced design system than in the traditional system \( (p_D^* > p_T^*) \).

In other words, a enhanced design system gives consumers a product that they value more
and which costs more to produce, both of which credibly serve to raise the equilibrium expected selling price.\(^6\) Although the price is higher with the enhanced design system, the equilibrium consumer action remains the same as the traditional system: all customers purchase at the full price rather than wait for the sale. Thus, the firm can exploit enhanced design capabilities to raise prices without increasing strategic waiting, which is clearly beneficial to the firm if the increase in costs \((c_D)\) is not too high. Thus, a necessary condition for enhanced design to be profitable is \(p_T^* < p_D^* - c_D\), which implies that the margin on each sale increases as a result of enhanced design. Note that this is not a sufficient condition for the profitability of enhanced design, as an increase in production costs also implies an increase in costs due to excess inventory.\(^7\)

6 Fast Fashion

The fast fashion system combines operating characteristics of the rapid production and enhanced design systems. As a result, the firm is capable of both raising consumer values for the product and eliminating supply-demand mismatch. The sequence of events in the fast fashion system is the same as that depicted in Figure 2. As in the enhanced design model, consumers earn an extra value of \(m\) per unit, and every unit incurs an additional cost of \(c_D \geq 0\). As in the rapid production system, the firm has the option of obtaining additional inventory close to the selling season after receiving perfect demand information, at an additional cost of \(c_P \geq 0\) per unit. Thus, the firm possesses a comparable cost structure to the alternative systems.

Because the sequence of events is similar in the rapid production and the fast fashion systems, the equilibrium follows immediately from Lemma 2 by setting consumer valuations equal to \(v + m\) and increasing the production cost on every unit (procured both before and after the forecast update) by \(c_D\).

Lemma 6 In a fast fashion system, an equilibrium with non-zero production exists and is unique.

\(^6\)In our model, enhanced design results in greater consumer value, which the firm then exploits to raise the selling price. An alternative model might assume that the selling price is fixed (possibly for competitive reasons), but enhanced design results in a more popular product and hence greater market share or size. Such a model, particularly one incorporating competition, may prove to be a fruitful direction for future research.

\(^7\)Because enhanced design increases prices and production costs, it increases both the underage cost (the profit loss from a lost sale, i.e., the margin) and the overage cost (the profit loss from one unit of excess inventory at the end of the season, i.e., the production cost minus the salvage value). Thus, equilibrium inventory levels (and profit) in the enhanced design may be higher or lower than in the traditional system.
In equilibrium, all consumers purchase early. The equilibrium full price is

\[ p_F^* = v + m - \delta \frac{c_p}{c + c_D + c_p - s} (v + m - s) . \]

Using Lemma 6, we derive the following result:

**Lemma 7** The equilibrium price is greater in the fast fashion system than in all of the other systems if \( c_p < p_D^* - c \).

**Proof.** Comparing the equilibrium prices from Lemmas 2 and 6, it is easy to see that \( p_F^* > p_D^* \). Comparing prices from Lemmas 4 and 6, observe that the price in the \( F \) system is greater than the price in the \( D \) system if and only if the equilibrium \( \phi \) is lower in the \( F \) system, i.e., if

\[ \frac{cp}{c + c_D + cp - s} < \frac{p_D^* - c}{p_D^* - s} . \]

Rearranging the terms, the inequality holds if

\[ c_p (c - s) < (p_D^* - c) (c + c_D - s) . \]

Since \( c + c_D - s > c - s \), a sufficient condition for the relationship to hold is if \( p_D^* - c > c_p \). The result that \( p_F^* > p_P^* \) then follows from Lemma 5 if \( p_D^* - c > c_p \) holds. □

In other words, the firm can leverage a fast fashion system to raise the equilibrium selling price in two ways: rapid production reduces the probability of a clearance sale and decreases consumer incentives to delay purchasing, while enhanced design increases consumer value and hence increases consumer incentives to buy at the full price. The combination of both effects results in a fast fashion system yielding the greatest equilibrium price (provided, as in the rapid production system, costs are not too high so as to make the second inventory procurement option unprofitable).

### 7 The Interaction of Enhanced Design and Rapid Production

Having derived equilibria in each of the four systems, we may now address the impact of combining enhanced design and rapid production in a fast fashion system. Specifically, we seek to answer
the following question: are enhanced design and rapid production complements, or substitutes? If they are complements, then investing in a fast fashion system results in a superadditive benefit: the incremental value of a fast fashion system (the change in profit over a traditional system) is more than the combined incremental value of enhanced design and rapid production employed in isolation. On the other hand, if they are substitutes, then combining both techniques in a fast fashion system results in a subadditive benefit. While we are unable to make universal statements about the interaction of enhanced design and rapid production, we are able to derive conditions under which the direction of this interaction is clear:

**Theorem 1** If the following two conditions hold, enhanced design and rapid production are complements:

1. Adding enhanced design yields the greatest price increase if the firm also possesses rapid production $(p_F^* - p_P^* \geq p_D^* - p_T^*)$;
2. The equilibrium initial inventory level is lower in the rapid production system than in the enhanced design system $(q_P^* \leq q_D^*)$.

**Proof.** Rapid production and enhanced design are complements if $\pi_F^* - \pi_P^* \geq \pi_D^* - \pi_T^*$. Let $S(x) = \mu - L(x)$ be the expected sales given an inventory level of $x$. Note that $S(x) \leq \mu$ for any $x$. The equilibrium profit in each of the four systems is then

\[
\begin{align*}
\pi_T^* &= (p_T^* - c) S(q_T^*) - (c - s) I(q_T^*), \\
\pi_P^* &= (p_P^* - c) \mu - (c_P) L(q_P^*) - (c - s) I(q_P^*), \\
\pi_D^* &= (p_D^* - c - c_D) S(q_D^*) - (c + c_D - s) I(q_D^*), \\
\pi_F^* &= (p_F^* - c - c_D) \mu - (c_P) L(q_F^*) - (c + c_D - s) I(q_F^*).
\end{align*}
\]

Let $\pi_\Omega(q)$ be the profit in system $\Omega \in \{T, D, P, F\}$ at quantity level $q$. Observe that $\pi_F^* - \pi_P^* = \pi_F(q_F^*) - \pi_P(q_P^*) \geq \pi_F(q_P^*) - \pi_P(q_P^*)$, and hence

\[
\begin{align*}
\pi_F^* - \pi_P^* &\geq (p_F^* - p_P^* - c_D) \mu + c_P (L(q_P^*) - L(q_F^*)) + (c - s) I(q_P^*) - (c + c_D - s) I(q_F^*) \\
&= (p_F^* - p_P^* - c_D) \mu - c_D I(q_P^*).
\end{align*}
\]
Similarly, \( \pi^*_D - \pi^*_T = \pi_D (q^*_D) - \pi_T (q^*_T) \leq \pi_D (q^*_D) - \pi_T (q^*_D) \), which implies

\[
\pi^*_D - \pi^*_T \leq (p^*_D - p^*_T - c_D) S (q^*_D) - (c + c_D - s) I(q^*_D) + (c - s) I(q^*_T)
\]

\[
= (p^*_D - p^*_T - c_D) S (q^*_D) - c_D I(q^*_T).
\]

If \( p_F^* - p_P^* \geq p_D^* - p_T^* \), then

\[
(p_F^* - p_P^* - c_D) \mu \geq (p^*_D - p^*_T - c_D) S (q^*_D).
\]

Because \( q^*_F \leq q^*_D \), the expected amount of discounted inventory \( (I) \) in the rapid production system is less than in the enhanced design system, \( I(q^*_P) \leq I(q^*_D) \), which implies \(-c_D I(q^*_P) \geq -c_D I(q^*_D)\). The result \( (p^*_F - p^*_P \geq p^*_D - p^*_T) \) follows.

Theorem 1 demonstrates that—provided two conditions hold—enhanced design and rapid production are complementary activities. We emphasize that each of these conditions are merely sufficient for the complementarity result. Indeed, we have observed many instances in which one or more of these conditions are violated while the result continues to hold; we discuss these cases further in the numerical study in §8.

The intuition behind this result lies in the fact that there are four ways that rapid production interacts with enhanced design: via expected sales, via the equilibrium price, and via leftover inventory and overage costs. With respect to sales, the two practices are always complements. That is, rapid production increases expected sales (by essentially eliminating lost sales). Enhanced design increases the equilibrium price (by increasing consumer value for the product). An increase in the price is more valuable when sales are higher (i.e., when the firm has rapid production) and the price increase is enjoyed on a greater number of units, and an increase in sales is more valuable if the equilibrium price is greater. Thus, if rapid production only impacted sales, and enhanced design only impacted the price, then the two practices would always be complimentary.

However, rapid production also increases the equilibrium selling price by reducing consumer incentives to delay purchasing. As a result, it is possible (as we argued earlier) for the marginal value of the price increase resulting from enhanced design to be lower if the firm also possesses rapid production because rapid production already results in a substantial increase in the equilibrium
price; in other words, with respect to price, the two practices may be complements or substitutes, and in numerical experiments we have verified that both cases are possible (see §8), though the latter case is rare.

Enhanced design and rapid production may be either complements or substitutes because there are two counteracting forces impacting the change in equilibrium selling price. To understand these forces, first note that the equilibrium price in any system can be generically written as

$$p^*_Ω = v_Ω (1 - \delta \phi^*_Ω) + \delta \phi^*_Ω s,$$  \hfill (5)

where $\phi^*_Ω$ is the equilibrium in-stock probability in system $Ω \in \{T, D, P, F\}$, and $v_Ω$ is the total consumer valuation in system $Ω$, i.e., $v_Ω \in \{v, v + m\}$. The impact of increasing $v_Ω$ (i.e., adopting enhanced design) on the equilibrium selling price is greatest if $\phi^*_Ω$ is small. $\phi^*_Ω$ is, generally speaking, smaller when the firm has rapid production capabilities than when it does not. Hence, enhanced design yields the greatest benefit when the firm also possesses rapid production. This force helps cause rapid production and enhanced design to be complements with respect to price.

Examining equation (5) again, we observe that, all else being equal, the impact of decreasing $\phi^*_Ω$ (the critical ratio, or in-stock probability) is greatest on the equilibrium selling price (in absolute terms) when $v_Ω$ is large. Hence, rapid production (which decreases $\phi^*_Ω$) is most beneficial to the firm in terms of the equilibrium increase in the selling price when the firm also possesses enhanced design. However, there is another factor at work: when adopting rapid production, $\phi^*_Ω$ tends to decrease less if the firm also has enhanced design. The reason is that $\phi^*_Ω$ is typically already lower with enhanced design than in the traditional system (i.e., usually $\phi^*_D \leq \phi^*_T$, because the product is more costly, despite garnering a greater price). While $\phi^*_Ω$ is lower in the fast fashion system than in the rapid production system ($\phi^*_F \leq \phi^*_P$), the difference between the two is not typically as great as the difference between $\phi^*_Ω$ in the traditional and enhanced design systems. Because a greater (absolute) decrease in $\phi^*_Ω$ has, all else being equal, a greater impact on the equilibrium selling price, this effect causes rapid production and enhanced design to be substitutes with respect to price.

Either of these effects may dominate, and the net result is that enhanced design and rapid production may or may not be complementary with regards to price. Even when combining the price effect with the sales effect discussed above, the direction of the relationship is ambiguous: account-
ing for both factors, enhanced design and rapid production may be complements or substitutes. Condition 1 given in Theorem 1, however, eliminates any ambiguity: requiring \( p_R^* - p_D^* \geq p_D^* - p_R^* \) ensures that with regards to price, the complementarity effect dominates the substitution effect.

Finally, the second condition in Theorem 1 addresses the third and fourth potential interactions between enhanced design and rapid production: leftover inventory and inventory markdown costs. Similar to the equilibrium selling price, enhanced design and rapid production may either be complements or substitutes with regards to expected inventory and markdown costs; however, requiring \( q_P^* \leq q_D^* \) ensures that the complementarity effect dominates. If this inequality holds, then the reduction in the amount of inventory sold on markdown is greatest when adding rapid production to an enhanced design system (see the proof of Theorem 1). Because marginal markdown (or overage) costs in the traditional and rapid production systems are \( c - s \), while in the enhanced design and fast fashion systems, the marginal markdown cost is \( c + c_D - s \geq c - s \), the total reduction in inventory markdown costs is greater when adding rapid production to an extant enhanced design system than to a traditional system. Hence, the two practices are complements with respect to leftover inventory and inventory markdown costs if condition 2 holds.

From Theorem 1, we may also immediately derive conditions that dictate when a fast fashion system is optimal:

**Theorem 2** A fast fashion system is optimal if conditions (1) and (2) of Theorem 1 hold and if enhanced design and rapid production is profitable in isolation.

Theorem 2 is a natural conclusion of Theorem 1; if both enhanced design and rapid production are valuable as stand-alone strategies, and they are complements, then clearly they will be valuable when used together in a fast fashion system. Once again, the conditions in the theorem are sufficient, but not necessary, for the result.

### 8 Numerical Study

Demonstrating that enhanced design and rapid production are (under certain conditions) complementary leads to several interesting questions. First: how restrictive are the conditions given in Theorems 1 and 2, and what happens if they are violated? Second: what is the magnitude of
the complementarity effect? Third: how is the complementarity effect impacted by changes in the various parameter values (in particular, δ, the consumer discount factor)? Because the equilibrium expressions for prices, inventory levels, and profits are complex and difficult to decipher analytically, we employ an extensive numerical study in §8.1 to answer these questions. In addition, §8.2 considers the important issue of how rapid production and enhanced design impact consumer and social welfare.

8.1 The Value of Fast Fashion

The study consists of 8,019 total instances resulting from every possible combination of the values listed in Table 2. These parameters represent a wide range of plausible values. The coefficient of variation of demand (σ/μ) equals 0.5, 0.75, or 1. Maximum gross margins (i.e., (v − c)/v in the standard design systems and (v + m − c − CD)/v in the enhanced design systems)) range from 40% to 78% (actual gross margins depend on the equilibrium selling price and can even be negative in “unprofitable” enhanced design systems). Enhanced design and rapid production each incur 10% to 50% cost premiums (thus, fast fashion incurs 20% to 100% cost premiums), and “hot” products generated with enhanced design generate between 11% and 43% more consumer value than safe products created without enhanced design.

We found that, of the conditions listed in Theorem 1: condition 1 held in 99% of the sample and condition 2 held in 62% of the sample. The combination of both conditions held in 61% of the sample. Thus, the sample includes a large number of instances (39% of the sample, or 3,124 total cases) in which the assumptions behind the complementarity result are not satisfied.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand Distribution</td>
<td>Normal</td>
</tr>
<tr>
<td>μ</td>
<td>150</td>
</tr>
<tr>
<td>σ</td>
<td>{75, 112.5, 150}</td>
</tr>
<tr>
<td>v</td>
<td>{7, 8, 9}</td>
</tr>
<tr>
<td>v + m</td>
<td>10</td>
</tr>
<tr>
<td>c</td>
<td>{2, 3, 4}</td>
</tr>
<tr>
<td>CD</td>
<td>{0.1c, 0.3c, 0.5c}</td>
</tr>
<tr>
<td>CP</td>
<td>{0.1c, 0.3c, 0.5c}</td>
</tr>
<tr>
<td>s</td>
<td>{0.75c, 0.85c, 0.95c}</td>
</tr>
<tr>
<td>δ</td>
<td>{0, 0.1, 0.2, ..., 1}</td>
</tr>
</tbody>
</table>

Table 2. Parameter values used in numerical experiments.
For each parameter combination, we calculated the equilibrium under all four systems and determined expected prices and profits. Even though the sufficient conditions for complementarity were not satisfied in every case, the complementarity result very nearly was: in 8,012 cases (99.9% of the sample), we observed that the value of a fast fashion system (the increase in profit over the traditional system) was weakly greater than the combined value of rapid production and enhanced design operating alone.\textsuperscript{8} Furthermore, the fast fashion system was optimal (provided the greatest expected profit) in 7,069 cases (88%). Thus, we conclude that while the complementarity result (Theorem 1) usually holds, the optimality result (Theorem 2) is slightly less pervasive: in cases where the complementarity result holds but fast fashion is not optimal, enhanced design is unprofitable on its own.

Note that the sample includes a large number of instances (1,485) in which enhanced design is seemingly an ill-advised strategy (because the consumer value increase, $m$, is less than or equal to the cost of enhanced design, $c_D$). Nevertheless, we found that in 111 of these cases enhanced design was profitable on its own; in 677 cases (46% of the the instances in which $c_D \geq m$), a fast fashion system was optimal among all systems. Hence, the presence of strategic customers can make even seemingly costly enhanced design systems a profitable endeavor.

Next, we consider the magnitude of the complementarity effect. In particular, we analyze the complementarity effect as a function of the consumer discount factor ($\delta$). Figure 3 plots the percentage increase in firm profit (relative to the base case of the traditional system) from each of the three alternative strategies, averaged over our entire sample. Included in the graph is a plot of the sum of the values of rapid production and enhanced design, expressed as a percentage increase in firm profit; if the value of fast fashion lies above this sum, then the complementarity effect exists. As the figure demonstrates, when $\delta$ is small (consumers are not very strategic), the complementarity effect is also small; when $\delta$ is large (consumers are very strategic) the complementarity effect is dramatic, with fast fashion adding about twice as much profit as the combined values of enhanced design and production. Hence, the magnitude of complementarity appears to increase as consumers become more strategic, implying that fast fashion systems are most valuable when consumers are

\textsuperscript{8}In the 7 cases in which enhanced design and rapid production were not complementary, we observed that enhanced design provided strongly negative value on its own (because the cost of enhanced design was too high to justify the relatively small price increase), and both conditions in Theorem 1 were violated. However, 2,868 cases yielded negative value in enhanced design, but nevertheless the complementarity result held in 2,861 of these.
Figure 3. The percentage increase in expected profit (over the traditional system) in each system as a function of the consumer discount factor ($\delta$), averaged over the entire sample.

We stress, however, that it isn’t always the case that complementarity increases as $\delta$ increases. This can be seen by examining equation (5): note that while a decrease in the probability of a clearance sale (i.e., by adopting rapid production) is most valuable if $\delta$ is large and consumer value is high (implying complementarity increases with $\delta$), an increase in consumer value (i.e., by adopting enhanced design) is most valuable if $\delta$ small and the probability of a clearance sale is small (implying complementarity decreases with $\delta$). Hence, there are multiple forces at work, though on average in our sample (by a wide margin), complementarity does tend to grow as $\delta$ increases and consumers become more strategic.

The strengthening of the complementarity effect as customers become more strategic can also be seen in Figure 4, which depicts the ratio between the value of fast fashion and the sum of the values of enhanced design and production as a function of $\delta$. If $\delta$ is small (consumers are myopic), then fast fashion is roughly 1.8 times as valuable as the sum of the independent systems; when

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9Indeed, it is possible to find parameter combinations for which expected profit is zero in the traditional production system, and positive in one or more of the alternative systems. Thus, it is possible for the systems to possess “infinite value,” in relative terms, though we designed the numerical study to avoid these cases to facilitate analysis of the percentage profit increase resulting from the three alternative strategies.
Figure 4. The magnitude of the complementarity effect—expressed as a ratio of the value of a fast fashion system to the sum of the values of rapid production and enhanced design—as a function of the consumer discount factor ($\delta$), averaged over the entire sample.

consumers are perfectly strategic ($\delta = 1$), it is more than 2.3 times as valuable as the independent strategies.

By observing our sample, we see that this behavior exists primarily due to the effect of $\delta$ on equilibrium prices. Recall our discussion on the impact of $\delta$ on the equilibrium selling price: specifically, we identified counteracting forces that implied complementarity may strengthen or weaken as $\delta$ increases. Our numerical study demonstrates that the former effect tends to dominate. Figure 5 demonstrates that the gap between $p^*_F - p^*_T$ and $p^*_D - p^*_T$ (the “complementarity gap”) typically widens as $\delta$ increases. Note that the average value increase resulting from enhanced design in our sample is $m = 2$, hence the figure also demonstrates that the price boost resulting from enhanced design is typically greater than $m$ in a fast fashion system and less than $m$ in a enhanced design (slow production) system.

The implication of Figure 5—and the intuition behind the increasing complementarity result—is that the fast fashion system appears to be most robust to strategic behavior while the enhanced design system is least robust. Put another way, increasing $\delta$ decreases prices in all four of the systems; however, this has little impact on the equilibrium price in the fast fashion system (relative
to the rapid production system), but has a very large impact on the price in the enhanced design system (relative to the traditional system). This is intuitive: because fast fashion generally results in the highest consumer value and lowest inventory levels, an increase in $\delta$ should have the least impact. Because enhanced design has high consumer value but also has high inventory levels (due to the lack of a second procurement opportunity), increasing $\delta$ has a much more substantial effect on consumer incentives to wait for the sale (relative to the other three systems), thereby decreasing the equilibrium price significantly. On average in our sample, comparing prices when $\delta = 0$ to prices when $\delta = 1$, the fast fashion system experiences the least reduction (2.8) while the enhanced design system experiences the greatest reduction (4.4); rapid production (3.3) and traditional (3.9) lie between the two.

### 8.2 Consumer and Social Welfare

Thus far, we have focused entirely on the impact of rapid production and enhanced design on firm profit. It is also important to consider the impact of these practices on consumer welfare—that is, the total expected surplus of the consumer population, which we define to be the surplus of...
each individual consumer (valuation minus the purchase price) times the number of consumers who purchase the product. We assume that consumers who purchase on the salvage market garner zero surplus. Thus, total consumer welfare in each of the four systems is:

$$w^*_T = (v - p^*_T) \mu - (v - p^*_T) L(q^*_T),$$

$$w^*_P = (v - p^*_P) \mu,$$

$$w^*_D = (v + m - p^*_D) \mu - (v + m - p^*_D) L(q^*_D),$$

$$w^*_F = (v + m - p^*_F) \mu.$$

Clearly, for a given set of parameters, it is possible that any of the four systems is optimal from the consumer point of view (yields the highest total surplus), depending on the equilibrium price and inventory level. Table 3 demonstrates this fact by providing the frequency with which each system yields the greatest consumer welfare, as a function of $\delta$, for our numerical sample. When consumers are completely myopic ($\delta = 0$), all systems are equivalent, yielding zero consumer surplus. As consumers become more strategic ($\delta$ increases), the traditional and enhanced design systems are initially favored, while for large $\delta$, rapid production and fast fashion also become attractive from a consumer point of view. This reflects the fact that, generally speaking, when $\delta$ is small the equilibrium prices are high, meaning the firm naturally sets a high inventory level (and stock-outs are relatively infrequent). Thus, in these cases, the slightly lower prices resulting from the slow production systems are favored by consumers. As $\delta$ increases, the equilibrium prices decrease, and hence the firm sets progressively smaller and smaller inventory levels, resulting in more frequent stock-outs—in these cases, consumers prefer the fast production systems (rapid production and fast fashion) because they increase the total number of sales (eliminate stock-outs) despite also resulting in an increase in the selling price.

Next, we consider the impact of these production and design practices on social welfare—the
Table 3. The frequency of optimality of each of the four systems from a consumer welfare perspective.

<table>
<thead>
<tr>
<th>δ</th>
<th>Trad.</th>
<th>Enhanced Design</th>
<th>Rapid Production</th>
<th>Fast Fashion</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>25%</td>
<td>75%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>0.2</td>
<td>28%</td>
<td>71%</td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td>0.3</td>
<td>30%</td>
<td>68%</td>
<td>1%</td>
<td>2%</td>
</tr>
<tr>
<td>0.4</td>
<td>31%</td>
<td>64%</td>
<td>3%</td>
<td>2%</td>
</tr>
<tr>
<td>0.5</td>
<td>32%</td>
<td>59%</td>
<td>5%</td>
<td>4%</td>
</tr>
<tr>
<td>0.6</td>
<td>33%</td>
<td>53%</td>
<td>8%</td>
<td>6%</td>
</tr>
<tr>
<td>0.7</td>
<td>30%</td>
<td>50%</td>
<td>12%</td>
<td>8%</td>
</tr>
<tr>
<td>0.8</td>
<td>29%</td>
<td>41%</td>
<td>18%</td>
<td>12%</td>
</tr>
<tr>
<td>0.9</td>
<td>24%</td>
<td>37%</td>
<td>24%</td>
<td>15%</td>
</tr>
<tr>
<td>1.0</td>
<td>20%</td>
<td>30%</td>
<td>30%</td>
<td>20%</td>
</tr>
</tbody>
</table>

We make several observations about these values. First, the firm’s inventory level in the rapid production and fast fashion systems maximizes social welfare. To see this, note that in these two systems, the societal costs of under-ordering and over-ordering ($c_P$ and $c - s$ or $c + c_D - s$, depending on the system) are the same as the firm costs of under-ordering and over-ordering. All consumers always purchase a unit in these systems, and hence all inventory costs are fully internalized by the firm, resulting in socially efficient inventory levels.

In the traditional and enhanced design systems, however, this is not the case. In particular, the societal cost of under-ordering ($v - c$ or $v + m - c - c_D$) depends only on the consumer valuations and costs, not the equilibrium prices. The firm charges a price lower than the consumer valuation, and hence the firm’s under-ordering costs are lower than the societal costs; thus, the firm’s inventory level is too low from a social perspective.

Because of this, the rapid production and fast fashion systems are always socially preferred to the traditional and enhanced design systems, respectively. The option of a second procurement always provides positive value if the initial inventory level is set optimally, which it is. Furthermore,
in our numerical sample, we found that the fast fashion system was usually socially optimal (in 76% of cases).

Finally, it is interesting to consider two related questions: first, does strategic behavior benefit consumers (i.e., does consumer welfare increase in $\delta$), and how does strategic consumer behavior impact societal welfare? The answer to the first question is that strategic behavior does benefit consumers. This can be seen (analytically) in the rapid production and fast fashion systems by observing that equilibrium consumer welfare depends only on $\delta$ via the equilibrium price, which is decreasing in $\delta$. We observe similar behavior in the traditional and enhanced design systems numerically. With regards to the second question, we observed that social welfare typically decreases in $\delta$ in the traditional and enhanced design systems; that is, strategic behavior decreases societal surplus in these systems. In the rapid production and fast fashion systems, however, welfare is insensitive to $\delta$. This is because equilibrium inventory levels depend only on firm cost parameters (not equilibrium prices) and hence are independent of $\delta$; consequently, for the rapid production and fast fashion systems, the social welfare expressions in (6) do not depend on $\delta$.

9 Conclusion

With the success of fast fashion retailers, an increasing amount of attention—both academic and practical—has been paid to these innovative firms. In this paper, we present a modeling framework that allows us to capture and isolate the key aspects that define a fast fashion system: enhanced design efforts and rapid production capabilities. By employing this approach, we analyze four potential operating systems: traditional systems (with standard design efforts and slow production), rapid production systems, enhanced design systems, and fast fashion systems (with both enhanced design and rapid production), and characterize equilibrium inventory levels, prices, and consumer purchasing behavior in each case.

We focus much of our discussion on the issue of whether rapid production and enhanced design are complements or substitutes. We find that, while it is possible for the two practices to be substitutes, it is much more likely that they are complements. The reason is that there are multiple forces at work which determine complementarity: sales, prices, and markdown costs. In the vast majority of our numerical cases (over 99%), the complementarity factors (significantly) outweigh
the substitution factors, leading enhanced design and rapid production to be overall complements.

This result occurs despite the fact that, as we alluded to earlier, we have ignored a crucial aspect of how enhanced product design interacts with rapid production: namely, that enhanced design may simply be more effective if production leadtimes are shorter. If, for example, the production leadtime is six months, then no matter how much effort the firm places on product design, it still must finalize design well in advance of the selling season, meaning it may miss important trends and changes in consumer preferences. On the other hand, if the production leadtime is one month, then design may be finalized much later, allowing the firm to pursue changing trends in a much more agile and responsive manner. Consequently, the potential value of enhanced design—all else being equal—can be greater if the firm has achieved rapid production.

We find that, even controlling for the latter complementarity effect (assuming that it is zero), the two practices are almost always complements. Thus, the complementarity of these two strategies does not, in general, depend on the fact that production leadtime reduction allows a firm to delay its design decisions. However, if we were to include this effect in concert with the other forces we have described, the complementarity of enhanced design and rapid production would be even more dramatic, a fact which leads us to conclude that there is substantial value—operationally and behaviorally—from adopting a fast fashion approach.

The fact that enhanced design and rapid production are complements—and that the magnitude of complementarity increases as customers become more strategic—helps to explain how even seemingly costly systems can be profitable. European fast fashion retailers such as Zara, H&M, and Benetton, for example, employ large staffs of in-house designers and even use costly local labor and expedited shipping methods when necessary. While this seemingly puts these firms at a heavy cost disadvantage with many of their competitors, they manage to reap additional benefits by minimizing strategic behavior, more so even than employing either production strategy by itself. This result implies that fast fashion can be an all-or-nothing proposition: merely initiating one-half of a fast fashion system (enhanced design or rapid production) may be unprofitable, while employing both simultaneously yields significant benefits.

Naturally, when choosing whether to implement one of the strategies we describe, a firm must evaluate fixed costs in addition to the variable costs and operating profits that we analyze. However, the fact remains that even when fixed costs are accounted for, the value of the fast fashion system,
relative to the alternative systems, generally increases as consumers become more patient (and hence more strategic in their purchasing behavior), a fact which justifies the use of sophisticated production systems capable of enhanced design and rapid production in markets characterized by savvy consumer populations.

Taken together, these results help to aid our understanding of the impact of fast fashion systems—both at the design and production phases—on consumer purchasing behavior and firm profit. While rapid production and enhanced design practices are not suited to every industry or every product, in cases where the strategies are feasible and not prohibitively expensive, the reward for implementing such systems can be significant, particularly when consumers are sophisticated.

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References


