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The Effect of Product Variety and Inventory Levels on Retail Store Sales: A Longitudinal Study

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We examine the effects of product variety and inventory levels on store sales. Using 4 years of data from stores of a large retailer, we show that increases in product variety and inventory levels are both associated with higher sales. We also show that increasing product variety and inventory levels has an indirect negative effect on store sales through their impact on phantom products—products that are physically present at the store, but only in storage areas where customers cannot find or purchase them. Our study highlights a consequence of increased product variety and inventory levels that has previously been overlooked in studies of retail product variety and inventory management. It also quantifies the impact of phantom products on store sales. In addition, our study provides empirical evidence to support earlier claims that higher product variety and inventory levels lead to an increase in defect rate. We discuss the implications of our findings for retail inventory and assortment planning and for the design of retail stores.

Key words: retail inventory management; assortment management; product variety; misplaced products; quality management
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1. Introduction

Higher product variety and inventory levels at retail stores are typically associated with higher sales. Having more products at a store increases the probability that customers will find what they want (Baumol and Ide 1956). Having more inventory of a particular product increases sales by increasing service levels (Cachon and Terwiesch 2006) and stimulating customer demand (Dana and Petruzzi 2001, Larson and DeMarais 1990). In this paper, using 4 years of data from stores of a large retailer, we empirically confirm the theories that higher product variety and inventory levels lead to higher sales. But we also show that higher product variety and inventory levels have an indirect negative effect on sales through their effect on in-store logistics. Increasing product variety and inventory levels increases the complexity and confusion in the operating environment (Hayes and Clark 1986, Skinner 1974), making it more likely that store employees will make errors in performing in-store logistics activities such as shelving and replenishing merchandise. Such errors result in phantom products—products that are physically present in the store, but only in storage areas where customers cannot find them (Ton and Raman 2005).

Phantom products are a common and expensive problem in many retail settings. For example, Andersen Consulting (1996) estimates that sales losses due to products being in storage areas but not on the selling floor amount to $560–960 million per year in the United States supermarket industry. A study by the Grocery Manufacturers of America (2004) estimates that 25–30% of grocery stockouts are caused by products that are placed in areas where customers cannot find them. In our study, we show that a one-standard-deviation increase in percentage of phantom products is associated with a 1% decrease in store sales which, assuming a 30% gross margin, translates to a loss of roughly 7% of the net income generated by an average store.

One contribution of our study is to build on the existing literature on retail assortment and inventory management by highlighting a consequence of increased product variety and inventory levels that has been overlooked. In some extreme cases, increasing inventory for a particular product has been associated with lower sales because of a substantial increase in phantom products. This can occur when a retailer's employees are better at shelving newly arrived products than at replenishing products from storage areas. For example, inventory planners at a large electronics specialty retailer increased inventory levels for a very popular item at several test stores to estimate how much sales would increase if this item were always in stock. Several weeks later, the planners observed a decrease in sales for that item. Visits to several stores revealed that this surprising result could be explained by problems with inventory replenishment processes. Previously, when the inventory level for the item had been lower, store employees were able to fit most of the units on the display shelves and there were very few units in storage areas. Consequently, when the units on the shelves were sold, the low inventory level for the item would trigger a replenishment order and the store would receive a new shipment from the distribution center. Now, with increased inventory levels, store employees had to keep many more units of that item in storage locations, intending to move them to the display shelves once the units on the shelves were sold. But when the planners visited the stores, they found the display shelves empty and the inventory still in various storage locations. Apparently, once the units on the display shelves were sold, the remaining units were never replenished. Failure to replenish from storage locations limited total sales for the item to the number of units that were placed on the display shelves when the large shipment arrived at the store.

In our study, the direct positive effect on sales of increasing inventory levels and product variety is much greater than its indirect negative effect on sales through phantom products. Nevertheless, with a better understanding of the mechanisms by which inventory levels and product variety affect store sales, researchers and retail managers can make the appropriate trade-offs in determining a store's optimal product variety and inventory levels.

This paper differs from our earlier work (Ton and Raman 2005), in which we examined phantom products and their drivers but not their impact on store sales. Our previous analysis was limited to cross-sectional data and hence focused on inter-store variation—why some stores had a higher percentage of phantom products than others. In this paper we use panel data—data from multiple stores over time—which allow us to capture within-store changes over time and permits a more sophisticated research design controlling for store-specific fixed effects. For example, linear shelf space in the selling and storage areas could affect inventory levels, product variety, phantom products, and sales. However, since our research site does not track its stores' linear shelf space, we could not include this measure in our earlier cross-sectional study. In the present study, the inclusion of store fixed effects controls for linear shelf space. And because panel data allow researchers to explain changes within a unit over time, they are an improvement over cross-sectional data for making causal statements.

Our study also makes two contributions to the literature on quality management. First, by showing the effect of phantom products on store sales, we provide empirical support for studies that demonstrate the beneficial impact of increased quality on firm performance. Second, we provide empirical evidence to support earlier assertions that higher product variety and inventory levels increase defect rates. Although several researchers have hypothesized a negative relationship between product variety and quality, empirical evidence for this assertion has been limited, Fisher and Ittner (1999) being the exception. Moreover, as stated in a recent literature overview (Ramdas 2003), studies of product variety in operations management literature have generally focused on manufacturing environments, particularly on the relationship between product variety and manufacturing costs (e.g., Anderson 1995, Banker et al. 1990, Datar et al. 1993, Kekre and Srinivasan 1990). Ramdas (2003) notes that the effect of product variety on downstream processes such as distribution and retail operations has not been empirically examined.

The rest of the paper is organized as follows: In section 2, we review the relevant literature and highlight the contributions of this study. In section 3, we describe our research methodology and econometric model. In section 4, we present our results and in section 5, we conclude.

2. Theoretical Motivation

Our study builds on earlier work on retail inventory and assortment management and on the literature on quality management. The relationship between inventory levels, product variety, and sales has been studied extensively in the operations management and marketing literatures. Numerous studies examine the effect of inventory on sales. In stochastic inventory theory, increase in inventory levels leads to an increase in expected sales by improving service levels (Cachon and Terwiesch 2006, Silver et al. 1998). Because customers may be more willing to visit a store when they expect a high service level (Dana and Petruzzi 2001), increasing inventory is also associated with an increase in sales through stimulating customer demand (Larson and DeMarais 1990). Several shelf-allocation models in marketing literature therefore consider the consumer demand rate as a function of shelf space allocated to the product (e.g., Corstjens and Doyle 1981, Zufryden 1986).

The relationship between a store's product variety and its sales is also considered to be positive. Increasing the number of products at a store increases the choice set for the customer and is assumed to increase the likelihood that the customer will buy something (e.g., Baumol and Ide 1956, Smith and Agrawal 2000, van Ryzin and Mahajan 1999). In addition, increasing the number of products within a category increases the number of substitutes within that category and hence potentially decreases lost sales when customers cannot find their first choice (Mahajan and van Ryzin 1999). In the operations management literature, the increased product availability that results from increased variety is often traded off against the cost of additional inventory in order to determine the optimal variety at a store. In the marketing literature, several studies show that customers' perceptions of variety may be different than the real variety at the store (e.g., Broniarczyk et al. 1998, Hoch et al. 1999). Some studies argue that too much variety may lead to customer confusion or frustration (Huffman and Kahn 1998). In fact, at the category level, eliminating moderate amounts of low-selling products has been associated with unchanged or increased category sales (Boatwright and Nunes 2001, Broniarczyk et al. 1998, Sloot et al. 2006). But Borle et al. (2005), using data from an online grocer, find that at the store level reduction in variety is associated with both fewer store visits and smaller basket size.

Studies of retail inventory and assortment management typically assume that all products in the store are available to the customers. Most recently, several researchers have begun to examine product misplacement (Raman et al. 2001a, b, Ton and Raman 2005) and incorporate it into existing analytical models. Camdereli and Swaminathan (2005), for example, examine coordination issues between a retailer and a supplier when a proportion of the inventory at the retail stores is misplaced. Atalı et al. (2009) and Rekik et al. (2008) examine the use of auto identification technology to mitigate the cost of misplaced inventory.

Misplaced products are analogous to defects in conformance quality (Crosby 1980, Garvin 1988, Juran 1992, Ton and Raman 2005). At retail stores, products are assigned to locations that can be specified very precisely (e.g., at supermarkets, most products have a specific slot) or more broadly (e.g., at discount apparel stores, products are supposed to be located somewhere within a section). We denote a product that is not in its specified location as a defect in conformance quality terms because it fails to meet specifications.

In this paper we focus on a subset of misplaced products—those that are in storage areas but not on the selling floor. These products are "phantom" because, while they are physically present and shown as available in retailers' merchandising systems, they are unavailable to customers. We draw on the quality literature to derive our hypotheses related to (1) the effect of product variety and inventory levels on percentage of phantom products—that is, on the defect rate—and (2) the effect of the percentage of phantom products on sales.

Consider first the relationship between product variety and quality. Fisher and Ittner (1999) show, using data from automotive assembly, that greater variability in option content is associated with an increase in rework rate. Earlier, Fisher et al. (1995) argued that "the time for an assembly worker to access the correct part goes up with product variety, increasing the risk that the worker will choose the wrong part, resulting in quality problems and rework." MacDuffie et al. (1996) and Yeh and Chu (1991) hypothesized a similar relationship between product variety and quality. Hayes and Clark (1986) and Skinner (1974) also argued that increasing product variety would lead to greater "complexity" and "confusion" in a plant, which would be expected to contribute to lower quality.

We expect product variety to increase the complexity and confusion in a retail environment and to lead to more phantom products. Increasing product variety at a store leads to additional steps in in-store logistics activities. With more products and limited shelf space, employees are required to move more units to storage areas. Because the process of moving merchandise to storage areas and replenishing merchandise from storage areas is, like most operational processes, prone to errors, higher product variety would lead to a higher percentage of phantom products.

HYPOTHESIS 1: Increase in product variety is associated with an increase in percentage of phantom products.

Many authors have argued that quality deteriorates at higher inventory levels. Lower inventory levels lead to better quality for two reasons. First, lower inventory leads to clearer and more timely feedback to various parts of the operating process in case of an error. Ocana and Zemel (1996) argue that operational learning is triggered by inventory shortages, which the authors describe as "operationally observable" events. Since the likelihood of inventory shortages is lower at higher inventory levels, the authors argue that production systems with higher inventory levels are likely to have fewer learning opportunities and, hence, likely to achieve lower quality over the long term. Second, lower inventory, by fostering greater accountability in operations, leads to more consistent execution of standard operating procedures (Alles et al. 2000).

The detrimental effect of increased inventory levels on quality was central to the rationales for just-in-time manufacturing and lean production systems. Arguments for this assertion can be found in Schonberger (1982), Hall (1983), and Krafcik (1988).

At retail stores, increasing the inventory level of a product increases the complexity and confusion in the operating environment because, when there are more units of a product, employees are more likely to move extra units of these products to storage areas. In addition, higher inventory levels may lead to less accountability. In shelving merchandise, employees generally place as many units of a product as they can on the selling floor and shelve the rest in storage areas. Shelving merchandise in the storage areas is prone to errors; for example, employees might shelve products in the wrong place in the backroom. The more units of a product there are on the selling floor, the more time elapses between misplacement of that product in the backroom and the call to replenish it. As Alles et al. (2000) argue, slower feedback is likely to lead to less accountability and to cause employees to be more careless in shelving units in the storage areas. Consequently, we are likely to see a higher percentage of phantom products when a store has a higher inventory level per product.

HYPOTHESIS 2: Increase in inventory levels is associated with an increase in percentage of phantom products.

Several studies argue that increased quality leads to an improvement in firm performance. Using longitudinal data from two manufacturing plants, Ittner (1994) shows a positive relationship between quality and total factor productivity. In a study of the room air-conditioning industry, Garvin (1988) argues that higher quality may improve the profitability of firms by increasing sales and market share and also by decreasing costs. From a study of 43 projects, Krishnan et al. (2000) find that, for software products, improved conformance quality is associated with higher life-cycle productivity. Hendricks and Singhal (1997) show that firms that have won quality awards outperform control firms on operating income and sales growth.

In the context of retail stores, an increase in phantom products is likely to lead to a decrease in store sales. Customers cannot find and hence purchase products that are not on the selling floor unless they ask for help from a sales associate. In many retail settings, customers do not expect or receive help from sales associates. Even if they do, the sales associate may not take the time to go to the storage area to check the availability of products, and even if they do, they may not be able to find the product in the storage area.

HYPOTHESIS 3: Increase in percentage of phantom products is associated with a decrease in store sales.

3. Research Methodology

3.1. Research Site

We test our hypotheses using data from Borders Group Inc., a well-known retailer of "entertainment products" such as books, CDs, and videos. In 2002, Borders had approximately $3.5 billion in annual sales and $110 million in profit and employed about 30,000 people. At the end of 2002, the company operated 404 superstores (under the name "Borders") and 778 mall-based stores (under the name "Waldenbooks"). In this study, we focus solely on Borders superstores (which we will call "Borders stores").

Ever since Borders was founded, it has emphasized matching customers with the products they want. Borders' central merchandizing system was designed in-house to determine assortment and inventory levels for each store, based on historical sales data. The company devised proprietary algorithms to analyze sales data and identify—for each store—both the assortment levels and an appropriate inventory level for each product. These algorithms were considered so powerful that Borders Group had considered licensing the software to non-competing retailers. (See Raff [2000] for a discussion of the importance of this merchandising system to Borders' strategy.) Each Borders store has computer terminals that allow customers to find out whether that store has a particular product and, if so, where to find it.

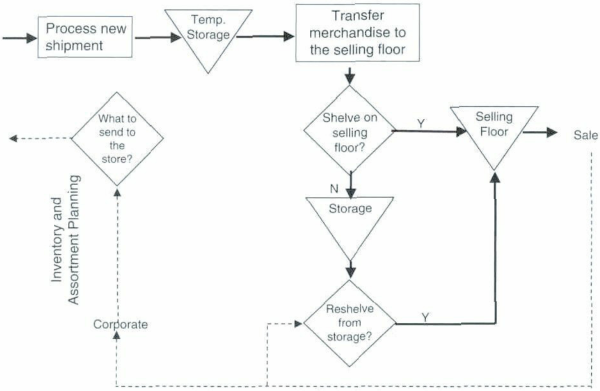
Borders' emphasis on matching customers with the products they want and its centralized approach to ensuring product availability makes it an attractive setting for this study. Because product variety and inventory levels are determined centrally, stores are expected to adhere to these decisions. Consequently, phantom products are considered defects at Borders stores. Moreover, because of the strength of Borders' merchandising system, store managers and employees typically do not question whether products sent to their stores should be displayed on the selling floor. Because Borders stores are predominantly self-service environments with limited help, managers do not deliberately keep some products in storage areas, inaccessible to the customers. If, for some reason, store managers or employees do not want to carry certain products in their stores, they can return these products to the company's distribution centers. Returning products to the distribution centers is a very common process at Borders stores, as it is at most bookstores. A typical Borders store returns approximately 110,000 units, or 40% of its inventory, every year.

3.2. Employee Errors in Managing Inventory at Borders Stores

Phantom products result when employees make errors in shelving and replenishing merchandise. In this section, we briefly describe inventory management processes at Borders stores and identify sources of error.

Figure 1 depicts a simplified process flow for inventory management at Borders stores. Additional detail on this process flow can be found in Ton (2002). Like most other retailers, Borders stores receive more units of inventory for some product than they can actually display on shelves. Employees are instructed to place some of each product on the selling floor and to move the rest to storage areas. When the units on the selling floor are sold, employees are supposed to

Figure 1 Simplified process flow for inventory management at Borders stores.



replenish the selling floor with the extra units from storage locations.

Five possible employee errors can be made during this process. Employees may (1) shelve a product in the wrong display area on the selling floor, (2) shelve extra units of a product in the wrong location in the storage area, (3) forget to shelve the new products and leave them in the receiving area, (4) place all the units of a new product in storage areas rather than shelving some of them, and (5) forget to replenish the selling floor when the units there are sold. In the first case, products are misplaced on the selling floor and there is some chance that they can be found by the customer or employees. In the second case, products are misplaced in the storage areas and employees may have difficulty finding these products when replenishing. In the last three cases, products are phantom. That is, they are physically present at the store but unavailable to the customers. A store employee may be able to find these products for a customer, but that would only happen if (1) the customer asks an employee for help, (2) the employee takes the initiative to look for the product in storage locations, and (3) the employee can actually find the product there.

3.3. Data

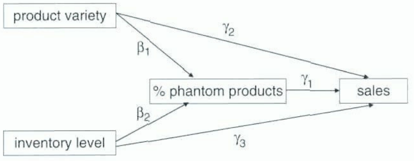
We tested our hypotheses using yearly data from all Borders stores that went though annual physical audits from 1999 to 2002. Some of the stores in our dataset opened between 1999 and 2001 so we do not have four observations for all 356 stores that went through physical audits. Because all our data come from a single retailer, we can observe many units without needing to worry about unobservable across-unit heterogeneity. Moreover, using data from a single retailer allows us to have consistent measures in our empirical analysis.

We collected data on phantom products, product variety, and inventory levels from physical audits conducted at each store by Borders' internal audit department, working in collaboration with a specialized third party. Store audits are performed once a year at each store between February and October; Borders deliberately avoids conducting audits during the busy sales period from November to January. Hence, we observe phantom products, product variety, and inventory levels during a month between February and October in a given year. During physical audits, auditors count and track the location of each product in the store and report the quantity, dollar value, and the number of products that are available in the store as well as the quantity, dollar value, and the number of products that are available in storage areas. Each store is closed during its audit. Note that, because percentage of phantom products is not used in evaluating store managers' performance, store managers do not have an incentive to alter this variable to show better performance.

3.4. Empirical Model

The theoretical model we would like to test is depicted in a path diagram in Figure 2. Models in which an independent variable causes an intervening variable, which then causes the dependent variable, are used in various disciplines and the intervening variable—percentage of phantom products in our

Figure 2 Relationships between product variety, inventory levels, phantom products, and sales.



model—is typically called a mediator (Baron and Kenny 1986, MacKinnon et al. 2002, Venkatraman 1989). The direct effects of product variety and inventory levels on sales are shown by the paths γ_2 and γ_3, respectively. The indirect effects of product variety and inventory levels on sales through percentage of phantom products are shown by the path's coefficients β_1, γ_1 and β_2, γ_1, respectively. Testing mediation requires three regression equations (Baron and Kenny 1986). Equation (1) regresses the mediator (percentage of phantom products) on the independent variables (product variety and inventory levels). Equation (2) regresses the dependent variable (store sales) on the independent variables. Equation (3) regresses the dependent variable on both the independent variables and on the mediator.

$$\begin{aligned}\%PHANTOM\ PRODUCTS_{it} &= \alpha_i + \lambda_t + \beta_1 PRODUCTVARIETY_{it} \\ &\quad + \beta_2 INVENTORYLEVEL_{it} + X_{it}\beta + \varepsilon_{it} \qquad (1)\end{aligned}$$

$$\begin{aligned}SALES_{it} &= \delta_i + \phi_t + \partial_1\ PRODUCT\ VARIETY_{it} \\ &\quad + \partial_2 INVENTORY\ LEVEL_{it} + X_{it}\partial + \varepsilon_{it}, \qquad (2)\end{aligned}$$

$$\begin{aligned}SALES_{it} &= \eta_i + \theta_t + \gamma_1 \%PHANTOM\ PRODUCTS_{it} \\ &\quad + \gamma_2 PRODUCTVARIETY_{it} \qquad (3) \\ &\quad + \gamma_3 INVENTORYLEVEL_{it} + X_{it}\gamma + \varepsilon_{it}.\end{aligned}$$

The dependent variable in Equation (1), % phantom products, represents the percentage of products that are in storage areas but not on the selling floor at store i in year t during the time of the physical audit. Note that % phantom products does not include those products that are available in storage areas *and* on the selling floor. Moreover, it does not count the *number of units*; it merely counts the number of products that are in storage areas and not on the selling floor.

Borders stores conduct annual physical audits during which they count the % phantom products. It is reasonable to assume that the % phantom products observed during the audit is prevalent for the previous month. Consequently, we use sales during the month preceding the audit as our second dependent variable. We do not include sales during earlier months because % phantom products during those months could be higher or lower than it is during the audit. Similarly, we do not include sales during months following the audits because stores are expected to reduce % phantom products right after the audits. Consequently, the dependent variable in Equations (2) and (3) is sales during the month preceding the audit at store i in year t.[1]

In addition to product variety, which is measured as the total number of products at store i at the time of the audit in year t, and inventory level, which is measured as the average number of units of inventory per product at store i at the time of the audit in year t, Equations (1), (2), and (3) include a vector X_{it} which contains several store-level variables that vary over time. These variables are a dummy variable for each of the months from February to October to indicate the month during which physical audit was conducted[2] (to control for differences in expected demand during different months), unemployment rate in the store's metropolitan statistical area[3] (to control for differences in labor market conditions), amount of labor used during the month preceding the audit (to control for employee workload), employee turnover during the month preceding the audit (to control for tacit knowledge lost as a result of the departure of employees), full-time employees as a percentage of total employees during the month preceding the audit (to control for employee mix), store manager turnover since the last audit (to control for management changes), and the number of competitors in the local market during the month preceding the audit. Managers of a Borders store consider Barnes & Noble and other Borders stores as their main competitors. As a result, they track the opening and closing of Barnes & Noble and other Borders stores near each Borders store.

Our specification also includes fixed effects for each store (α_i in Equation [1], δ_i in Equation [2], and η_i in Equation [3]) and fixed effects for each year (λ_t in Equation [1], φ_t in Equation [2], and θ_t in Equation [3]). Store fixed effects control for time-invariant, unobserved heterogeneity across stores (Hausman and Taylor 1981), which might otherwise affect both independent variables (inventory levels and product variety) and dependent variables (phantom products and sales), leading to biased estimates. For example, incompetent management at a store could result in both a higher percentage of phantom products and lower sales. In our setting, time-invariant factors include the store's layout, location, and available shelf space. The year fixed effects control for changes in factors such as economic conditions and corporate policies over time for all stores. Note that including store fixed effects forces us to focus our analysis solely on explaining *within-store* variation.

In Ton and Raman (2005), we show that the number of trainers at a store is associated with % phantom products. We do not control for the number of trainers in this study because we do not have consistent data for the number of trainers at each store for all 4 years. However, we do not expect the number of trainers at a store to be correlated with the store's product variety or inventory levels, so we do not expect exclusion of the training variable to affect the coefficients of those variables.

We define each of the variables used in our analysis in Table 1. Descriptive statistics and simple correlations for all variables used in the analysis are provided in Tables 2 and 3, respectively. Table 3 should be interpreted with caution because it pools observations from 356 cross-sections across 4 years.

3.5. Endogeneity

The causal paths shown in Figure 2 are derived from the literature on stochastic inventory, retail assortment models, and quality management. At Borders stores, however, sales also have an effect on product variety and inventory levels. Specifically, as we describe in section 3.1, Borders' merchandising system uses a store's historical sales to determine its inventory and product variety levels. High historical sales are often associated with expectation of high sales in the future. Stores expecting high sales are likely to have higher product variety and higher inventory levels. Since expectation of high sales is most likely correlated to actual sales, we might observe relationships between sales and product variety and between sales and inventory levels because stores maintain higher levels of variety and inventory in expectation of high sales.

Table 1 Description of Variables Used in Our Analysis

Variable	Description
%PHANTOM PRODUCTS$_{it}$	Products that are in storage areas but not on floor at store *i* in year *t* at the time of the physical audit divided by the # of products at store *i* in year *t* at the time of the physical audit
SALES$_{it}$	Sales during the month preceding the audit at store *i* in year *t*
PRODUCT VARIETY$_{it}$	The # of products in store *i* at the time of the physical audit in year *t*
INVENTORY LEVEL$_{it}$	The # of units in store *i* at the time of the physical audit in year *t* divided by the # of products in store *i* at the time of the physical audit in year *t*
UNEMPLOYMENT$_{it}$	Unemployment rate of store *i*'s metropolitan statistical area during the month preceding the audit in year *t*
LABOR$_{it}$	Payroll expenses during the month preceding the audit at store *i* in year *t*
EMPLOYEE TURNOVER$_{it}$	Fraction of employees charged with managing inventory that had left during the month preceding the audit at store *i* in year *t*
PROPORTION FULL$_{it}$	Fraction of full-time employees during the month preceding the audit at store *i* in year *t*
STORE MANAGER TURNOVER$_{it}$	Dummy variable with value 1 if the manager of store *i* had left the company voluntarily since the last physical audit in year *t*
COMPETITION$_{it}$	The total number of Barnes & Noble and Borders stores in the area during the month preceding the audit at store *i* in year *t*
AUDIT MONTH$_{it}$	Nine dummy variables that indicate the month during which physical audit was conducted at store *i* in year *t*
PLAN SALES$_{it}$	Planned sales during the month preceding the audit at store *i* in year *t*

Through its effect on sales, percentage of phantom products may also have an effect on inventory levels and product variety. If a store has high percentage of phantom products and hence low sales in a particular period, there may be an expectation of lower sales in future periods and hence lower inventory and product variety levels.

We wanted to ensure that the coefficients β_1 and β_2 in Equation (1) represent paths β_1 and β_2 in Figure 2, respectively, and not the effect of percentage of phantom products on product variety and inventory levels. We also wanted to ensure that the coefficients γ_2 and γ_3 in Equation (3) represent paths γ_2 and γ_3, respectively, and not the effect of sales on product variety and inventory levels. For that reason, we include an additional control variable—planned sales at a store—in both equations. Planned sales at a store is calculated for a given month using the store's historical sales and represents what Borders corporate expects sales at that store to be that month. Product variety and inventory levels are determined based on these forecasted sales.

Phantom products may also be endogenous to store sales. Higher sales may result in store employees spending a large portion of their time assisting customers and not enough time moving merchandise from storage areas to the selling floor, leading to higher percentage of phantom products. However, to the extent that we observe a negative sign for γ_1 in Equation (2), our results would only be conservative. Other characteristics of the store or its management could affect both phantom products and store sales. For time-invariant characteristics such as location, layout, and available shelf space, we use store fixed effects. We also control for store manager turnover for any changes that would result from new management. With our controls we do not expect endogeneity to be a major problem in Equation (3). Nevertheless, to test whether percentage of phantom products remains endogenous to store sales, we examine the effect of past sales on percentage of phantom products.

Table 2 Descriptive Statistics for All Variables

Variable	Mean	Std. Dev.	Minimum	Maximum
% PHANTOM PRODUCTS	3.24	1.83	0.15	13.49
MONTHLY SALES ($)	487,464	198,223	164,003	1,583,556
PRODUCT VARIETY	176,789	34,348	102,082	319,674
INVENTORY LEVEL (units/product)	1.38	0.09	1.10	1.88
UNEMPLOYMENT (%)	4.45	1.74	1.30	15.70
LABOR ($)	60,039	19,487	17,846	206,499
EMPLOYEE TURNOVER (%)	5.36	5.26	0.00	40.00
PROPORTION FULL	0.610	0.129	0.189	1
SM TURNOVER	0.150	0.350	0	1
COMPETITORS (#)	0.868	0.923	0	5
PLAN SALES ($)	494,919	198,777	167,167	1,604,676

3.6. Model Estimation

We estimate the parameters of Equations (1), (2), and (3) using ordinary least squares (OLS) estimators. When using OLS estimators, we report the heteroskedasticity robust standard errors for OLS, as suggested by Huber (1967) and White (1980). Note that in Equation (1) there are theoretical upper and lower bounds on our dependent variable, % phantom products, corresponding to the cases where all or none of the products are missing from the selling floor. None of the stores in our sample reach those bounds. Nevertheless, to confirm that our results are not affected by the fact that our dependent variable is bounded, we try a "logistic transform" of % phantom products, $\ln\left(\frac{\%\,PHANTOM\,PRODUCTS}{1-\%\,PHANTOM\,PRODUCTS}\right)$, which maps (0,1) symmetrically into $(-\infty, \infty)$. We then fit a weighted

Table 3 Pearson Correlations between Variables (*p*-values are Reported Below Correlation Coefficients)

	% PHANTOM PRODUCTS	*SALES ($)*	*PRODUCT VARIETY*	*INVENTORY LEVEL*	*UNEMPLOY-MENT*	*LABOR*	*EMPLOYEE TURNOVER*	*PROPORTION FULL*	*SM TURNOVER*	*COMPETITORS*	*PLAN SALES*
% PHANTOM PRODUCTS	1										
SALES ($)	0.080	1									
	0.004										
PRODUCT VARIETY	0.042	0.871	1								
	0.132	<.0001									
INVENTORY LEVEL	0.162	−0.239	−0.331	1							
	<0.0001	<0.0001	<0.0001								
UNEMPLOYMENT	0.139	−0.107	−0.172	0.030	1						
	<0.0001	0.000	<0.0001	0.292							
LABOR	0.035	0.872	0.770	−0.224	−0.102	1					
	0.215	<0.0001	<0.0001	<0.0001	0.000						
EMPLOYEE TURNOVER	0.018	−0.012	0.038	0.025	−0.118	−0.010	1				
	0.520	0.667	0.175	0.372	<0.0001	0.714					
PROPORTION FULL	−0.099	0.050	0.073	0.022	−0.010	0.118	0.003	1			
	0.001	0.067	0.010	0.425	0.730	<0.0001	0.912				
SM TURNOVER	0.007	0.031	0.039	0.001	−0.052	0.032	−0.008	0.020	1		
	0.795	0.252	0.160	0.981	0.058	0.246	0.777	0.461			
COMPETITORS	−0.080	0.023	0.121	−0.216	−0.124	0.043	−0.046	−0.056	−0.002	1	
	0.005	0.411	<.0001	<.0001	<.0001	0.121	0.095	0.041	0.939		
PLAN SALES	0.059	0.813	0.762	−0.254	−0.125	0.716	−0.027	0.045	0.019	0.084	1
	0.036	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.336	0.099	0.484	0.002	

least square (WLS) regression, using $\hat{w}_{it} = \frac{1}{\sqrt{c_{it}\hat{\theta}_{it}(1-\hat{\theta}_{it})}}$ as an estimate for the weight, where c_{it} = number of products at store i in year t, and $\hat{\theta}_{it}$ = observed % phantom products at store i in year t. (See Bickel and Doksum 1977 for a discussion of the technical aspects of this approach, including the choice of $\hat{w}_{it}$.) The WLS estimates of the parameters are reported in Table 4, column (3).

The Durbin-Watson statistic to check for autocorrelation revealed autocorrelation in the error terms in equation (3). Consequently, in addition to OLS, we consider a flexible structure of the variance-covariance matrix of the errors with first-order autocorrelation and use Beach and MacKinnon's (1978) algorithm to estimate the parameters of (3) using maximum likelihood estimation (MLE). (See Greene (2000) for details about this estimation methodology.) The MLE estimates of the parameters are reported in Table 5, column (3).

4. Results

4.1. The Effect of Product Variety and Inventory Levels on % Phantom Products

Table 4 presents the results of testing the effect of product variety and inventory levels on % phantom products. The OLS estimates of the parameters are reported in columns (1) and (2); the WLS estimates are reported in column (3). The parameter estimates reported in column (2) are different from those reported in column (3) because the dependent variable used in column (2) is % of phantom products and the dependent variable in column (3) is a logistic transformation of % phantom products.

Table 4 Regression Results for Testing the Effect of Inventory Levels and Product Variety on % Phantom Products

	OLS		WLS
Variable	(1) % *PHANTOM PRODUCTS*	(2) % *PHANTOM PRODUCTS*	(3) Logistic Transform of % *PHANTOM PRODUCTS*
PRODUCT VARIETY (in 100,000s)		0.018***	0.442***
		(0.005)	(0.170)
INVENTORY LEVEL		0.037***	1.071***
		(0.008)	(0.258)
UNEMPLOYMENT	0.000	0.000	0.003
	(0.001)	(0.001)	(0.020)
LABOR (in 100,000s)	−0.020***	−0.022***	−0.611***
	(0.006)	(0.006)	(0.179)
EMPLOYEE TURNOVER	0.012	0.010	0.415
	(0.009)	(0.009)	(0.280)
PROPORTION FULL	−0.004	−0.003	−0.095
	(0.005)	(0.01)	(0.17)
SM TURNOVER	0.004***	0.004***	0.099***
	(0.001)	(0.00)	(0.04)
COMPETITORS	0.000	−0.001	−0.015
	(0.001)	(0.001)	(0.042)
PLAN SALES (in 100,000s)	−0.0005	−0.0004	−0.013
	(0.000)	(0.000)	(0.010)
YEAR 1999	−0.002	−0.007***	−0.181***
	(0.002)	(0.002)	(0.062)
YEAR 2000	−0.004**	−0.005***	−0.129**
	(0.002)	(0.002)	(0.054)
YEAR 2001	−0.003*	−0.004***	−0.117***
	(0.002)	(0.002)	(0.046)
Observations	1247	1247	1247
Adjusted R^2	0.569	0.596	0.573

*, **, ***denote statistical significance at the 10%, 5%, and 1% levels, respectively. Regressions include dummy variables for audit months, fixed effects for stores, and a constant term not shown in the table. Standard errors are reported in parenthesis. Robust standard errors are reported when using OLS.

Table 5 Regression Results for Testing the Effect of % Phantom Products on Store Sales

	OLE		MLE
Variable	(1)	(2)	(3)
% PHANTOM PRODUCTS		– 263,826.0 ***	– 264,147.0 ***
		(104,798.0)	(88,910.0)
PRODUCT VARIETY (in 100,000s)	53,612.0 **	58,744.0 ***	59,540.0 ***
	(26,062.0)	(16,846.0)	(14,096.0)
INVENTORY LEVEL	105,847.0 ***	116,154.0 ***	123,379.0 ***
	(29,131.0)	(26,658.0)	(22,562.0)
UNEMPLOYMENT	– 8,885.3 ***	– 8,898.3 ***	– 8,891.5 ***
	(2569.3)	(2180.8)	(1833.4)
LABOR (in 100,000s)	216,643.0 ***	214,335.0 ***	223,420.0 ***
	(30,935.0)	(18,851.0)	(16,025.0)
EMPLOYEE TURNOVER	– 18,378.0	– 14,117.0	– 13,491.0
	(32,193.0)	(28,323.0)	(24,319.0)
PROPORTION FULL	– 17,576.0	– 18,171.0	– 18,629.0
	(23,799.0)	(17,057.0)	(14,450.0)
SM TURNOVER	– 3,909.7	– 2,855.6	– 3,025.0
	(5593.9)	(4106.8)	(3499.9)
COMPETITORS	54,104.0 ***	– 54,041.0 ***	– 53,788.0 ***
	(5386.1)	(4508.3)	(3782.0)
PLAN SALES	0.088 ***	0.084 ***	0.088 ***
	(0.014)	(0.014)	(0.010)
YEAR 1999	– 37,236.0 ***	– 39,047.0 ***	– 39,431.0 ***
	(9664.8)	(6629.4)	(5581.2)
YEAR 2000	– 28,718.0 **	– 30,095.0 ***	– 30,389.0 ***
	(7383.0)	(5770.8)	(4852.0)
YEAR 2001	– 20,550.0 ***	– 21,858.0 ***	– 22,137.0 ***
	(5593.4)	(4790.2)	(4088.6)
Observations	1253	1247	1247
Adjusted R^2	0.965	0.966	

*, **, ***denote statistical significance at the 10%, 5%, and 1% levels, respectively. Regressions include dummy variables for audit months, fixed effects for stores, and a constant term not shown in the table. Standard errors are reported in parenthesis. Robust standard errors are reported when using OLS.

The results of the regressions confirm our first two hypotheses. Increasing both inventory level per product and product variety at a store is associated with an increase in % phantom products. Product variety and inventory level are both significant at the 1% level when using OLS estimators (column 2) and when using WLS estimators and a logistic transformation of % phantom products as the dependent variable (column 3).

4.2. The Effect of % Phantom Products on Store Sales

Table 5 presents the results of testing the effect of % phantom products on store sales. The OLS estimates of the parameters are reported in columns (1) and (2); the maximum likelihood estimates are reported in column (3). The results of the OLS and MLE regressions are very similar and confirm that an increase in % phantom products is associated with a decrease in store sales. % phantom products is significant at the 1% level in both regressions.

Note that, theoretically, the relationship between inventory levels and sales is not linear. To take into account expected decreasing returns to increasing inventory levels, we also used a natural log transformation of the inventory levels in Equation (2). We tried the same transformation for product variety with very similar results (reported in Table 6). We did not observe any improvement in fit with the transformed variables.

Finally, Table 7 reports results of testing the effect of past sales (sales 3 and 6 months before the audit) on percentage of phantom products.[4] The absence of significant effects in the reverse regressions suggests that

Table 6 Regression Results for Testing the Effect of % Phantom Products on Store Sales Using a Nonlinear Relationship between Product Variety and Sales and between Inventory Level and Sales

Variable	OLS (1)
% PHANTOM PRODUCTS	− 259,923.0 ** (128,490.0)
LN (*PRODUCT VARIETY* (in 100,000s))	50,186.0 * (27,477.0)
LN (*INVENTORY LEVEL*)	108,529.0 *** (28,483.0)
UNEMPLOYMENT	− 9,038.2 *** (2531.6)
LABOR (in 100,000s)	218,441.0 *** (31,659.0)
EMPLOYEE TURNOVER	− 13,781.0 (33,454.0)
PROPORTION FULL	− 18,504.0 (24,023.0)
SM TURNOVER	− 2,806.4 (5668.9)
COMPETITORS	− 53,568.0 *** (5396.6)
PLAN SALES	0.084 *** (0.015)
YEAR 1999	− 38,371.0 *** (9875.3)
YEAR 2000	− 29,850.0 *** (7469.7)
YEAR 2001	− 21,118.0 *** (5609.2)
Observations	1247
Adjusted R^2	0.964

*, **, ***denote statistical significance at the 10%, 5%, and 1% levels, respectively. Regressions include dummy variables for audit months, fixed effects for stores, and a constant term not shown in the table. Standard errors are reported in parenthesis. Robust standard errors are reported when using OLS.

we need not be concerned about store sales driving percentage of phantom products.

4.3. Indirect Effect of Product Variety and Inventory Levels on Store Sales

All conditions associated with a mediating effect, as described in Baron and Kenny (1986), hold in our model. Specifically, product variety and inventory levels are both significant in Equations (1) and (2) and % phantom products is significant in Equation (3). The fact that product variety and inventory levels are both significant in Equation (3) suggests that percentage phantom products is not a perfect mediator; that is, there are other mechanisms by which product variety and inventory levels affect store sales. This result is consistent with the literature we discussed in section 2. Consistent with path models, the estimates for the indirect effects of product variety and inventory levels on sales are represented by the product of coefficients $\beta_1\gamma_1$ and $\beta_2\gamma_1$, respectively. We use the formula developed by Sobel (1982) to calculate the standard errors associated with $\beta_1\gamma_1$ and $\beta_2\gamma_1$ and to test the significance of the indirect effects (H_o: $\beta_1\gamma_1 = 0$ and H_o: $\beta_2\gamma_1 = 0$):

$$\sigma_{\beta_1\gamma_1} = \sqrt{\beta_1^2\sigma_{\gamma_1}^2 + \gamma_1^2\sigma_{\beta_1}^2}, \sigma_{\beta_2\gamma_1} = \sqrt{\beta_2^2\sigma_{\gamma_1}^2 + \gamma_1^2\sigma_{\beta_2}^2}.$$

The indirect effect of product variety on sales, − 4,748.87 (= 0.018* − 263,826), is significant at the 4% level and the indirect effect of inventory levels on sales, − 9,761.56 (= 0.037* − 263,826), is significant at the 3% level. Note that the indirect effects of product variety and inventory levels on sales are small compared with their direct effects on sales (58,744 and 116,154, respectively). For example, at an average store that carries 178,711 products and 1.37 units per product, a one-standard-deviation[5] increase in product variety of 34,348 products and a one-standard-deviation increase in inventory levels of 0.087 units per product are associated with \$20,177.39 and \$10,105.40 increases in monthly store sales, respec-

Table 7 Regression Results for Testing the Effect of Store Sales 3 Months and 6 Months Preceding the Audit on % Phantom Products

Variable	OLS (1)	OLS (2)
STORE SALES 3 MONTHS PRECEDING THE AUDIT (in 1,000,000s)	0.000	
	(0.000)	
STORE SALES 6 MONTHS PRECEDING THE AUDIT (in 1,000,000s)		0.000
		(0.001)
PRODUCT VARIETY (in 100,000s)	0.018 ***	0.017 **
	(0.007)	(0.007)
INVENTORY LEVEL	0.037 ***	0.037 ***
	(0.013)	(0.013)
UNEMPLOYMENT	0.000	0.000
	(0.001)	(0.001)
LABOR (in 100,000s)	− 0.021 ***	− 0.022 ***
	(0.008)	(0.007)
EMPLOYEE TURNOVER	0.010	0.009
	(0.013)	(0.013)
PROPORTION FULL	− 0.003	− 0.004
	(0.006)	(0.006)
SM TURNOVER	0.004 **	0.004 **
	(0.002)	(0.002)
COMPETITORS	− 0.001	0.000
	(0.002)	(0.002)
PLAN SALES	− 0.0004	− 0.0005
	(0.000)	(0.000)
YEAR 1999	− 0.007 **	− 0.006
	(0.003)	(0.003)
YEAR 2000	− 0.005 *	− 0.004
	(0.003)	(0.003)
YEAR 2001	− 0.004 **	− 0.004 *
	(0.002)	(0.002)
Observations	1247	1247
Adjusted R^2	0.596	0.596

*, **, ***denote statistical significance at the 10%, 5%, and 1% levels, respectively. Regressions include dummy variables for audit months, fixed effects for stores, and a constant term not shown in the table. Standard errors are reported in parenthesis. Robust standard errors are reported when using OLS.

tively. The indirect effects of similar increases in product variety and inventory levels on monthly sales are −$1,631.14 and −$849.26, respectively.

The effect of percentage of phantom products on store sales is economically significant. A one-standard-deviation increase in percentage of phantom products leads to a 1% decrease in average monthly sales of $487,464, which is $4,828.02. Assuming a gross margin of 30%, the associated profit impact of a $4,828.02 drop in sales is roughly $1,448.41 per month or $17,380.87 per year. Borders' annual report shows an average net profit of $252,475.25 for Borders superstores in 2002. Hence a one-standard-deviation improvement in % phantom products would be associated with an approximately 7% increase in store profit.

5. Conclusion

Increasing inventory levels and product variety at a store has long been associated with higher sales. Increasing product variety increases the probability that the store will have the products that customers want, while increasing inventory levels for a particular item increases service levels for that item. While confirming the direct positive effect of increasing product variety and inventory levels on sales, our empirical analysis shows that increasing product variety and inventory levels also has an indirect negative effect on sales through its impact on phantom products.

Our study is an attempt to better understand the different mechanisms by which inventory levels and product variety affect store sales so that retailers can make the optimal trade-offs when determining inventory and variety levels. But more research is needed on this topic. For example, while the direct positive effect of increasing inventory levels and product variety on sales is larger than the indirect negative effect in our particular setting, there may be settings in which the indirect negative effects outweigh the direct positive effects. Researchers could also examine (a) the relationship between inventory levels and sales at the SKU level and (b) the effect of inventory levels and product variety on other measures of store performance, such as profit and labor productivity.

Because percentage of phantom products is analogous to defect rate, our study highlights the effect of conformance quality on store performance. In our context, a one-standard-deviation improvement in percentage of phantom products—one measure of conformance quality at retail stores—is associated with a 1% increase in store sales. Given that lost sales is only one negative consequence of phantom products and that phantom products is only one of several measures of conformance quality at retail stores,[6] we expect the overall effect of improved conformance quality to be higher than what we identified in this paper. Recent research highlights other positive effects of conformance quality on store performance: Ton (2008a, b) shows a positive relationship between a store's conformance quality and its profit margins and Ton and Huckman (2008) show that conformance quality moderates the effect of employee turnover on store performance.

The findings in this paper are consistent with our earlier work. As shown in Table 4, not only increasing product variety and inventory levels but also decreasing store labor and departure of store managers are associated with a higher percentage of phantom products.[7] These four factors were all identified as drivers of phantom products in Ton and Raman (2005). Verifying our earlier cross-sectional results in a longitudinal setting is reassuring and gives us more confidence in the strength of the relationship between these variables and the percentage of phantom products.

Because we examine a single retailer in a single category, our results may not generalize to other settings. Nevertheless, focusing on a single firm allows us to avoid having to control for unobservable firm-level factors, such as store manager incentives or merchandising systems, which may be correlated with the variables used in our models. Further, our results could be generalized to other retailers whose stores carry high product variety and low inventory per product and do not assign a specific shelf location for each product.

The problem of phantom products is common in other retailing settings (Andersen Consulting 1996, Corsten and Gruen 2003, Hardgrave et al. 2006).[8] Moreover, like Borders, several other retailers, such as Office Depot, Toys"R"Us, and Best Buy, offer high levels of product variety in a specific category and thus carry relatively few units of each product. Even more traditional retailers, such as grocery stores, are now maintaining high levels of product variety (Ketzenberg et al. 2000, Ketzenberg and Ferguson 2008). While the types of products other retailers carry may differ from the books and CDs at Borders, increasing the variety of these products and their inventory levels is just as likely to increase the complexity of the operating environment and hence the likelihood of problems such as phantom products. In a different retail setting, for example, DeHoratius and Raman (2008) find that higher variety and inventory are associated with more inventory record inaccuracy.

Certain kinds of products may be more prone to becoming phantom than others. For example, it may be easier for employees at Home Depot to recognize missing doors or windows than missing nuts and bolts. Smaller products may also be more difficult to differentiate than larger products. Products that do not have assigned locations, such as apparel in discount retailers, may more easily become phantom. Finally, slow-turnover or less expensive products may be more prone to becoming phantom because less attention is paid to them. DeHoratius and Raman (2008) find that more expensive products are associated with less inventory record inaccuracy. The magnitude of the effect of product variety and inventory levels on phantom products may differ across different product categories. We did not have category-level data with which to perform a category-level analysis.

Obviously, simplifying the store by eliminating storage areas would solve the problem of phantom products. But given the extensive use of storage areas in retailing, eliminating them may be too radical for most retailers. Reducing their size, however, might be a feasible intermediate step, which could help reduce phantom products and improve inventory and assortment planning by encouraging merchandise planners to be more selective about which items to send to the stores and by encouraging store employees to monitor those products more effectively. This recommendation is consistent with the literature on lean production systems, which has argued repeatedly that smaller repair areas in factories would improve manufacturing performance by forcing employees to reduce defects.

In fact, research on lean production systems may shed even more light on store operations. Krafcik (1988) found that the negative effect of increasing product variety on productivity was minimized in factories using lean production systems. Similarly, the design of store processes and policies that emphasize process conformance may be used to reduce the complexity and confusion arising from increased product variety and inventory levels.

Our findings have implications for the design and management of retail stores. We show that factors that increase the complexity and confusion in the operating environment also increase employee errors and cause phantom products. There is an opportunity to identify other factors that increase the complexity and confusion in the operating environment and examine their effect on store performance.

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Notes

[1]We considered an alternate model in which we used sales during the 3 months preceding the audit at store i in year t as the dependent variable. The results, not reported in this paper, were very similar.

[2]To control for differences in expected demand during different months, we also considered alternate models in which we de-seasonalized our variables using sales seasonality. We calculated seasonal coefficients using chain-wide monthly sales data. The results using a multiplicative model of seasonality, not reported in this paper, were very similar to those we obtained using monthly dummy variables. Note that we do not observe great seasonal fluctuations in our data because physical audits are not conducted during busy periods—seasonality for different months ranges from 0.78 to 1.08. Moreover, we do not observe any seasonality for several of our variables (e.g., store manager turnover, proportion of full-time employees, competition).

[3]Source: Bureau of Labor Statistics. Note that unemployment rate is measured at a more aggregated level than the unit of analysis.

[4]Note that, in these models, we use the same control variables used in other models. Changing the control variables to reflect the 3- and 6-month periods (as opposed to the month preceding the store audit) did not make a difference in the results.

[5]We use the standard deviations reported in Table 2. We observed a large variation in standard deviations *within* different stores.

[6]Phantom products also distort demand data, lower labor productivity, and reduce customer good will. Other measures of conformance quality in retail stores include nonconformance with promotions, nonconformance with display requirements, and nonconformance in returning obsolete products.

[7]Employee turnover, which was a significant variable in our earlier cross-sectional study (Ton and Raman 2005), is not significant in the models in Table 4.

[8]Even those retailers, such as Home Depot, that do not have large backrooms have storage areas on the selling floor where they keep extra units of inventory and which are not accessible to customers.

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