

Product Variety and Vertical Integration

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Ross School of Business Working Paper
Working Paper No. 1315
April 2016

Strategic Management Journal, Forthcoming

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PRODUCT VARIETY AND VERTICAL INTEGRATION

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April 2016

(Forthcoming, Strategic Management Journal)

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ABSTRACT

Research summary: In vertical relationships the potential for scale economy in manufacturing often calls for specialization and outsourcing. Specialization, however, depends critically on the stability of the task and contractual environment. In a highly uncertain environment the need for frequent mutual adjustments favors integration instead of outsourcing. To evaluate vertical relationships in value chains where one stage competes on product variety under great uncertainty and the other stage competes on scale, we compare operations data at about 300 distribution centers within a major soft-drink bottler before and after it was integrated into an upstream firm. We find that vertical integration improved coordination for the integrated firm by aligning incentives and reducing strategic information asymmetry, but it worsened coordination for upstream rivals who shared the same downstream facilities.

Managerial summary: Managers make frequent decisions about outsourcing vs. integration. This paper helps to crystalize the costs and benefits of integration by pointing to two important factors: the potential for economies of scale and the need for coordination under uncertainty. It studies an industry where one stage of the value chain competes on product variety under great uncertainty and the other stage competes on scale. Based on operations data at about 300 distribution centers within a major soft-drink bottler before and after it was integrated into an upstream firm, we find that vertical integration improved coordination for the integrated firm (by reducing both stockouts and inventory, and improving sales forecasts), but it worsened coordination for upstream rivals who shared the same downstream facilities.

Key words: vertical integration; coordination; product variety; information asymmetry; stockout.

INTRODUCTION

Repeated exchange relationships between two neighboring stages of the value chain are vulnerable to coordination problems when an upstream firm competes on product variety, with the products manufactured and distributed by a downstream firm that competes on scale. From the upstream firm's perspective, vertical integration helps to coordinate product sequencing and successive innovations that require frequent mutual adaptation along the value chain (Helfat & Campo-Rembado, 2016; Helfat & Raubitschek, 2000), thereby accommodating product variety and differentiation (Argyres & Bigelow, 2010). From the downstream firm's perspective, contracting accommodates gains to specialization by allowing the downstream firm to pool contacts from different customers to achieve greater economies of scale and learning (Jacobides & Hitt, 2005). Uncertainty will aggravate these incentive conflicts between the upstream and downstream firms and make contracting costly (Klein, 2000; Teece, 1996; Williamson, 1975). Should the two stages vertically integrate to pursue product differentiation despite the higher production cost, or should they continue to contract based on scale and give up product variety? In this paper, we investigate the mechanisms by which contracting solution gives way to vertical integration when demand uncertainty with respect to product variety increases, and how upstream competitors will be affected if one of them vertically integrates the downstream facility.

We focus on the impact of vertical integration on the coordination challenges along the value chain. We argue that the very demand for economies of scale may require the downstream firm to produce for multiple upstream firms, exacerbating vertical coordination challenges and jeopardizing the upstream firm's product variety strategy. In particular, sharing downstream capacity among multiple upstream firms creates problems of strategic information asymmetry. On the one hand, a downstream firm seeking to maximize its profits may under-forecast sales for

one upstream firm so that it produces less for this firm but more for another (Yehezkel, 2008). On the other hand, an upstream firm may not fully share strategic information down the value chain (Novak & Eppinger, 2001). For instance, while providing incomplete or untimely information makes the downstream firm's sales forecasts noisy, the upstream firm may keep promotion or new product launch plan in secrecy until shortly before the actual event because it fears the information could be leaked to competing upstream firms that share the same downstream facility. If one of the upstream firms integrates the downstream firm, the coordination between these two firms can be enhanced by aligning incentives and sharing information, albeit at a cost to the other upstream firms that still share the downstream facility.

To test these ideas, we take a quantitative case study approach using detailed unit–product-level operations data to offer a granular view of the tradeoffs firms face along the value chain and shed light on the relationship between a firm's product variety and its vertical scope. The context of our empirical study is the soft drink industry, where the two dominant concentrate producers (CPs), Coca-Cola and Pepsi, compete fiercely on product variety and on-time store delivery. For decades the CPs have been taking advantage of their market power and securing supply through exclusive contracts with the bottlers, who rely on the large business volume to achieve economies of scale. In order to extract value from maximum scale, the large CPs also share bottling facilities with other smaller CPs. This sharing arrangement maximizes scale but creates obstacles along other dimensions, such as making it more difficult to introduce and coordinate new products. These difficulties became more pronounced over the last decade as the CPs faced increasing pressure to diversify their product categories from traditional carbonated soft drinks (CSDs) to healthier, non-carbonated soft drinks (NonCSDs). However, bottlers have strongly opposed this change, as their existing capital-intensive production process relies heavily

on economies of scale from CSD products (Financial Times, 2009a). To overcome the burden of increased coordination, both Coca-Cola and Pepsi restructured their largest bottlers from minority shareholdings to fully-owned subsidiaries—a change that makes it possible for us to compare multiple operations variables before and after the full integration.

Our analyses are based on operations data at the product (stock-keeping unit, or SKU) level across hundreds of distribution centers (DCs) within a major bottling company (the Bottler) for one dominant CP between 2008 and 2011, during which time the Bottler was fully acquired by the CP. Our focus is a key measure of coordination performance along the value chain: stockouts. Stockouts happen when customer orders are not completely fulfilled. Frequent stockouts result in customer dissatisfaction and ultimately hurt sales, profitability, and future demand (Anderson, Fitzsimons, & Simester, 2006a; Musalem *et al.*, 2010; Wan, Evers, & Dresner, 2012). It is therefore an important performance measure in the product variety literature.

We first examined about 1200 SKUs that were produced and distributed by the Bottler for the parent CP both before and after full integration. We found that despite the Bottler's significantly increased product offerings in the NonCSD category after integration, the stockout rate for an average DC–SKU pair in our sample dropped by 2% (from a pre-integration sample average of 26%), and that the reduction was significantly more for NonCSDs than for CSDs.

We then explored the mechanisms of incentives and information that could influence stockouts. An upstream firm has incentive to develop new products and promote brands; it needs the downstream firm to produce and deliver its products promptly to minimize stockouts, especially in its newly entered and strategic segments. In contrast, a downstream firm wants to lower its production and distribution costs, mainly through producing and delivering a single category of products with large volumes and avoiding products with relatively low and uncertain

demand, as well as through minimizing excess inventory. Because NonCSDs have smaller and less certain demand, and producing them requires bottlers to frequently adjust their process away from producing CSDs, bottlers have less incentive to carry NonCSDs, notwithstanding the greater strategic value of NonCSDs for the CPs. A full integration reduces incentive conflicts, we therefore expected our analysis to show DCs carrying higher inventories after integration, particularly among NonCSDs. However, to our surprise, we found that the inventory of NonCSDs decreased (relative to both actual and forecasted sales) after integration. The reduction in *both* stockouts and inventory suggests that integration created an overall improvement in coordination efficiency.

We next examined if the improved efficiency was consistent with an improvement in information sharing along the value chain. We compared DCs' sales forecasts before and after integration. We found that DCs adjusted their sales forecast upwards, especially if they were located close to the CP, where integration could enable closer monitoring by the CP. We also found that DCs reduced the noise (standard deviation) in their sales forecasts. This reduction was greater for DCs located far from the CP, where they could not easily observe the CP's plan for product launches and promotions, and would therefore benefit more from explicit notification from the CP after integration. We also found that DCs reduced forecast noise more for newer products, whose demand is more susceptible to disturbance caused by promotion and other product launches.

As a comparison, we examined about 300 SKUs (mostly CSDs) produced and distributed by the Bottler for its CP parent's competitors under license agreements. We find that for these products, stockout rates increased after integration, while both inventory and sales forecasts reduced. In addition, the noise in sales forecasts increased. This is consistent with a worsened

incentive and information problem between the upstream competitors of the CP parent and the CP parent's now fully integrated Bottler.

Overall, our results suggest that, on the one hand, vertical integration plays a positive role in coordinating between an upstream and a downstream firm by aligning incentives and facilitating monitoring and information sharing along the value chain. On the other hand, vertical integration introduces a competitive disadvantage for the CP parents' competitors that share the same downstream facilities through contracts.

Our theoretical analyses and empirical findings have relevance for several strands of literature. First, they complement recent studies on the relationship between firms' horizontal and vertical scopes. On the one hand, they confirm the coordination benefits of vertical integration for enhancing firms' adaptability across markets (Forbes & Lederman, 2009; Novak & Stern, 2009), and the benefit of integrative capability for seizing strategic opportunities in industries dominated by successive innovations (Helfat & Campo-Rembado, 2016; Helfat & Raubitschek, 2000). On the other hand, the finding that integration worsens coordination with rival upstream firms is consistent with the hypothesis that firms' horizontal and vertical scopes can also be substitutive due to constraints in a firm's total coordination capacity (Zhou, 2011).

Secondly, for the literature on product variety, our focus on coordination problems echoes prior research on the operational risk of product variety despite its strategic value (Barnett & Freeman, 2001; Cottrell & Nault, 2004; Sorenson, 2000). While the operations issues that arise with product variety in stockouts, inventory, and forecast error have been studied in the operations management literature (Fisher, 1997; Fisher & Ittner, 1999; Wan & Dresner, 2015), studies about product variety and organizational interactions along the supply chain are rare

(Ramdas, 2003). By focusing on vertical integration, this paper introduces organizational factors to the analyses.

Finally, our analyses add to a rich body of case studies on vertical integration in general and the soft drink industry in particular (Karnani, 2010; Klein, 2000; Muris, Scheffman, & Spiller, 1992; Yoffie & Kim, 2012). While the majority of prior cases examine transaction costs arising from relationship-specific investments, the current paper focuses on a narrow time window around vertical integration, during which no significant physical investments were made. This allowed us a unique vantage from which to analyze adaptation-related coordination issues.

THEORETICAL DEVELOPMENT

Product Variety and Vertical Coordination

By catering to a wider range of customer preferences, product variety increases the aggregated demand for a firm's products but often reduces the demand and increases the sales volatility for individual variety (e.g., Anupindi *et al.*, 2011; Cachon & Terwiesch, 2012), which exacerbates coordination problems along the value chain. First, it increases incentive conflicts between the upstream and downstream firms. For the downstream firms, product variety increases production costs by compromising economies of scale, increases equipment and overhead costs, and lowers worker productivity. It also increases distribution costs as the downstream firm has to deliver each variety in smaller batches and keep extra inventory (wasting working capital) to account for unexpected variation in consumer demand across varieties.

In addition, product variety exacerbates information asymmetry between the upstream and downstream firm. The information asymmetry can be in both directions. On the one hand, a downstream firm has better information about consumers' willingness to pay for various varieties and may not accurately share that information with the upstream firm. In our context, the Bottler collects most of the demand information directly from the stores when its truck

drivers make deliveries or when its sales representatives conduct routine inspections of store shelves. The downstream firm may under-forecast demand so that (1) the upstream firm extracts less value (e.g., in the form of franchise or license fees); (2) the downstream firm produces less of the variety that does not maximize its profit; or (3) the downstream firm has more freedom to manufacture other varieties (Yehezkel, 2008), including varieties for other upstream firms. Sharing markets, facilities, and production processes across multiple product varieties makes it difficult for the upstream firm to separate the demand, costs, and performance of individual varieties for evaluation, compensation, and, therefore, contracting.

On the other hand, an upstream firm might hesitate to share proprietary information down the value chain, especially if the downstream firm also manufactures for other upstream firms. The upstream firm's proprietary knowledge about technological innovation and product design, as well as its plans for promotions and new product launches, can be more readily leaked to competitors with whom they share production or distribution facilities. Strategic information withholding by upstream firms due to concern over leakage in the supply chain is prevalent in many contexts with differentiated products (Anand & Goyal, 2009). These concerns may cause the upstream firm to restrict its downstream firm's access to strategic information, even when those restrictions hinder coordination (Novak & Stern, 2009). In private conversations with us, the Bottler's forecasting staff often complained about how, before integration, the CP waited until the last minute to give them accurate information about promotion and launch plans, leaving the Bottler too little time to refine its sales forecasts and plan production. When the CP launches a new variety without giving the Bottler sufficient lead time, the Bottler will not be able to adequately account for the substitution effect between the demand for the new variety and the demand for the existing varieties; it will therefore over-forecast the demand for the existing

varieties. On the other hand, when the CP announces a price promotion for an existing variety too late, the Bottler will under-forecast the demand for the existing variety. Therefore, secrecy on the part of the CP about either new variety launch or old variety promotion against the Bottler leads to forecast noise.

In sum, expanding in a new product category increases sales volatility, as well as production and distribution costs. If the strategic value of product variety outweighs these additional costs, then the jointly optimal decision along the value chain should be to increase variety. However, contracting between the upstream and downstream firms to achieve a jointly optimal outcome is not easy. Increasing product variety increases the number of contingencies that need to be covered, monitored, and enforced under a contract. In addition, to the extent that different product varieties are interdependent in their needs for resources and adjustments, the contract may get overly complex or even infeasible. Because of these contracting problems *we expect the Bottler to have a higher stockout rate for NonCSDs than for CSDs before integration.*

Vertical Integration and Coordination

Vertical integration can improve coordination in several ways. First, it aligns incentives by providing both transacting parties ownership over residual claims (Williamson, 1985; Hart and Moore, 2005). It subjects organizational units to more compatible profit objectives that facilitate an integrated response to changes in global circumstances (Gulati, Lawrence, & Puranam, 2005; Lawrence & Lorsch, 1967), such as rapidly evolving technology and consumer demand (Weigelt & Sarkar, 2012). Second, vertical integration enables closer monitoring of employee effort (Hart, 1995; Williamson, 1975). Similar to arguments made by Joskow (2008), employees within a subsidiary have more incentive (e.g., avoiding termination for false reporting) and obligation to reveal information to the parent company than employees within a less closely affiliated

contractor; the parent company also has more authority and means (e.g., internal auditing) to collect information from its own subsidiary than from a less closely affiliated contractor. Finally, vertical integration facilitates information sharing by weakening the incentives for knowledge appropriation and better protecting trade secrecy (Nickerson & Zenger, 2004; Novak & Stern, 2009).

In our context, after integration the Bottler has greater incentive to carry more NonCSDs, therefore it will be more likely to increase inventory. The Bottler will also have more incentive and obligation to share information with the CP, and the CP will have more authority to visit the stores to assess demand and evaluate sales forecasts directly. Finally, the Bottler will have greater incentive and obligation to protect the CP's proprietary information, so that the CP will share its promotion and product launch plans with the Bottler in a timelier manner, thereby enabling the Bottler to make more accurate adjustments to its forecasts and production schedule. *We therefore expect the Bottler to have a lower stockout rate for the products of its CP parent after integration, particularly among NonCSDs.*

Vertical Integration and Competition

Vertical integration offers competitive advantages in oligopolistic industries. Mainly, the integrated firm can foreclose either sources of supply or channels of distribution to prevent their non-integrated rivals from accessing these sources or channels (Chipty, 2001; Hart et al., 1990). In the soft drink industry the upstream segment is occupied by a small number of CPs, while the downstream segment is populated by a large number of bottling plants and distribution centers owned by a few dozen "bottlers." This gives the large upstream CPs more bargaining power over the bottlers. The large CPs' bargaining power is further enhanced by the bottler's need for large

contracts to achieve economies of scale to improve their thin profit margin. Under such conditions, the large upstream firms can use exclusive contracts to secure supply.

However, even with business from the major upstream firms, some downstream firms may not have enough volume to maximize economies of scale. This makes it advantageous for them to contract with smaller upstream firms that need to source downstream production plants and distribution networks but lack the volume to justify an exclusive contract. In such cases, the large upstream firm can share its downstream facilities with smaller upstream firms, provided that the downstream firm does not carry rival products that are in direct competition with products of the large upstream firm. For example, in our context, Coca-Cola and Pepsi each allow their bottlers to defray the high capital costs of bottling facilities and distribution networks by carrying products for their smaller competitors under license agreements. In fact, bottlers for Coca-Cola and Pepsi each manufacture and distribute about one-third of Dr. Pepper's products. Given that this sharing arrangement mainly results from concerns about economies of scale, it might create constraints along other dimensions (e.g., production introduction and coordination).

We do not conceptualize our particular context as a world where firms play strategic games with full rationality and foresight. Rather, we view the firms as following an evolutionary process in adapting their product-introduction and vertical-integration decisions. The old arrangement in which Coca-Cola and Pepsi owned a minority share (<40%) in their downstream facilities and share the facilities with smaller CPs through contracts discouraged (but did not totally prohibit) new product introductions. As new product introduction became more important due to the exogenous shift in consumer demand toward healthier NonCSDs, the disadvantage of the contractual arrangements became more and more constraining. One way to overcome these disadvantages is vertical integration.

Therefore we examine a more subtle form of “foreclosure” that happens not through a total denial of the competitors’ access to production resources or distribution channels, but through a substitution of coordination along the value chain. More specifically, vertical integration can align incentives and the flow of information between an upstream firm and its downstream subsidiary, while at the same time magnifying incentive and information problems between the subsidiary and the upstream parent’s competitors that also source from the subsidiary. The subsidiary may now maximize its parent’s market share at a cost to the parent’s rivals. The subsidiary may reduce its inventory holding and demand forecasts for rival products. The rivals may also feel less comfortable sharing strategic information with the subsidiary, leading to noisier demand forecasts for their products.¹ Even when an integrated company does not intentionally foreclose its rivals, the increase in internal coordination demands between the subsidiary and its upstream parent after integration might crowd out coordination for rival products. Because of this substitution in coordination, *we expect the Bottler to have a greater stockout rate for rival’s products after integration.*

THE SOFT DRINK INDUSTRY AND THE BOTTLING COMPANY

The soft drink industry is dominated by two CPs, Coca-Cola and Pepsi. Most bottlers in the soft drink industry used to be independently owned but had exclusive long-term partnerships with a CP. Bottlers purchase concentrate from the CP, add carbonated water and high-fructose corn syrup, bottle the resulting beverage, and deliver it to customers. Coca-Cola and Pepsi bottlers provide direct store delivery, where the bottlers’ sales or delivery staff routinely visit the stores

¹ Of course, foreseeing that coordination problems could lead to a loss of revenue from other upstream firms after integration, the downstream firm’s current shareholders may demand an acquisition premium from the acquiring parent. However, if the strategic value of integration is greater than the potential loss of revenue from the competitors, the parent and the downstream shareholders will be able to reach an agreement to split the net gain from integration.

to survey sales, check product display, stock the shelves, and place orders for replenishment (Cokesolutions, 2015). The bottling process is capital-intensive and relies on high-speed production lines; changing between products of different type or sizes is difficult. In contrast, the distribution process is largely influenced by “drop size” (size of each delivery). As a result, bottlers prefer to distribute standard products with steady and high demand. To achieve greater scale economy, anchor bottlers for Coca-Cola and Pepsi also produce and distribute for their CP partner’s rivals, provided these products do not compete directly with their CP partner’s products.

Over the last decade, major soft drink companies have been under increasing pressure to expand their product lines because consumers are shifting to healthier, NonCSD drinks. For example, while U.S. soda consumption slid for the tenth straight year in 2014, the U.S. bottled-water consumption jumped by 7.3% (The Wall Street Journal, 2015). According to a recent Gallup survey, more than 60% of Americans now avoid soda (Beverage Daily, 2015). This has shifted both Coca-Cola and Pepsi’s strategic focus toward NonCSDs. However, most NonCSDs have required smaller, specialized production processes that were challenging for bottlers’ existing infrastructure. Adding to the problem is the relatively small volume and uncertain demand for NonCSD sales, leading to higher production and distribution costs. As a result, bottlers are less inclined to carry NonCSDs.

In response to the pressing need from the market to expand their product lines, and the lack of incentive for bottlers to cooperate with that expansion, in 2009–2010 both Coca-Cola and Pepsi fully integrated their largest bottlers. Before the integration, each CP had owned a 30% to 40% shareholding stake in its anchor bottlers; the rest of the shares were publicly traded. After the integration, both CPs established wholly owned subsidiaries that bought out all the shares in

the bottlers.² Both CPs claimed that the change would give them greater flexibility to adapt to consumer tastes, more direct control over investments in the bottling processes, and the ability to coordinate. According to Indra Nooyi, CEO of Pepsi, “The fully integrated beverage business will enable us to bring innovative products and packages to market faster, streamline our manufacturing and distribution systems and react more quickly to changes in the marketplace, ... Ultimately it will put us in a much better position to compete and to grow both now and in the years ahead” (Pepsi Press Release, 2009). Muhtar Kent, CEO of Coca Cola, gave similar comments: “Our North American business structure has remained essentially the same since ... 1986, while the market and industry have changed dramatically. ... With this transaction, we are converting passive capital into active capital, giving us direct control over our investment in North America to accelerate growth and drive long-term profitability”(Coca Cola Press Release, 2010).

Our data come from the largest anchor bottler for one of the two dominant CPs. The Bottler owns dozens of bottling plants and hundreds of distribution centers (DCs), accounting for more than half of the beverages its CP sold in North America. Like most of its competitors, the Bottler employs a make-to-stock (as opposed to make-to-order) inventory system. Products are produced and stocked at a stable pace according to a forecast of future sales, i.e., before customers place actual orders. Orders are placed based on the CP parent’s product lists, national advertisements, and promotion deals without knowledge of the DCs’ actual inventory.

² Because of the big difference between the CP’s and the bottler’s business models and profit margins, partial ownership does not sufficiently solve the incentive or information problems between the two parties. Vertical integration fully aligns the two entities’ incentives, thereby improving coordination. Empirically, studying a transition from partial ownership (as opposed to from an arms-length relationship) to integration implies that our estimation of the integration impact is more conservative.

The Bottler delivers its products on trucks to retailer stores both large (e.g., supermarkets) and small (e.g., convenience stores). Stockouts occur when a DC cannot deliver an entire order to a given retail outlet. Unfilled demand is not backordered. New orders are placed based on the retail store's current inventory levels. Demand is forecasted for eight, four, and two weeks in the future and updated every week on a rolling-horizon basis. Production plans are based on the four-week-advance forecasts and the current inventory level. The Bottler tries to retain four weeks of forecasted demand in inventory at the beginning of every four-week period, though actual inventory varies both across product categories and over time.

EMPIRICAL DESIGN

The exogenous shock in the demand for Non-CSDs became especially salient toward the end of the last decade. The upstream CPs responded with an increased rate of product introductions in the non-CSD category. The newness of these products implies more information asymmetry: the upstream firm will have greater uncertainty about consumers' willingness to pay, while the downstream firm will find it more difficult to predict the upstream firm's product promotion and launch plans. This is therefore a valuable period of time to carry out our empirical investigation.

Data and Sample

We obtained operations data for all U.S. DCs from the beginning of 2008 to the second month of 2011. Together these 264 DCs delivered thousands of SKUs over the sample period, including SKUs owned by the CP parent and SKUs delivered for other companies under license agreements. An SKU is defined as a unique combination of brand, flavor, weight, container material, container size, and package size. It is a commonly used measure of product variety (Fosfuri & Giarratana, 2009). Our data is weekly except for inventory, which is only available at the period level. Each period contains four weeks. In order to accommodate the frequency of the inventory data and to save computation time, we aggregated the data to the period level.

We first examined some summary statistics at the DC level. We found that on average about 37% of the SKUs and 20% of the sales carried by a DC were for NonCSDs. In addition, there was a significant increase in both the number of SKUs and total sales at the DC level after integration, especially for NonCSDs. The number of NonCSD SKUs increased by 27%, NonCSD sales per DC increased by 15%, and the share of NonCSD sales increased by 2%.

To compare operations variables before and after integration, we limited our sample to those SKUs that the 264 DCs carried at the time of integration, including about 1,200 SKUs owned by the CP parent and 300 SKUs delivered to other upstream CPs under license agreements. Our final sample contains about two million DC–SKU–period observations.

Variables

We first examined $Stockout_{sit}$, a dummy variable that takes the value of 1 if SKU s experiences at least one stockout at DC i in period t , and is 0 otherwise. We then examined a few other operations variables in order to explain any change we observed in stockouts. Among them, $Inventory_{sit}$, is inventory (in days of sales) of SKU s carried by DC i in period t . $Sales\ forecast\ level_{sit}$ is the ratio between actual and forecasted sales of SKU s carried by DC i in period t . It is also called AF ratio, a standard measure of forecast accuracy in operations management. It reflects the bias in sales forecasts. $Sales\ forecast\ noise_{sit}$ is the standard deviation in weekly AF ratios for SKU s carried by DC i in period t . It reflects the noise in sales forecasts.

Our main independent variables include $Integration_t$, a dummy variable that indicates the time periods after the integration, $NonCSD_s$, a dummy variable that indicates whether the SKU is a NonCSD product, and the interaction term between $Integration_t$ and $NonCSD_s$. We also included several control variables, all at the DC–SKU–period level, that might affect each dependent variable. Among them, $Sales_{sit}$ is the quantity (in standardized cases) of SKU s sold by

DC i in period t , log transformed. $Sales\ Volatility_{sit}$ is measured using the coefficient of variation (CV) in sales, or the standard deviation of sales normalized by its mean.

Table 1 provides sample descriptive statistics and correlation matrix for the combined sample of own- and rival products. The unit of analysis is DC–SKU–period. An average SKU had a 25% chance of stockouts at a DC in every period. About 40% of the observations were for NonCSDs. An average SKU was sold in 154 ($\exp(5.04)$) cases per period per DC. The volatility in weekly sales for an average DC–SKU–period was 0.17. The average inventory was about 31 days of actual sales. The average AF ratio was 1.01. That is, on average, sales forecasted by DCs were about 99% of actual sales. The standard deviation in forecasting was 0.14.

Insert Table 1 about here

Table 2 compares mean values before and after integration, for own-CSDs, own-NonCSDs, and rival brands, respectively.³ A few key differences can be observed from the table. First, before integration DCs sold far more own-CSDs ($\exp(5.58)=265$ cases per DC-SKU-period) and rival CSDs ($\exp(5.39)=219$ cases) than own-NonCSDs ($\exp(4.47)=89$ cases). Secondly, there was no significant change in stockout rates for own-CSDs after integration. In comparison, there was a significant reduction in stockout rates for own-NonCSDs ($p\text{-value}=0.040$) and an increase in stockout rates for rival products ($p\text{-value}=0.080$). Thirdly, there was a reduction in sales per SKU and an increase in sales volatility across the board, most likely due to increased product variety. Fourthly, DCs kept more inventory for NonCSDs than for both own- and rival CSDs, reflecting the extra buffer needed to satisfy uncertain and more volatile NonCSD sales. After

³ The majority (95%) of rival products were CSDs; we therefore did not separately examine rival-NonCSD products. Even though the Bottler carried mostly CSD products for the upstream rivals, the upstream rivals could still learn from the Bottler Coca-Cola and Pepsi's plans for NonCSDs and use this information to develop their own NonCSD products bottled by themselves or other plants.

integration, inventory increased for own-CSDs and rival products but decreased for own-NonCSDs ($p\text{-values} < 0.0001$). Finally, DCs' sales forecast became less noisy for own-products but more noisy for rival products ($p\text{-values} < 0.0001$). Of course, these mean comparisons do not control for any factor that might influence these variables, such as time trend, seasonal fluctuation, or unobservable heterogeneity at the DC–SKU level. We will consider these factors in our econometric analyses.

 Insert Table 2 about here

Specifications

We designed most of our specifications based on standard textbooks of operations management (e.g., Anupindi *et al.*, 2011; Cachon & Terwiesch, 2012). We included DC–SKU and seasonal fixed effects and an annual trend in all main specifications. For linear regression models, we also clustered robust standard errors at the DC level to account for correlation among SKUs carried by the same DC.

Our main regression estimated stockout rate for products owned by the CP parent at the DC–SKU–period level:

$$E[\text{Stockout}_{sit}] = DCSKU_{si} + \text{Season}_t + \alpha_0 \text{Annual trend}_t + \alpha_1 \text{Integration}_t + \alpha_2 \text{Integration}_t * \text{NonCSD}_s + X_{sit}\gamma \quad (1),$$

where $DCSKU_{si}$ and Season_t are DC-SKU pair and season fixed effects, respectively.

According to these textbooks, assuming sales follow a normal distribution, the probability of stockouts (stockout rate) can be illustrated as the probability of the actual demand being greater than the available inventory; such probability depends on sales quantity and volatility. We therefore include them as control variables in X_{sit} .

We then compared a few operations variables that might have contributed to the change in stockouts. To do that, we estimated the following fixed-effects specifications:

$$DV_{sit} = DCSKU_{si} + Season_t + \alpha_0 Annual\ trend_t + \alpha_1 Integration_t + \alpha_2 Integration_t * NonCSD_s + X_{sit}\gamma + \varepsilon_{sit} \quad (2),$$

where DV_{sit} represents different operations variables such as inventory, and sales forecast (both level and noise), as defined before.

Finally, we replicated Equations (1) and (2) on the subsample of rival products to identify any difference between the own- and rival products in changes after integration.

RESULTS

Pre-integration Coordination (Own Products)

Table 3 compares stockouts and the other main operations variables for CSDs and NonCSDs owned by the CP parent before integration. The coefficients in Columns (1)–(4) are consistent with our expectation. NonCSDs had a higher rate of stockouts. A marginal effect calculation (keeping all other variables at their mean values) shows that NonCSDs were 6% more likely to experience a stockout than CSDs. This was despite the fact that NonCSDs had five more days of buffer inventory. DCs also tended to under-forecast sales more for NonCSDs, and the standard deviation in sales forecast for NonCSDs tended to be higher than that for CSDs. The *p-values* were less than 0.001 for all these coefficients.

 Insert Table 3 about here

Column (5) investigates any time trend in stockouts before integration. For each DC–SKU pair we compared the stockouts two years before the integration and the stockouts for the last period before integration. The dependent variable, pre-integration increase in stockouts, assumed

the value of 1 if the DC–SKU pair did not experience a stockout two years before integration but experienced a stockout during the last period before integration. A marginal effect calculation based on the coefficient (keeping all other variables at their mean values) shows that NonCSDs were 3% ($p\text{-value}<0.001$) more likely to experience an increasing likelihood of stockouts before integration.

Post-integration Coordination (Own Products)

Table 4 estimates the probability of stockouts for the CP's own products. All models included an annual trend, seasonal dummies, and DC–SKU fixed effects. A marginal effect calculation based on Column (1) suggests that stockout rate fell by 2% ($p\text{-value}<0.001$) after integration, from a pre-integration stockout rate of 26%. The change is sizable given that it happened during the short period of one year after integration. Interviews with the Bottler's management confirmed that there had not been any significant adjustments in the Bottler's operations, such as investments in physical assets and equipment or a reallocation of sourcing relationships, that would have dramatically improved production capacity and reduced stockouts.

Columns (2) and (3) show a negative coefficient to the interaction between integration and NonCSD dummies ($p\text{-values are } 0.035 \text{ and } 0.079, \text{ respectively}$). However, the significance of the interaction term in logit models may not be read directly from the coefficients (Hoetker, 2007; Norton, Wang, & Ai, 2004; Wiersema & Bowen, 2009). To properly interpret the interaction term, we first examined the odds ratios (Buis, 2010). Our calculation based on Column (3) suggests that the odds of a stockout was 5% lower after integration, and the odds of a stockout after integration for NonCSDs was 0.98% of the odds for CSDs. In addition, we estimated stockouts separately for CSDs and NonCSDs in Columns (4) and (5). Results show a highly significant reduction in stockouts for NonCSDs after integration ($p\text{-value}<0.001$) and a less

significant reduction in stockouts for CSDs ($p\text{-value}=0.050$). A Wald's test confirms that the difference in the integration coefficients across the two groups is statistically significant ($p\text{-value}<0.001$).⁴ These additional tests support our expectation that stockouts decreased more for NonCSDs than for CSDs after integration.

Insert Table 4 about here

Alternative Explanations. Integration can bring about multiple benefits other than improving coordination between the CP and the Bottler (Financial Times, 2009b; The Wall Street Journal, 2010). Some of these benefits are alternative explanations for the integration decision, although they will not necessarily reduce stockouts. For example, integration helps introduce more innovative products, but this will not reduce stockouts for products in our sample, which includes only products that the Bottler was already carrying at the time of the integration. If anything, increasing product variety increases rather than reduces stockouts (Anderson, Fitzsimons, & Simester, 2006b; Musalem *et al.*, 2010; Wan *et al.*, 2012). Integration benefits that are unrelated to stockouts would make our estimation less endogenous and more conservative. In addition to product innovation, integration might also create opportunities for process innovation that could potentially reduce stockouts. Because a large number of own- and rival products share the same facilities and processes (which drives scale economy for the Bottler in the first place), we estimated separately the change in stockouts for own- and rival products after integration. Column (1) in Table 7 suggests that stockouts for rival products increased rather than decreased after integration, refuting the process-innovation story. Our interviews with company staff also

⁴ To account for potential difference in residual variations across the two groups, we also followed Hoetker (2006) and calculated the difference in a ratio of two coefficients, e.g. coefficients for integration and $\log(\text{sales quantity})$ (or sales volatility). These calculations confirmed that the negative effect of integration (relative to the effect of sales quantity or volatility) was both economically and statistically more significant for NonCSDs than for CSDs.

confirmed that no significant process changes had been made during the short duration of our sample period.

An alternative explanation for the reduction in stockouts is unobserved factors (omitted variables). For example, it could be that the CP decided to integrate (and obtain a larger share of the Bottler's profit) because the change in consumer preferences had made NonCSD products more profitable for the DCs. At the same time, if NonCSD products became more profitable for a DC, it would have also carried more NonCSDs and thereby reduced stockouts. Factors like this could drive a spurious relationship between integration and stockouts. Unfortunately, we do not have price or profit information at the product level to control for this. Instead, we took a few steps to mitigate this concern. First, if DCs carry more NonCSDs because they become more profitable, these products should experience an increase in sales. Therefore we control for sales quantity and time trend in all of our regressions. Second, as a robustness check we performed a test that corrects for selection at the DC level. We exploited the fact that a number of states had imposed and credibly threatened a penalty for soda consumption during our sample period.⁵ Based on this information, we first estimated the likelihood that a DC had more than 20% of sales from NonCSDs during our sample period; these DCs are called diversified DCs. Our results show that DCs in states with a soda penalty were more likely to be diversified. In the second stage, we estimated the likelihood that a DC reduced stockouts after integration, correcting for self-selection using an Inverse Mills Ratio calculated from the first stage. Our results are included in the online Appendix. They confirm that after correcting for selection diversified DCs

⁵ For example, Washington imposed a \$0.02 per ounce tax on CSDs in 2010 (The Seattle Times, 2010) and New York proposed a \$0.01 per ounce tax on soft drinks in its 2009 state budget (The New York Times). Virginia imposed a state excise tax on soda in addition to a sales tax. A number of other states, such as Maryland, levy sales taxes on soda but not on other grocery food (Pinho, 2012).

were still more likely to see a reduction in their average stockout rate after integration, which is consistent with our main results in Table 4.

In sum, while multiple expected benefits can explain the CP's motivation to vertically integrate, not all of them can explain the reduction in stockouts that we observe in Table 4. The next subsection will examine a few operations variables to shed light on the exact mechanisms through which stockouts reduced after integration.

Inventory and Sales Forecasts. Table 5 explores a few mechanisms that could reduce stockouts. The most obvious one is to increase inventory. While before integration the DCs might not be willing to hold too much inventory at the cost of working capital, after integration they should have more incentive to do so. Table 5 first compares inventory before and after integration. Coefficients in Column (1) suggest that, as expected, inventory of own-CSDs increased by close to a day of sales after integration ($p\text{-value} < 0.001$). However, to our surprise, inventory of own-NonCSDs decreased by three days ($p\text{-value} < 0.001$). This implies that if inventory for NonCSDs had not been reduced after integration, the stockout rate for NonCSDs would have fallen even more.

Insert Table 5 about here

One potential explanation for the reduction in *both* stockouts and inventory is that within each four-week period the fluctuation in inventory more closely matched that in sales after integration; therefore stockouts could fall despite less period-average inventory relative to sales. Unfortunately, we do not have daily or weekly inventory data to test this idea at a granular level, even though we notice that the standard deviation of inventory in days of sales during the post-integration period was two days less than before integration.

One of the most important ways to better match inventory to sales is through more accurate sales forecasting. After all, real-time inventory (in days of sales) is determined based on forecasted quantity, adjusted with the lagged actual-to-forecast (AF) ratio and forecast noise (standard deviation in AF ratio) (e.g., Anupindi et al., 2011; Cachon & Terwiesch, 2012). More accurate sales forecasts will not only better match inventory and sales to reduce stockouts, but also give DCs the confidence to hold less “buffer” inventory.

Column (2) compares sales forecast. It suggests that DCs increased their sales forecasts (reduced AF ratio) from about 99% to 100% of actual sales after integration ($p\text{-value}=0.004$). We argued in the theory section that improved sales forecasting could be caused by better monitoring and more information sharing by the CP. To test this mechanism, column (3) adds a dummy to capture if the DC is in the same or a neighboring state of the CP parent. A number of scholars have found that the integration benefit of better monitoring is more prevalent for units that are geographically near headquarters than for units that are far away (Brickley & Dark, 1987; Kalnins & Lafontaine, 2013; Rubin, 1978). This is because monitoring often requires managers from headquarters to visit the units routinely, which can be costly for units in remote locations. Consistent with this line of logic, the coefficients in column (3) confirm that the upward correction in sales forecasts was mostly experienced by DCs that were located near the CP ($p\text{-value}=0.011$). Column (3) also included the age of the product (number of periods since its initial launch). Older products have more sales information to reduce forecast bias and should benefit less from integration. This coefficient is supportive but not statistically significant.

Columns (4) and (5) compare the noise in sales forecasts. Results suggest that DCs reduced the noise in their sales forecasts after integration ($p\text{-value}<0.001$), and the reduction was greater for DCs far away from the CP ($p\text{-value}=0.001$). Consistent with our arguments above, DCs close

to the CP would be able to partially observe some “hint” that the CP will initiate a new product launch or promotion, whereas a DC far away would have to wait for the CP’s explicit notification. DCs faraway therefore experienced a greater information disadvantage before integration and would benefit more from integration. Column 5 also confirms that forecasts of newer products benefited (experienced a greater reduction in forecast noise) from integration ($p\text{-value}<0.001$).

Overall, results in table 5 suggest that the joint reduction in *both* stockout rates and inventory after integration was due to an overall improvement in coordination efficiency, most likely reduced information asymmetry in both directions. While reductions in the bottler’s information misrepresentation (i.e., increasing sales forecasts) after integration can explain the reduction in inventory in days of forecasted sales, it cannot not explain the reduction in inventory in days of actual sales. We think the inventory reduction (beyond what can be explained by reduced forecast bias) may be due to the DCs reducing buffer inventory as they became more confident in a less noisy sales forecasts. In a supplementary analysis, we do find that inventory was positively associated with both the downward forecast bias and forecast noise in the previous period.

In order to see if inventory and sales forecasts explain the reduction in stockouts, in Table 6 we re-estimated stockouts with the additional variables of inventory and sales forecasts. The results first confirm that stockouts were negatively related to inventory and positively correlated with AF ratio and noise in sales forecasts. In addition, columns (1) and (2) confirm that after controlling for the changes in inventory, stockouts increased for CSDs ($p\text{-value}=0.069$) and reduced even more) for NonCSDs ($p\text{-value}<0.001$). Columns (3) and (4) confirm that after controlling for the improvement in sales forecasts, the change in stockouts became smaller.

Wald's tests of these coefficients across models suggest that their differences are statistically significantly.

Insert Table 6 about here

Vertical Integration and Rival Products

To facilitate a comparison with the CPs' own products, Table 7 estimates the changes in stockouts, inventory, and sales forecasts for the products of rival CPs. The coefficients show that the stockout rate and forecast noise increased while inventory and sales forecast reduced after integration ($p\text{-value} < 0.001$), consistent with our expectation.

Insert Table 7 about here

In sum, the results in Tables 4–6 imply that, despite the increased sales volatility that accompanies a greater level of variety in the NonCSD category, DCs were able to reduce both stockouts and inventory for own-NonCSDs after integration. This is consistent with DCs having more incentive to increase sales forecast levels and having better information to reduce noise in their forecasting. In contrast, Table 7 suggests that there was a deterioration in DCs' operational performance for rival products, in terms of both holding adequate inventory and accurately forecasting sales.

In addition to the main results in Tables 3–7, we ran a host of robustness checks. For example, to reduce potential simultaneity we lagged all independent variables. To avoid any estimation bias due to some dependent variables being left-censored, we re-estimated these variables using their logtransformed values and Tobit models, respectively. Our main results were robust to these alternative specifications.

DISCUSSION AND CONCLUSIONS

This paper studies how product variety creates coordination problems along the value chain, and how vertical integration helps to solve these problems through incentive alignment and information sharing. In particular, we examined challenges between a concentrate producer (CP) and its anchor bottler in coordinating product introduction, manufacturing, and distribution. We show that, in this particular case, vertical integration had a positive impact on coordination (in terms of stockouts, inventory, and sales forecast) for the CP's own products but a negative impact on coordination for products the bottler carried for the CP's rivals.

The key theoretical contribution of the paper is to marry two primarily unrelated streams of prior work on product variety and vertical scope. It relates product scope extension to coordination challenges along the value chain and examines the coordination benefits and tradeoffs of vertical integration. It complements recent studies on the coordination challenges firms face when they pursue economies of scope. It also complements studies on the coordination benefits of vertical integration for enhancing firms' adaptability. Finally, by highlighting how an integrated firm improves coordination at the cost of its upstream rivals, the paper implies an intricate mechanism of non-price discrimination.

A second theoretical contribution of the paper is to bridge existing work on product variety in operations management and strategy, respectively. On the one hand, even though there is a large body of mathematical models about variety-related problems in operations management, these models are usually built at the level of a single plant or production line. Studies about variety and the interaction between organizational units along the supply chain are rare. This paper fills this gap. At the same time, while there is a large body of literature on the benefits of vertical integration in strategy, the empirical investigation has been limited to aggregate, firm-level performance under different governance modes or to a single performance measure at the

transaction level. By incorporating basic models from operations management on stockouts, inventory, and sales forecasts, this paper paints a more complete picture of the mechanisms behind coordination and vertical integration.

The paper has a few limitations that create opportunities for future research. Because this is a case study of one company, it cannot answer the general question of whether an increase in product variety should be accompanied by an increase or a reduction in vertical scope. On the one hand, product scope and vertical scopes may be complementary because vertical integration allows firms to exercise stronger control over resources and processes that are shared across related markets (Forbes & Lederman, 2009; Novak & Stern, 2009). On the other hand, because firms are constrained in their total coordination capacity, their product and vertical scopes may act as substitutes (Zhou, 2011). Our study presents one scenario where vertical integration improves product-level efficiency for the integrated company, to the disadvantage of its rivals. This is consistent with both the coordination-benefit and coordination-capacity-constraint arguments.

Firm scope is a dynamic phenomenon that shifts with the relative magnitude of transaction and integration costs. Integration is justified when benefits of a coordinated response to environmental changes outweigh the potential organization and production costs that can be saved through outsourcing, or when firms need to develop integrative capabilities to face future challenge of successive system innovations (Helfat & Campo-Rembado, 2016). In the context of this study, the CPs integrated their bottlers, in spite of low profit margins in the bottling business, in order to achieve a coordinated response at a time when consumer demand for NonCSDs was

evolving rapidly.⁶ Historically, CPs have repeatedly integrated and disintegrated their bottlers. The recentness of this particular integration event prevents us from investigating whether the integration benefits are sustainable given the worsening service for upstream rivals' products and the potential burden of coordinating the integrated firm. On the one hand, integration provides incentives for more information sharing. On the other hand, integration removes the boundary that used to insulate the upstream and downstream firms from each other and imposes more complex relationships between the two. Only three years after acquiring their bottlers, both CPs announced that they intended to rebrand their distribution networks (Beverage Daily, 2013; Coca-Cola Company Press, 2016). Future studies may examine the CPs' performance in the now more mature NonCSD segment after franchising.

Studying hundreds of organization units and thousands of product varieties within a single company allowed us to eliminate unobserved firm heterogeneity and extract detailed operations data about key elements of coordination. However, we did not have a control group that could help us to identify the causal effect of integration more sharply. While we cannot fully solve this endogeneity issue, we tried to mitigate it by (1) ruling out alternative explanations, (2) adding a strict set of control variables and fixed effects, (3) adopting a selection model and other robustness checks, (4) comparing post-integration changes in multiple operations variables to construct a cohesive story, (5) exploiting pre- and post- integration differences across various product categories (CSDs vs. NonCSDs, own- vs. rival, new vs. old) and distribution centers (those close to vs. those far away from the CP headquarters, those diversified vs. those never

⁶ In addition to potentially lower profit margin in adjacent stages along the value chain, firms that vertically integrate might also suffer from a lack of expertise and experience in the acquired stages. In our particular setting, the CP has had a close partnership with the Bottler for decades. It also retained most of the production equipment and management of the Bottler after integration. Therefore, the integrated firm can still benefit from the Bottler's manufacturing expertise and experience.

significantly diversified), and (6) using rival products as a “placebo” or “falsification” test that further removes some time-varying DC characteristics. By using this comparative approach, the paper aimed to identify the exact mechanisms that could explain the change in stockouts.

In conclusion, this paper highlighted the intricate and important challenges facing firms that pursue product variety. It showed that vertical integration plays a positive role in coordination by aligning incentives and facilitating information sharing along the value chain. At the same time, integration has the potential to crowd out coordination for rival products.

Acknowledgement

The authors gratefully acknowledge the thoughtful suggestions provided by Gautam Ahuja, Ravi Anupindi, Seth Carnahan, Sendil Ethiraj, Wally Hopp, Aseem Kaul, Jun Li, Xiaoyang Li, Gabriel Natividad, Amy Nguyen-Chyng, Catherine Thomas, James Westphal, Editor Connie Helfat, and two reviewers. We appreciate the questions and comments raised by participants at University of Maryland and University of Michigan strategy seminars, the Academy of Management Meetings, Midwest Strategy Meetings, NYU Econ Strategy Workshop, Strategy Management Society Meetings, Strategic Research Forum, and the Tuck Strategy Summer Camp. All errors remain ours.

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Table 1 **Summary statistics and correlation matrix**

| Variable | Mean | SD | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|--|-------------|-----------|------------|------------|------------|------------|------------|------------|------------|------------|
| (1) Stockout (1,0) | 0.25 | 0.44 | 1.00 | | | | | | | |
| (2) Integration (1,0) | 0.37 | 0.48 | -0.001 | 1.00 | | | | | | |
| (3) NonCSD (1,0) | 0.42 | 0.49 | 0.01 | -0.002 | 1.00 | | | | | |
| (4) Sales | 5.04 | 1.68 | 0.15 | -0.05 | -0.31 | 1.00 | | | | |
| (5) Sales volatility | 0.17 | 0.16 | 0.01 | 0.03 | 0.08 | -0.54 | 1.00 | | | |
| (6) Inventory (in days of sales) | 31 | 32 | -0.10 | -0.01 | 0.20 | -0.45 | 0.36 | 1.00 | | |
| (7) Sales forecast level (AF ratio) | 1.01 | 0.34 | 0.12 | 0.03 | -0.05 | 0.18 | -0.07 | -0.31 | 1.00 | |
| (8) Sales forecast noise | 0.14 | 0.10 | -0.03 | -0.004 | 0.06 | -0.25 | 0.35 | 0.11 | -0.03 | 1.00 |

Table 2

Mean comparison

| Own-CSDs | Pre-integration | Post-integration | Difference (p-value) |
|---------------------------------|------------------------|-------------------------|-----------------------------|
| Stockout (1,0) | 0.26 | 0.26 | 0 (0.907) |
| Sales | 5.58 | 5.50 | -0.08 (0.000) |
| Sales volatility | 0.15 | 0.16 | 0.01 (0.000) |
| Inventory (in days of sales) | 24.90 | 25.21 | 0.31 (0.000) |
| Sales forecast level (AF ratio) | 1.01 | 1.03 | 0.02 (0.000) |
| Sales forecast noise | 0.140 | 0.137 | -0.003 (0.000) |

| Own-NonCSDs | Pre-integration | Post-integration | Difference (p-value) |
|---------------------------------|------------------------|-------------------------|-----------------------------|
| Stockout (1,0) | 0.26 | 0.25 | -0.01 (0.040) |
| Sales | 4.49 | 4.30 | -0.19 (0.000) |
| Sales volatility | 0.18 | 0.19 | 0.01 (0.000) |
| Inventory (in days of sales) | 38.69 | 36.85 | -1.84 (0.000) |
| Sales forecast level (AF ratio) | 0.98 | 1.01 | 0.03(0.21) |
| Sales forecast noise | 0.152 | 0.15 | -0.002 (0.000) |

| Rival products (mostly CSDs) | Pre-integration | Post-integration | Difference (p-value) |
|---|------------------------|-------------------------|-----------------------------|
| Stockout (1,0) | 0.24 | 0.25 | 0.01 (0.080) |
| Sales | 5.39 | 5.13 | -0.26 (0.090) |
| Sales volatility | 0.16 | 0.17 | 0.01 (0.000) |
| Inventory (in days of sales) | 25.75 | 26.77 | 1.01 (0.000) |
| Sales forecast level (AF ratio) | 1.07 | 1.04 | -0.03 (0.340) |
| Sales forecast noise | 0.14 | 0.15 | 0.01 (0.000) |

Table 3 **Coordination challenges for own products before integration**

| | DV = Stockout (1,0) | | Inventory (in days of sales) | | Forecast Level (AF) | | Forecast Noise | | Pre-integration increase in stockouts (0,1) | |
|-----------------------|----------------------------|---------|-------------------------------------|---------|----------------------------|---------|-----------------------|---------|--|---------|
| | (1) | | (2) | | (3) | | (4) | | (5) | |
| NonCSD (1,0) | 0.324 | (0.000) | 5.353 | (0.000) | 0.011 | (0.000) | 0.003 | (0.000) | 0.196 | (0.000) |
| | [0.005] | | [0.333] | | [0.002] | | [0.001] | | [0.018] | |
| Sales | 0.362 | (0.000) | -6.868 | (0.000) | 0.045 | (0.000) | -0.004 | (0.000) | 0.278 | (0.000) |
| | [0.002] | | [0.236] | | [0.001] | | [0.000] | | [0.005] | |
| Sales volatility | 2.002 | (0.000) | 34.506 | (0.000) | 0.147 | (0.000) | 0.200 | (0.000) | 2.659 | (0.000) |
| | [0.016] | | [0.903] | | [0.010] | | [0.004] | | [0.055] | |
| Season dummies | Yes | | Yes | | Yes | | Yes | | Yes | |
| Observations | 1,297,634 | | 1,297,634 | | 1,297,634 | | 1,297,634 | | 100,672 | |
| Log-likelihood | -711,038 | | -6.19E+06 | | -408,500 | | 1.27E+06 | | -45,197 | |
| Pseudo R ² | 0.036 | | 0.243 | | 0.041 | | 0.135 | | 0.045 | |

Logit estimation is used for columns (1) and (5), and ordinary least square linear regressions are used for columns (2)–(4). Standard errors for columns (1) and (5) and robust standard errors clustered at DC level for columns (2)–(4) are included in square brackets. The dependent variable in column (5) is the probability that a DC-SKU did not experience a stockout in the two years before integration but experienced a stockout in the last four-week period before integration. P-values are in parentheses. All tests are two tailed.

Table 4 **Vertical integration and stockout rate for own products**

| DV = Stockout (1,0) | (1) ALL | | (2) ALL | | (3) ALL | | (4) CSD | | (5) NonCSD | |
|----------------------------|----------------|---------|----------------|---------|----------------|---------|----------------|---------|-------------------|---------|
| Integration | -0.049 | (0.000) | -0.040 | (0.000) | -0.054 | (0.000) | -0.019 | (0.050) | -0.153 | (0.000) |
| | [0.007] | | [0.008] | | [0.008] | | [0.009] | | [0.010] | |
| NonCSD_X_Integration | | | -0.017 | (0.035) | -0.015 | (0.079) | | | | |
| | | | [0.008] | | [0.008] | | | | | |
| Sales | | | | | 0.490 | (0.000) | 0.415 | (0.000) | 0.567 | (0.000) |
| | | | | | [0.004] | | [0.006] | | [0.006] | |
| Sales volatility | | | | | 2.568 | (0.000) | 2.702 | (0.000) | 2.439 | (0.000) |
| | | | | | [0.016] | | [0.024] | | [0.023] | |
| Annual trend | Yes | | Yes | | Yes | | Yes | | Yes | |
| Season dummies | Yes | | Yes | | Yes | | Yes | | Yes | |
| DC-SKU pair fixed effects | Yes | | Yes | | Yes | | Yes | | Yes | |
| Observations | 2,016,158 | | 2,016,158 | | 2,016,158 | | 1,048,436 | | 967,772 | |
| Log-likelihood | -817,743 | | -817,741 | | -801,719 | | -416,493 | | -384,569 | |
| Pseudo R ² | 0.021 | | 0.021 | | 0.021 | | 0.019 | | 0.025 | |

Fixed logit estimation is used for all columns. Standard errors are included in square brackets. P-values are in parentheses. All tests are two tailed.

Table 5

Alternative mechanisms for stockout reduction: inventory and sales forecasts

| | Inventory (in days of sales) | | Forecast-Level (AF) | | Forecast-Noise | |
|--------------------------------|------------------------------|----------------|---------------------|----------------|----------------|--|
| | (1) | (2) | (3) | (4) | (5) | |
| Integration | 0.808 (0.000) | -0.010 (0.004) | -0.015 (0.278) | -0.007 (0.000) | -0.051 (0.000) | |
| | [0.210] | [0.003] | [0.014] | [0.001] | [0.003] | |
| NonCSD_X_Integration | -3.843 (0.000) | 0.001 (0.587) | 0.002 (0.446) | -0.002 (0.000) | 0.0001 (0.855) | |
| | [0.227] | [0.003] | [0.003] | [0.0004] | [0.0005] | |
| Sales | -20.351 (0.000) | 0.333 (0.000) | 0.333 (0.000) | 0.020 (0.000) | 0.020 (0.000) | |
| | [0.243] | [0.005] | [0.005] | [0.0005] | [0.0005] | |
| Sales volatility | 7.739 (0.000) | 0.047 (0.000) | 0.048 (0.000) | 0.177 (0.000) | 0.177 (0.000) | |
| | [0.738] | [0.007] | [0.007] | [0.003] | [0.003] | |
| DC near CP (1,0)_X_Integration | | | -0.016 (0.011) | | 0.003 (0.001) | |
| | | | [0.006] | | [0.001] | |
| Product age_X_Integration | | | 0.002 (0.489) | | 0.010 (0.000) | |
| | | | [0.003] | | [0.0006] | |
| Annual trend | Yes | Yes | Yes | Yes | Yes | |
| Season dummies | Yes | Yes | Yes | Yes | Yes | |
| DC-SKU pair fixed effects | Yes | Yes | Yes | Yes | Yes | |
| Observations | 2,016,158 | 2,016,158 | 2,016,158 | 2,016,158 | 2,016,158 | |
| Log-likelihood | -8.94E+06 | -287854 | -595,322 | 2.24E+06 | 2.17E+06 | |
| Adjusted R ² | 0.593 | 0.303 | 0.308 | 0.308 | 0.308 | |

Fixed effects linear regressions are used for all columns. Robust standard errors clustered at DC level are included in square brackets for all columns. P-values are in parentheses. All tests are two tailed.

Table 6 **Impact of inventory and sales forecasts on stockouts**

| DV=Stockout (1,0) | (1) CSD | | (2) NonCSD | | (3) CSD | | (4) NonCSD | |
|------------------------------|----------------|---------|-------------------|---------|----------------|---------|-------------------|---------|
| Integration | 0.017 | (0.069) | -0.175 | (0.000) | -0.011 | (0.245) | -0.121 | (0.000) |
| | [0.010] | | [0.010] | | [0.010] | | [0.010] | |
| Sales | 0.105 | (0.000) | 0.156 | (0.000) | 0.004 | (0.523) | 0.046 | (0.000) |
| | [0.006] | | [0.007] | | [0.006] | | [0.008] | |
| Sales volatility | 2.763 | (0.000) | 2.491 | (0.000) | 1.809 | (0.000) | 1.749 | (0.000) |
| | [0.024] | | [0.023] | | [0.032] | | [0.033] | |
| Inventory (in days of sales) | -0.019 | (0.000) | -0.019 | (0.000) | -0.017 | (0.000) | -0.017 | (0.000) |
| | [0.001] | | [0.006] | | [0.0002] | | [0.0001] | |
| Forecast-Level (AF) | | | | | 0.669 | (0.000) | 0.550 | (0.000) |
| | | | | | [0.011] | | [0.012] | |
| Forecast-Noise | | | | | 1.860 | (0.000) | 1.362 | (0.000) |
| | | | | | [0.042] | | [0.045] | |
| Annual trend | Yes | | Yes | | Yes | | Yes | |
| Season dummies | Yes | | Yes | | Yes | | Yes | |
| DC-SKU pair fixed effects | Yes | | Yes | | Yes | | Yes | |
| Observations | 1,048,436 | | 967,772 | | 1,048,436 | | 967,772 | |
| Log-likelihood | -408,828 | | -373,511 | | -393,025 | | -360,260 | |
| Adjusted R ² | 0.037 | | 0.053 | | 0.054 | | 0.067 | |

Inventory and sales forecasts are measured at the beginning of each period. Fixed effects linear regressions are used for all columns. Robust standard errors clustered at DC level are included in square brackets for all columns. P-values are in parentheses. All tests are two tailed.

Table 7 **Integration and rival products**

| | Stockout (1,0) | Inventory (in days of sales) | Forecast-Level (AF) | Forecast-Noise |
|--------------------------------|--------------------------|-------------------------------------|----------------------------|--------------------------|
| | (1) | (2) | (3) | (4) |
| Integration | 0.055 (0.001) [0.017] | -2.332 (0.000) [0.293] | 0.085 (0.000) [0.004] | 0.004 (0.000) [0.001] |
| Sales | 0.526 (0.000) [0.010] | -17.177 (0.000) [0.430] | 0.307 (0.000) [0.008] | 0.015 (0.000) [0.001] |
| Sales volatility | 2.822 (0.000) [0.042] | 9.082 (0.000) [1.021] | 0.078 (0.000) [0.015] | 0.216 (0.000) [0.005] |
| Annual trend | Yes | Yes | Yes | Yes |
| Season dummies | Yes | Yes | Yes | Yes |
| DC-SKU pair fixed effects | Yes | Yes | Yes | Yes |
| Observations | 315,870 | 304,983 | 315,870 | 315,870 |
| Log-likelihood | -124828 | -1.37E+06 | -62280 | 354696 |
| Pseudo/Adjusted R ² | 0.026 | 0.576 | 0.259 | 0.317 |

Fixed effects logit estimation is used for column 1 and fixed effects ordinary least square linear regressions are used for columns (2)–(4). Standard errors for column (1) and robust standard errors clustered at DC level in columns (2)–(4) are included in square brackets. P-values are in parentheses. All tests are two tailed.