An empirical test of inventory, service and cost benefits from a postponement strategy

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Postponement of the point of product differentiation is a potentially powerful strategy to improve supply chain management. The literature offers theoretical arguments supporting the relationship between postponement and improved inventory turns and customer service quality, as well as lower operational costs. This study empirically examines these proposed benefits. Data from a disk drive manufacturer that applied postponement to simplify its supply chain are used to test the benefits of this strategy. During the time of the case study, the company implemented an initiative to create a generic product that needed less customization; what configuration remained could be delayed until the product was integrated at the customers’ sites, instead of at the company’s distribution centres. Regression analysis is used to investigate whether higher levels of postponement are associated with better service, lower inventory, and lower cost. Our results indicate that higher levels of postponement—measured as the percentage of generic products shipped—are associated with better on-time delivery and lower variable costs. Our results also indicated the importance of redesigning products and processes and working together with customers.

Keywords: Postponement; Product variety; Empirical research; Supply chain; Case study

1. Introduction

Managing product variety is challenging given the complexities of today’s supply chains (Ramdas 2003). However, empirical evidence suggests firms that match their supply chain structure to the type of product variety they offer, outperform firms that do not make use of such opportunities (Randall and Ulrich 2001). One solution for managing product variety is to postpone the configuration of a product to customers’ specifications as late as possible in the supply chain. This approach has recently received considerable attention as one of the most beneficial concepts for reducing the costs and risks of product variety and improving the performance of supply chains (e.g. Lee 1996, Feitzinger and Lee 1997, Lee and Tang 1998,

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Postponement can be defined as moving the point of differentiation further downstream (Lee and Tang 1997). A point of differentiation is where the number of SKUs increases, because a material, component, subassembly, or product is split into separate items (Lee and Tang 1998). This may occur because components with different technical specifications are created, multiple end products with diverse functionalities are created, a product is packaged in different ways, or the exact same item is stored in different geographical locations (Lee and Tang 1998, Van Hoek 2001).

Several examples of the implementation of postponement have been described in the literature. Hewlett Packard sent PCs to Europe and configured these for specific countries (for example through selection of the keyboard, manuals, and software settings) in its distribution centre. They postponed the point of customization compared to the before-situation where each unit was already made country-specific in its Singapore factory (Lee and Billington 1995). HP also standardized its laser printer so that the same printer could be sold in Europe as well as North America; previously the power supply was specific for each one of these markets and two different types of printers were produced at the factory in Japan (Feitzinger and Lee 1997). Another example is Xilinx who redesigned its integrated circuits so that a “generic” device could be customized within a certain range of parameters, rather than determining all product characteristics during fabrication (Brown et al. 2000). Imation used a contract manufacturer in Asia to produce its CDs, shipped them in bulk to Kansas in the U.S.A. and packaged for retail customers into several different pack sizes with different types of labels. A small number of SKUs was differentiated into many different products (Andel 2002). A European wine producer sourced base wines from suppliers in Australia, South Africa, South America, and southern and eastern Europe. Bottling, labelling, and packaging were delayed until customer orders had been received. Each of the 48 base wines could be sold into at least 9 different types of bottles (and also in bulk) that could be combined with, in principle, unlimited labelling variants; and the bottles could also be packed in several ways (Van Hoek 1997). These examples indicate benefits of postponing the point of customisation, but they also show that additional efforts are often required, such as product redesign, modification of the configuration processes, or redesign of the supply chain.

Several theoretical models have been developed to analyse the benefits of postponement such as better service, lower inventories, and lower costs associated with inventory risk pooling and reduced supply chain complexity (e.g., Lee and Tang 1997, Fisher et al. 1999). Simulation studies have provided support for such models (e.g., Benton and Srivastava 1993, Tsubone et al. 1994, Graman and Magazine 2002), and the implementation and effects of postponement have also been investigated using survey data (e.g., Yang et al. 2005a,b).

Our study aims to contribute to the literature by empirically investigating the relationship between postponement and service quality, inventory reduction and operating costs of logistic processes. We test these empirical predictions using data from a U.S. disk drive manufacturer. During the observation period, the company implemented an initiative—called Generic Drive Program—to redesign its supply chain using postponement principles. The initiative was aimed at either eliminating customization activities or postponing them to later stages in the supply chain.
In particular, the objective was to work with customers to decrease the level of customization, postpone any remaining customization to later in the supply chain and execute it through software modules that could be downloaded into the disk drives at the customers’ production lines. The increased costs at the customers’ premises were considered to be very small and reflected in the prices of the new disks. The dataset spans over eighteen months since the initial stages of the initiative until the initiative was considered fully implemented. We examine the association between the level of process complexity and three performance measures: on-time delivery service, inventory turns, and operating costs. Our results indicate that a higher level of postponement was associated with improved on-time delivery, lower operational costs, but not with increased inventory turns.

The remainder of this paper is structured as follows. We first review studies on the concept of postponement of product differentiation. Then we review theoretical and empirical studies on the benefits of implementing postponement. These studies, in section 2.1, focus on customer service and inventory, while studies that are reviewed in section 2.2 focus on cost as a result of reducing complexity and increasing commonality. Based on this literature, we state our research hypotheses in section 2.3. Section 3 describes the research setting. The empirical results are in section 4, and section 5 concludes.

2. Literature review

2.1 Postponement of the point of product differentiation

Three types of postponement can be used in supply chains: time postponement (delay the downstream movement of goods until customer orders are received), place postponement (storage of goods at central locations until customer orders are received), and form postponement (delay product customization until customer orders are received). We focus on form postponement in this study, and we refer to Van Hoek (2001) for a comprehensive review of the postponement literature (See figure 1). Form postponement entails the delay of activities, such as labelling, packaging, assembly, or manufacturing, in order to move the point of product differentiation downstream in the supply chain (i.e., keeping products to their generic form as long as possible, as depicted in figure 1). This increases the flexibility to cope with market uncertainties (Lee 1996).

Typically (or ideally), activities that are conducted upstream (“before”) the point of differentiation are based on forecasts, whereas activities that are performed downstream this point are based on customer orders (Skipworth and Harrison 2004). Also without that particular arrangement, postponing product differentiation may have significant benefits (Lee and Tang 1997). Note further that a supply chain may have multiple points of differentiation.

Lee and Tang (1997) analysed the costs and benefits of delayed product differentiation. They formalized three basic approaches to postponement: (1) standardization, (2) modular design, and (3) process restructuring. Standardization and modular design enable a firm to configure a large number of different end products from a limited set of standard components; typically by combining a limited number of core modules with an array of modules that provide
different levels and different types of functionality (Ulrich 1995, Lee and Tang 1997). Process restructuring aims to move production activities that create the most diversity to a later stage in the supply chain. This objective can be achieved by moving an activity that creates diversity to a later stage (postponement of operation) or re-sequencing operations (Lee and Tang 1998).

A major benefit of postponement in the supply chain relates to inventory reduction and service improvement, because holding inventory of a non-specific product requires less safety stocks compared to holding inventory of several specific products (Aviv and Federgruen 2001). This benefit is quite similar to the risk pooling effect of multi-echelon inventory systems.

Several authors use mathematical models to study how postponement reduces the total inventory required for meeting a specified service level. An early paper by Dogramaci (1979) demonstrates that component commonality may result in lower prediction errors and therefore lower levels of safety stocks, and he proposes algorithms for grouping products in clusters that are served by a common component. Later papers analyse this risk pooling effect in different settings (e.g., Baker et al. 1986, Gerchak et al. 1988, Gerchak and Henig 1989, Bagchi and Gutierrez 1992, Eynan 1996, Garg and Tang 1997, Swaminathan and Tayur 1998). Eynan and Rosenblatt (1996) and Hillier (1999, 2000) include the effect of common components being more expensive than unique components and find that the savings in inventory costs and service do not always exceed the increases in material cost due to more expensive common parts. Garg and Lee (1998) and Aviv and Federgruen (1998) provide a review of the analytical literature that has explored the theoretical implications of postponement and process commonality.

Simulation studies also support the positive impact of commonality upon inventory levels (Benton and Srivastava 1993, Tsubone et al. 1994, Bartezzaghi and Verganti 1995, Graman and Magazine 2002, Alfaro and Corbett 2003, Rabinovich and Evers 2003,) as well as upon manufacturing lead-time (Sheu and Wacker 1997). Some studies use empirical data from one company and simulate the impact of postponement in that particular setting (Garg 1999, Lin et al. 2000).
Recent studies also use survey data to investigate research questions related to the implementation of postponement (e.g., Chiou et al. 2002, Sánchez and Pérez 2005, Yang et al. 2005a,b). For example, companies consider the delivery performance of suppliers a barrier to implementation (Yang et al. 2005a). Nair (2005) investigates the perceived benefits of postponement using survey data from 306 respondents from the Council of Logistics Management membership database. He finds postponement to be associated with better asset productivity, delivery performance, and value chain flexibility.

Krajewski et al. (2005) conducted five case studies of firms in Taiwan involved in the production of notebook computers and their components. Based on cross-case analysis, they proposed that postponement was used as part of a strategy to reduce uncertainty in responding to short-term dynamics in the supply chain. Cross-case analysis is also applied by Van Hoek et al. (1998), based on four case studies in different industries in Europe. They found that the history of a company’s operating base had a substantial effect on the implementation of postponed manufacturing.

Descriptive case studies detailed in the introduction also provide evidence on the benefits of using a postponement strategy in supply chains (Lee and Billington 1995, Feitzinger and Lee 1997, Van Hoek 1997, Andel 2002, Skipworth and Harrison 2004). Of particular relevance for the research setting of this paper, is the study by Brown et al. (2000). Xilinx, an integrated circuit manufacturer designed its products to be programmable to allow customers to fully configure them using software. This strategy allowed postponing the point of customization until after the customer receives the product. Brown et al. (2000) report that postponement helped the company to reduce inventory levels while maintaining customer service.

Skipworth and Harrison (2004) is the only study using archival company data to statistically investigate postponement. They describe results of implementing postponement at a manufacturer of specialist high-voltage cabling equipment. Production used to be make-to-order for some items, causing long delivery times, and make-to-stock for other items, which caused inventory risks. The postponement initiative involved making a standardized semi-finished product to stock and postponing the subsequent production steps that led to many different end-products until receipt of a customer order (Skipworth and Harrison 2004). The study combines quantitative data about demand, order lead-times, delivery reliability, product standardization, and efficiency with qualitative data gathered in interviews. They find that responsiveness had improved after implementing postponement but not delivery reliability. They also find that benefits varied with the ability to adapt the manufacturing planning and production planning systems.

In sum, mathematical models, simulation studies, qualitative descriptive case studies, and perceptual survey data indicate that postponement improves inventory levels and/or customer service. The literature reviewed here forms the basis for hypotheses 1a and 1b in section 2.3. Implementation of postponement is not only a matter of deferring a customization activity downstream in the supply chain, but it requires additional changes to enable the delay of that activity. Our study aims to contribute to the literature by using both qualitative data on how a company implemented postponement, as well as quantitative, archival data on the impact on costs, inventory, and service levels.
2.2 Postponement and the cost of complexity

Diversity of products, subassemblies, components, and materials, is costly, because it requires additional support activities (involving overhead resources) such as product development, tooling, scheduling, inventory management, set-up, and quality control (Fisher et al. 1999). As diversity and complexity increases, the demand for these overhead resources (complexity cost) increases and, if these resources are scaleable, their supply and costs will increase (Kaplan and Cooper 1998). Several empirical studies provide evidence consistent with this prediction (Banker and Johnston 1993, Datar et al. 1993, Anderson 1995, Banker et al. 1995, MacDuffie et al. 1996, Fisher and Ittner 1999), while other studies do not support this (Faster and Gupta 1990, Kekre and Srinivasan 1990).

While postponement decreases operational costs it may increase other types of costs. A component has to meet the most stringent performance requirements across the group of products in which it is used, and this is likely to increase costs because of excess capability of shared components. Alternatively, if component performance is compromised, there will be the cost of performance degradation of the end product (Fisher et al. 1999, Ulrich and Ellison 1999, Thonemann and Brandeau 2000). Product commonality may also negatively affect the revenue stream, for components that affect customers’ perception of the quality of functionality of the end product (Kim and Chhajed 2000, Desai et al. 2001, Krishnan and Gupta 2001, Ramdas and Sawhney 2001, Rai and Allada 2003).

In sum, postponement of the point of product differentiation reduces complexity of the supply chain, which may lead to lower operational costs. This effect is investigated in the present study, and it is summarized in hypothesis 2 in section 2.3.

2.3 Hypotheses

The theory outlined in the previous section 2.1 predicts that postponement will improve inventory levels and/or customer service. Because service requires inventory, a trade-off exists between inventory turns and service (Baker et al. 1986, Gerchak et al. 1988, Bagchi and Gutierrez 1992). The relationship between service and the level of safety stock is reflected in an “exchange curve” between service and inventory turns (Silver et al. 1998, Garg 1999). Keeping the same level of customer service, increased postponement is expected to reduce inventory and, accordingly, increase inventory turns (Baker et al. 1986, Gerchak et al. 1988). Inventory turns are expected to increase because a generic product that serves many different customers requires lower inventory compared to a customized range of products where each one is specific to one customer. Alternatively, the arguments described in the section 2.1 suggest that common inventories may not be used to increase inventory turns (through lower inventory levels), but to increase the level of service. Companies may also adopt a combination where postponement improves simultaneously inventory turns and service (although the improvement in any of the dimensions is not as large as it would be if all the benefits of postponement where focused on one of the dimensions).

The above arguments predict a positive relationship between postponement and inventory turns and service level.

Hypothesis 1a: A higher level of postponement is associated with improved customer service.
Hypothesis 1b: A higher level of postponement is associated with increased inventory turns.

As outlined in section 2.2, activity based costing theory is informative to predict the impact of postponement on operational costs of the logistic process or, more broadly, the supply chain. Previous studies have found empirical support for the relationship between complexity and costs (Banker and Johnston 1993, Datar et al. 1993, Anderson 1995, Banker et al. 1995, MacDuffie et al. 1996, Fisher and Ittner 1999) and in this study we aim to extend these findings to operational supply chain costs. Postponement may simplify the complexity of the supply chain—through fewer steps like unpacking, configuring, and repacking (Lee and Tang 1997, Van Hoek 2001). Because of the lower complexity associated with postponement, activity based costing predicts a relationship between increased postponement and lower operating costs (Kaplan and Cooper 1998). Note that we focus on operational cost and do not address potential effects on material costs of excess performance or on revenues, because these effects do not apply to the research site. Thus, we hypothesize:

Hypothesis 2: Increased postponement is associated with lower operational costs.

An important distinction highlighted in the activity-based costing literature (Kaplan and Cooper 1998) exists between scalable and non-scalable costs. Scalable costs are those that decrease proportionally with a decrease in the volume of cost drivers, and we label them as variable costs. Non-scalable costs (fixed costs) do not decrease with decreasing cost drivers’ volume; rather a decrease in the volume of cost drivers generates excess capacity that does not translate into lower costs. A relationship between complexity and fixed costs exists only if the resource associated with these costs can be eliminated and in this case the relationship is not linear but step-like. Because our time frame is not long enough to capture major changes in fixed costs (like closing a logistic facility), we expect hypothesis two to hold for variable costs but not for fixed costs.

3. Research design

3.1 Research site

The study was conducted at a disk drive manufacturer during the time it implemented form postponement through its Generic Drive Program. The company worked with its supply chain partners to redesign and simplify its products and processes and to reduce costs. The initiative involved the so-called Personal Computing Storage Division (PCSD) drives within the company’s Hard Disk Drive Group that served personal computer OEM (Original Equipment Manufacturer) customers, such as Apple, Compaq, Dell, Hewlett-Packard, IBM, and Gateway.

The original supply chain started at the company’s manufacturing partner in Japan, which manufactured the disk drives and shipped them to the disk drive company’s four logistics sites in Japan, Singapore, North America, and Ireland. At the sites a large percentage of drives needed to be configured to customer specifications. These customization procedures involved adding labels, adjusting switches, and performing customer-specific tests. The main cost associated with the
The configuration process was not the process itself but the cost of unpacking and repackaging the units and managing inventories.

The objective of the postponement strategy, or “Generic Drive program” as it was called at the company, was to defer the point of differentiation to the customer, by creating a product that needed less configuration, which could be performed at the customers’ sites. To make this happen, a team of people at the company had to implement several significant changes. They worked with OEM customers towards a situation where they would receive generic products instead of customer-specific products; and the remaining customization would happen at the customers’ premises during the final assembly of the drives, using only software solutions for configuration. Product variety was avoided when possible by finding specifications common to all customers. For example, since OEM customers had different testing requirements for the disk drives that they used, the testing procedure at the end of the production line was adjusted to the toughest requirements of all OEM customers. This procedure ensured that every unit was acceptable to each OEM customer, without undergoing any downstream customer-specific testing. The configuration of those specifications that needed to be specific to each customer was delayed to the point in the supply chain where the drive was integrated into the OEM’s product. To achieve this goal without simply shifting customization costs across different parts of the supply chain, products were redesigned to allow software-based modules to be downloaded during the configuration stage at the customers’ production line. For example, the configuration of a disk drive as the “master” or “slave” was previously done at the logistic sites—disk drives were unpacked and a switch moved to determine the “role” of the drive. The product was redesigned to have the configuration done with a software module. The implementation of form postponement in this situation is illustrated in figure 2†.

In both situations, products were made to stock. In the old supply chain, most drives were customer-specific products stocked either at the disk drive company’s logistical sites or in third-party warehouses close to customers. In the new supply chain,

†The technical changes to implement the Generic Drive Program were minor, but the changes in the structure of the supply chain were major. The thrust of the effort was postponement although its implementation included broader efforts including product redesign, parts commonality, re-sequencing, negotiations with customers, and pricing policies.
generic drives could be stocked at the disk drive company’s logistic sites or in third-party warehouses. Lead times did not allow for alternative stocking policies.

After implementation of the generic drive initiative, the company planned to significantly increase direct shipments from the factory in Japan directly to its customers. During the period of study, no logistical sites were closed and direct shipments from the factory to customers were limited. During the observation period fixed costs did not change significantly. However, the company eliminated two of its distribution centers soon after the data collection period, with the expected significant reduction in fixed costs.

The company expected several benefits from the program, such as greater flexibility towards their customers, cost reduction, and improved asset management. Implementation of the program required working closely with OEM customers to communicate the benefits of changing from customized to generic products, adjust processes, and negotiate the configuration activities at the customers’ premises so that they would shift to generic products. It has happened that an OEM customer required an unexpected volume of customer-specific drives that were not available. The company offered to supply these drives, but it would require a lead-time of at least one week. As an alternative, they could supply the generic drive immediately. This demonstrated very clearly to the customer the advantage of working together to implement the generic drive initiative. Any incremental costs associated with postponement were included as operational costs within the logistic sites. While we do not have information about the potential impact of postponement activities on the revenue side, managers believed that the postponement strategy had a positive impact on the bottom line of the company (estimated in several million dollars), even after including any price adjustments with customers. The savings from the postponement program—captured at the disk drive company—exceeded any price effects from customers.

Our interview data allow an examination of how the postponement program changed costs or inventory at suppliers and customers. The program did not require the manufacturing partner to perform additional activities, which would imply shifting costs from the company to the supplier, nor did existing activities become more costly. The supplier delivered generic products to the company as before, only certain parameters in the testing procedures changed, but these tests were not more elaborate or costly. The program did shift certain configuration activities to the company’s OEM customers. Given the size of the OEM customers, it is unlikely that the negotiating power of the disk drive company allowed them to benefit from shifting costs (if any) to customers without being charged for it. OEM customers passed cost increases to the company in the form of price reductions, which the company found acceptable, given their internal cost savings from avoiding configuration activities. The program did not increase inventories with customers, as these parties carried almost no inventories and used the supplier’s flexibility and short lead times. Thus, the disk drive company gained most of the efficiencies associated with the postponement program and all the increased costs through price adjustments. Evaluation of the postponement program’s effects upon the disk drive company’s supply chain offers a good approximation of the overall effect of the program upon the supply chain.
3.2 Data

We gathered data from the four logistic sites for a period of 18 fiscal months from October 1998 through April 2000. We collected data for seven different product families that had shipments of both generic and customized products from all logistic sites. The average life cycle of the product was seven months. These families represented 91% of the unit shipped during the observation period. Each product family included several generic products (for example, with different capacities) and several configured versions (for different customers). Thus, “product” means a specification defined by the product family, the storage capacity, the interface, and includes both generic and customized versions. We collected data on all shipments during this period of time involving products within these seven product families. Each transaction record included information about product family for the product delivered, whether it was generic or configured, commit date and delivery date, and whether it was shipped directly from the manufacturer to the customer without going through any logistic site. We also collected inventory data for the four logistic sites: inventory level at the end of each week measured in number of units per product family. We gathered monthly information on the operational costs of the logistic sites. The company classified its costs as variable or fixed. Variable costs included direct labour, freight, manufacturing expenses, rework and scrap and other variable costs; fixed costs included indirect labour costs, travel expenses, engineering, supplies, recruiting, equipment, and facilities.

For each variable, and these are listed below, we have data measured in monthly time buckets and specific per logistic site. Operational costs for the logistic sites are recorded at this level since the company does not allocate them to product families. Furthermore, shipment dates and inventory records come from two different databases, and we pool the data at the site level because certain product families can be used to satisfy the demand of other families to avoid missing deadlines, and thus inventory turns and service level become meaningful at the aggregate level.

We define the following variables to measure operational costs and performance:

**Inventory turns per month and per site**: We calculate the average inventory from the inventory database for both work-in-process and end products for every month (average of end-of-week inventory levels during the month). Work-in-process inventory are units in the process of being customized within the logistic site. We multiply each product family’s inventory by its product unit cost to have a measure of inventory valued in dollars. We use the price that the manufacturing partner charged the company as product cost. This measure of inventory is likely to be more relevant to management than units per se and more significant to evaluate performance. From the shipment data, we add the number of units of each product family shipped during one month and estimate the value of the products shipped to customers as the number of units shipped times their unit cost. Inventory turns are defined as the value (price from the manufacturing partner) of products shipped during the month divided by average inventory for the month.

**On-time delivery per month and per site**: For each customer order we assess whether it was delivered on time: if the delivery date was before or on the commit date. We then calculate the number of orders delivered on time over all the orders served during the month. This measure was the company’s measure of service performance.
Variable cost per unit: We measure operational costs as variable costs per unit. This variable is defined as total monthly variable costs (as classified by the company) over units shipped. Variable costs include direct labour, freight, rework and other variable costs.

Total fixed costs: For completeness, we also include fixed costs to capture any potential impact that postponement may have on fixed costs. However, if postponement only creates excess capacity rather than allow a reduction of resources supplied, then we do not expect to find an association between postponement and fixed costs. We define this variable as the overall fixed costs for the month for each site.

Total costs per unit: We also include a measure of total costs per unit as an alternative measure of cost efficiency. This variable is measured as the monthly costs for the logistic site over the number of units shipped. It includes variable and fixed costs; therefore it does not depend on the company’s classification between variable and fixed costs. However, because total cost per units includes fixed cost per unit, which may not depend on the level of postponement, this variable is expected to be noisier.

Our explanatory variable is the level of postponement, and we proxy it through the percentage of generic products shipped.

Proportion generic per month and per site: This variable is calculated as the percentage of generic units shipped over the total shipments to customers. The higher the percentage of generic products, the larger the number of units for which customization is postponed and done at the customers’ premises and, following our hypotheses, improved supply chain performance.

In addition to the previous variables, we include several controls.

End-of-quarter: This variable controls for potential effects related to the last month of the quarter being longer than the other two, as well as to control for the seasonality in shipments—shipments tend to be much larger in the third month of each quarter. We include a dummy variable that takes value of one if the month is the third month of a quarter. The number of units shipped tends to be larger in this month, therefore inventory turns is expected to increase.

Number of units shipped (in millions): To control for the impact of volume on the performance of the supply chain, we include as a control variable the number of units shipped during the month. We expect a higher number of units shipped to increase inventory turns. Moreover, in the presence of economies of scale we expect this variable to be negatively related to variable costs and positively to total costs per unit as fixed costs are spread throughout more units. Demand is mostly exogenous and determined by economic conditions in the PC market; the company did not expect big changes in the demand curve because of the cost improvements associated with postponement.

Direct shipments: Some orders of generic products are shipped directly from the manufacturer to OEM customers. These direct ships may impact on the service because the logistic sites do not manage the process.

Months: To control for the trend that may exist over time due, for example, to learning at the logistic sites, we include a variable that takes value of one the first month, two the following month and so forth.

Site dummy variables: We also include site dummy variables to control for differences across sites.
3.3 Empirical specification

To test our hypotheses, we examine the impact of the various dependent variables on the performance of the distribution centres. Because of the panel structure of the data, we use a GLS regression model with variances differing across sites, we control time-dependent covariates through dummy variables as described in the prior section and an AR(1) error structure common across sites—reflecting the assumption that the behaviour over time is comparable across sites. Finally, we use a linear model reflecting the early stage of implementation of the Generic Drive strategy—this model assumes that in these early stages changes in the dependent variables will translate in linear changes in the performance variables. To check the validity of this assumption, we included the square term for proportion of generic, units shipped and direct shipments; the inferences remained unchanged. We also used a first differences model to control for potential spurious correlations not captured by the AR(1) structure†. The inferences remained unchanged.

The general specification of the regression model for our tests is:

\[
\text{Performance} = \beta_0 + \beta_1 \text{ Percentage Generic} + \sum \beta_i \text{ control variables} + \varepsilon
\]

where Performance is inventory turns, on-time delivery, or variable costs per unit. Hypothesis one (two) predicts \( \beta_1 > 0 \) (\( \beta_1 < 0 \)) and, accordingly use one-tailed tests to assess significance. When Performance is inventory turns (on-time delivery) we include as control on-time delivery (inventory turns) to control for the relationship between these two variables.

4. Empirical results

4.1 Descriptive statistics

Before testing the hypotheses using regression analysis, we will present some descriptive statistics in tables 1 and 2. Table 1 presents the descriptive statistics for each logistic site per month. The sites are different in the volume that they handle with North America being the largest and Japan the smallest. The standard deviation for the number of units is quite large; this effect reflects the seasonality in the industry—a significant part of sales happens in the third month of each quarter. On average, the company turns its inventories at the logistic sites 1.42 times a month, and has an on-time delivery record of 86%. The sites are also different in their cost structures with North America and Europe being more expensive on a per unit basis. Because of these differences between logistics sites, we will include site as a control variable in our regression analyses.

Table 2 provides correlations among the variables. The proportion of generic products is correlated with cost variables as theory predicts; however inventory turns and on-time delivery show no relationship with postponement. Time (\( \text{Month} \)) is positively related to inventory turns as well as costs. End-of-quarter is positively related to inventory turns reflecting the increase in units shipped at the end of the quarter (as reflected in the correlation between end-of-quarter and units).

†The variables in the model (other than the dummy variables) were defined as the change between consecutive months.
On-time delivery is negatively correlated with direct shipments. Finally the proportion of generic is positively correlated with direct shipments because the latter ones are typically generic products. These correlations indicate that a multivariate analysis is required, whereby the relationship between the proportion of generic products and our dependent variables (inventory turns, on-time delivery, or variable costs per unit) can be controlled for various factors, such as month, end-of-quarter, and logistic site.

### 4.2 Multivariate analysis

Our panel data combines cross-sectional (i.e., across logistic sites) and time information (i.e., eighteen months). We test for the presence of autocorrelation in the error terms for each of the time series, and we find that no significant serial correlation is present. The four sites perform similar activities in the supply chain, manage the same type of products, and belong to the same company thus having comparable operational designs and policies. However, sites show differences—especially in their cost structures—and to control for these differences, we include a dummy variable for each site. We also control for heteroskedasticity across sites using an estimated generalized least squares specification where the variances in the error terms are allowed to vary across panels.

Table 3 has on-time delivery as its dependent variable. To control for the potential interaction between inventory turns and service level, inventory turns is included as an additional control term (in M3); this variable is insignificant. The results for this model are consistent with hypothesis 1a and the proportion of generic has a positive
Table 2. Correlations (Pearson) between variables.

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<td>3</td>
<td>Total fixed costs</td>
<td>-0.27*</td>
<td>-0.26*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Total cost per unit</td>
<td>-0.34*</td>
<td>-0.28*</td>
<td>0.65**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Variable cost per unit</td>
<td>-0.27*</td>
<td>-0.29*</td>
<td>0.65**</td>
<td>0.98**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Proportion Generic</td>
<td>-0.08</td>
<td>-0.02</td>
<td>0.02</td>
<td>-0.45**</td>
<td>-0.47**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Units</td>
<td>0.20</td>
<td>-0.00</td>
<td>0.49**</td>
<td>0.04</td>
<td>0.17</td>
<td>0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Month</td>
<td>0.24*</td>
<td>-0.18</td>
<td>-0.24*</td>
<td>-0.30**</td>
<td>-0.24*</td>
<td>0.21</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>End-of-quarter</td>
<td>0.60**</td>
<td>0.05</td>
<td>0.10</td>
<td>-0.24*</td>
<td>-0.17</td>
<td>0.11</td>
<td>0.37**</td>
<td>0.14</td>
</tr>
<tr>
<td>10</td>
<td>Direct shipments</td>
<td>-0.20</td>
<td>-0.47**</td>
<td>0.23</td>
<td>-0.05</td>
<td>-0.06</td>
<td>0.59**</td>
<td>0.04</td>
<td>0.39**</td>
</tr>
</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
impact on service levels. Because proportion of generic is measured in absolute terms (where 1 means 100% generic), a 10% increase in the percentage of generic products is translated into an increase of 0.0173 of on-time deliveries (M3). Using the intercept as the reference point, it means that this 10% increase in generic increases on-time delivery from 0.838 to 0.855. No other control variable is consistently significant and only the dummy variable for Ireland is negative and significant.

Table 4 presents the results for inventory turns. The table follows the same structure as table 3. We also include on-time delivery as an additional control variable (in M3). The coefficient for proportion of generic is not significant in any of the regressions against hypothesis 1b. End-of-quarter and Units are both significant. Inventory turns increase at the end of the quarter as well as in those months with higher volume. This is also consistent with the company maintaining the same level of inventories and being favoured (in terms of inventory turns) when units shipped are higher. The end-of-quarter effect may also reflect lower inventories at the end of each quarter when the spike in sales has been satisfied. Japan is the only significant site dummy.
As a robustness check to the prior results we combine inventory turns and customer service into an overall measure of performance. This variable, that we call supply chain performance, is calculated as follows. For each site, we identify the month with the minimum inventory turns and the month with the worst on-time delivery. We define performance as the square root of the sum of squares of the standardized inventory turns for the site and month relative to the minimum inventory turns for the site plus the standardized on-time delivery again relative to the site minimum, so Performance = \( \sqrt{\text{(Inventory turns)}^2 + \text{(On-time delivery)}^2} \). The definition is similar to a Euclidian distance where the origin is different for each site and defined as the minimum inventory turns and on-time delivery. According to theory,

\[ \text{Performance} = \sqrt{\text{(Inventory turns)}^2 + \text{(On-time delivery)}^2} \]

Table 4. The impact of process commonality on inventory turns.

<table>
<thead>
<tr>
<th></th>
<th>M1 Inventory turns</th>
<th>M2 Inventory turns</th>
<th>M3 Inventory turns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.181 (0.44)</td>
<td>0.343 (0.49)</td>
<td>1.110 (0.99)</td>
</tr>
<tr>
<td>North America</td>
<td>0.181 (0.44)</td>
<td>-0.632* (1.74)</td>
<td>-0.642* (-1.80)</td>
</tr>
<tr>
<td>Japan</td>
<td>1.093** (2.03)</td>
<td>1.687*** (3.11)</td>
<td>1.704*** (3.18)</td>
</tr>
<tr>
<td>Ireland</td>
<td>-0.271 (-0.85)</td>
<td>-0.142 (-0.49)</td>
<td>-0.308 (-0.91)</td>
</tr>
<tr>
<td>Proportion generic</td>
<td>1.259 (1.15)</td>
<td>-0.159 (-0.18)</td>
<td>0.061 (0.07)</td>
</tr>
<tr>
<td>End-of-quarter</td>
<td>0.813*** (4.06)</td>
<td>0.823*** (4.09)</td>
<td></td>
</tr>
<tr>
<td>Units shipped</td>
<td>2.700*** (4.24)</td>
<td>2.650*** (4.16)</td>
<td></td>
</tr>
<tr>
<td>Direct shipments</td>
<td>0.963 (1.04)</td>
<td>0.723 (0.75)</td>
<td></td>
</tr>
<tr>
<td>Month</td>
<td>-0.006 (-0.26)</td>
<td>-0.011 (-0.85)</td>
<td></td>
</tr>
<tr>
<td>On time delivery</td>
<td>-0.895 (-0.85)</td>
<td></td>
<td></td>
</tr>
<tr>
<td># of observations</td>
<td>72</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>Pseudo-(R^2)</td>
<td>0.35</td>
<td>0.74</td>
<td>0.74</td>
</tr>
</tbody>
</table>

North America, Japan, and Ireland are dummy variables. Proportion generic is the percentage of all units shipped that were generic. End-of-quarter is a dummy variable that takes value of one for the last month of the quarter. Units shipped are the total units shipped in millions of units. Direct shipments are the percentage of units directly shipped from the OEM manufacturer to customers. Month takes a value of one for the first month of the series, two for the following month and so forth. The regression model uses an estimated generalized least squares estimation; the error terms have different variances for each site. A conventional \(R^2\) is no longer a measure of goodness of fit (Greene 2000), alternatively we use a pseudo-\(R^2\) is the correlation between fitted and actual variables. *, **, *** indicate significance at 10%, 5%, and 1% respectively (two-tailed tests except for proportion generic where it is one-tailed). \(z\)-statistic in parenthesis.

As a robustness check to the prior results we combine inventory turns and customer service into an overall measure of performance. This variable, that we call supply chain performance, is calculated as follows. For each site, we identify the month with the minimum inventory turns and the month with the worst on-time delivery. We define performance as the square root of the sum of squares of the standardized inventory turns for the site and month relative to the minimum inventory turns for the site plus the standardized on-time delivery again relative to the site minimum, so Performance = \( \sqrt{(\text{Inventory turns})^2 + (\text{On-time delivery})^2} \). The definition is similar to a Euclidian distance where the origin is different for each site and defined as the minimum inventory turns and on-time delivery. According to theory,\(\dagger\)

\(\dagger\) We also used a simultaneous equation specification to control for the potential endogeneity of on-time delivery and inventory turns. Such specification requires the isolation of exogenous variables to identify the simultaneous equations is hard and may lead to misspecified models, moreover the results on tables 3 and 4 do not suggest that endogeneity is a problem. The results were very similar to those in tables 3 and 4.
increased postponement pushes the inventory turns-on-time delivery frontier out. Thus postponement is expected to be positively associated with this new variable.

Table 5 reports the results using supply chain performance as the dependent variable. Proportion of generic is positive and significant, indicating that the performance frontier (as captured by the combined performance measure discussed above) improves as the proportion of generic increases. Thus, the improvement in on-time delivery captured in table 3 is also reflected in the overall measure of performance. End-of-quarter is also significant reflecting the improvement in inventory turns already identified in table 4.

The combination of these tables suggests that the expected improvement in performance due to postponement as described in hypotheses 1a and 1b is reflected in improved customer service but not in inventory management. Thus, it seems that the company translated the operational advantages of postponement into better customer service (as measured by on-time delivery), while keeping inventory turns at comparable levels. The objective being to reduce the implicit costs associated with low customer service. By keeping inventory at comparable levels, the pulling effect

Table 5. The impact of process commonality on a combined measure of inventory turns and on-time delivery.

<table>
<thead>
<tr>
<th></th>
<th>M1 Supply chain performance</th>
<th>M2 Supply chain performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.588* (2.93)</td>
<td>1.019 (1.26)</td>
</tr>
<tr>
<td>North America</td>
<td>1.302*** (2.93)</td>
<td>1.092*** (2.73)</td>
</tr>
<tr>
<td>Japan</td>
<td>0.087 (0.18)</td>
<td>0.317 (0.59)</td>
</tr>
<tr>
<td>Ireland</td>
<td>−0.261 (−0.79)</td>
<td>−0.010 (−0.59)</td>
</tr>
<tr>
<td>Proportion generic</td>
<td>2.514** (2.21)</td>
<td>2.948*** (2.93)</td>
</tr>
<tr>
<td>End-of-quarter</td>
<td>0.677*** (2.93)</td>
<td></td>
</tr>
<tr>
<td>Units shipped</td>
<td>0.767 (0.97)</td>
<td></td>
</tr>
<tr>
<td>Direct shipments</td>
<td>−2.430** (−2.33)</td>
<td>−0.018 (−0.75)</td>
</tr>
<tr>
<td>Month</td>
<td></td>
<td></td>
</tr>
<tr>
<td># of observations</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>Pseudo-R²</td>
<td>0.53</td>
<td>0.69</td>
</tr>
</tbody>
</table>

Performance combines of inventory turns and on-time delivery as the square root of the sum of the squared deviations of these two measures with respect to their minimums per site. North America, Japan, and Ireland are dummy variables. Proportion generic is the percentage of all units shipped that were generic. End-of-quarter is a dummy variable that takes a value of one for the last month of the quarter. Units shipped are the total units shipped in millions of units. Direct shipments are the percentage of units directly shipped from the OEM manufacturer to customers. Month takes a value of one for the first month of the series, two for the following month and so forth. The regression model uses an estimated generalized least squares estimation; the error terms have different variances for each site. We use a pseudo-$R^2$ is the correlation between fitted and actual variables. *, **, *** indicate significance at 10%, 5%, and 1% respectively (two-tailed tests except for proportion generic where it is one-tailed). z-statistic in parenthesis.
of a larger percentage of generic products allows the company to better serve demand. These results confirm empirically the advantages that theory associates with postponement.

Table 6 reports the impact of postponement on operating costs, as described in hypothesis 2. We include total costs per unit as an alternative proxy for operational costs (M2 and M5) and fixed costs for completeness (M3 and M6). We also ran separate regressions, not reported in table 6, for each of the cost items within variable costs—direct labour, freight, and other variable costs—to identify the line item for which proportion generic was more relevant. The coefficient for proportion generic was negative for all three line items but only significant for direct labour. Percentage of generic significantly decreases the cost of operating the logistic sites, providing support for hypothesis 2. The number of units shipped is also significant probably reflecting the fact that the costs included as variable costs may have a fixed component or, at least, do not move as rapidly as volume does. The coefficient of the time variable (Month) is also significant; this variable may reflect learning effects possibly associated with the more homogeneous process that generic products allow.

The significance of the site dummy variables reflects the different cost structures of each of the sites already identified in table 1. Postponement is not significant when the dependent variable is fixed costs (M3 and M6). Because these costs are not scalable, the effect of changes in the complexity of the logistic process is translated into excess capacity but not into lower fixed costs. A similar explanation may account for the lack of significance of the control variables. After the end of our study, the company decided to close one of its logistic centres because the activity had decreased enough to make closing the site cost effective; it is only at this point in time (not captured in our dataset) when the savings associated with increased postponement are reflected in the fixed costs.

The inclusion of site-specific dummy variables assumes that all differences are captured in the intercept and the slope coefficients are similar across sites. We checked the robustness of this assumption by running separate specifications for each site. We test for the joint significance of the relevant coefficients using a Z-statistic defined as $Z = \frac{\bar{z} \cdot \text{stdev}(z)}{\sqrt{N - 1}}$, where $N$ is the number of different regressions (four in our case). Because of the low number of observations per site (18), this specification does not have as much power as the pooled models. The $z$-statistic for proportion generic in the simultaneous equation specification is significant at the 5% level (one-tailed test). When the independent variable is supply chain performance, the average coefficient for postponement as measured through proportion of generic products is significant at the 1% level (one-tailed). However, the average coefficient of postponement on variable cost per unit is not significant at the overall level and significant only for the North America site.

5. Concluding remarks

The objective of this paper is twofold. First, by describing a project of the actual implementation of form postponement in a supply chain, it aims to provide qualitative insights into how form postponement is being implemented. The second objective is to examine the effect of postponement on customer service and on-time delivery, using quantitative data and building on the predictions of supply chain
Table 6. The impact of process commonality on operational costs.

<table>
<thead>
<tr>
<th></th>
<th>M1 Variable costs per unit</th>
<th>M2 Total costs per unit</th>
<th>M3 Fixed costs</th>
<th>M4 Variable costs per unit</th>
<th>M5 Total costs per unit</th>
<th>M6 Fixed costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>2.064***</td>
<td>3.247***</td>
<td>420***</td>
<td>2.738***</td>
<td>4.215***</td>
<td>498***</td>
</tr>
<tr>
<td></td>
<td>(4.61)</td>
<td>(4.83)</td>
<td>(5.79)</td>
<td>(6.15)</td>
<td>(6.97)</td>
<td>(3.08)</td>
</tr>
<tr>
<td>North America</td>
<td>2.421***</td>
<td>2.500***</td>
<td>440***</td>
<td>2.642***</td>
<td>3.023***</td>
<td>402***</td>
</tr>
<tr>
<td></td>
<td>(9.47)</td>
<td>(6.67)</td>
<td>(4.94)</td>
<td>(12.87)</td>
<td>(10.87)</td>
<td>(4.07)</td>
</tr>
<tr>
<td>Japan</td>
<td>0.395</td>
<td>0.377</td>
<td>−303***</td>
<td>0.187</td>
<td>0.041</td>
<td>−286**</td>
</tr>
<tr>
<td></td>
<td>(1.43)</td>
<td>(0.92)</td>
<td>(−7.84)</td>
<td>(0.62)</td>
<td>(0.10)</td>
<td>(−2.73)</td>
</tr>
<tr>
<td>Ireland</td>
<td>1.644***</td>
<td>1.985***</td>
<td>242***</td>
<td>1.554***</td>
<td>1.845***</td>
<td>225***</td>
</tr>
<tr>
<td></td>
<td>(9.63)</td>
<td>(7.64)</td>
<td>(3.81)</td>
<td>(100.53)</td>
<td>(9.00)</td>
<td>(2.80)</td>
</tr>
<tr>
<td>Proportion generic</td>
<td>−1.355**</td>
<td>−2.133**</td>
<td>−10.7</td>
<td>−1.186**</td>
<td>−1.487*</td>
<td>−135</td>
</tr>
<tr>
<td></td>
<td>(−2.22)</td>
<td>(−2.33)</td>
<td>(−0.11)</td>
<td>(−2.02)</td>
<td>(−1.84)</td>
<td>(−0.67)</td>
</tr>
<tr>
<td>End-of-quarter</td>
<td>−0.079</td>
<td>−0.158</td>
<td>23.3</td>
<td>−0.56</td>
<td>(0.61)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(−0.56)</td>
<td>(−0.82)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Units shipped</td>
<td>−0.853**</td>
<td>−1.700***</td>
<td>113</td>
<td>−2.03</td>
<td>−3.01</td>
<td>(0.73)</td>
</tr>
<tr>
<td></td>
<td>(−2.03)</td>
<td>(−3.01)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct shipments</td>
<td>0.360</td>
<td>0.535</td>
<td>200</td>
<td>0.59</td>
<td>0.63</td>
<td>(0.93)</td>
</tr>
<tr>
<td></td>
<td>(0.59)</td>
<td>(0.63)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Month</td>
<td>−0.040***</td>
<td>−0.061***</td>
<td>−7.27</td>
<td>−2.90</td>
<td>−3.23</td>
<td>(−1.43)</td>
</tr>
<tr>
<td></td>
<td>(−2.90)</td>
<td>(−3.23)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># of observations</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>Pseudo-$R^2$</td>
<td>0.88</td>
<td>0.82</td>
<td>0.81</td>
<td>0.92</td>
<td>0.89</td>
<td>0.84</td>
</tr>
</tbody>
</table>

North America, Japan, and Ireland are dummy variables. Proportion generic is the percentage of all units shipped that were generic. End-of-quarter is a dummy variable that takes a value of one for the last month of the quarter. Units shipped are the total units shipped in millions of units. Direct shipments are the percentage of units directly shipped from the OEM manufacturer to customers. Month takes a value of one for the first month of the series, two for the following month and so forth. Fixed costs are in thousands of dollars. The regression model uses an estimated generalized least squares estimation; the error terms have different variances for each site. A conventional $R^2$ is no longer a measure of goodness of fit (Greene 2000), alternatively we use a pseudo-$R^2$ is the correlation between fitted and actual variables. *, **, *** indicate significance at 10%, 5%, and 1% respectively (two-tailed tests except for Proportion generic where it is one-tailed). z-statistic in parenthesis.
management theory. Furthermore, this paper expands the theory behind activity based costing to postponement and reduced process complexity in supply chain processes.

Using data from a company that embarked in an initiative based on using postponement to improve the performance of its supply chain, we empirically test theory predictions. Our results indicate that an increase in the percentage of generic products had a positive impact on on-time delivery as well as on operational costs but not on inventory turns. Our findings suggest that in our particular research site, managers chose to increase customer service when translating the advantages of postponement into the trade off between inventory turns and on-time delivery.

Our results also suggest several elements that were important for the way in which postponement could be implemented. Cooperation with supply chain partners was central to make the implementation of postponement possible. Through collaboration it was possible to demonstrate the benefits to those partners, in terms of improved service and reduced costs. The implementation was also enabled by reducing the need for configuration and other customer specific activities (such as testing). One the one hand, the company focused on specifications that could work for every customer, and adjusted processes and products to those specifications. On the other hand, the remaining configuration was simplified through technological solutions, so that it could be delayed until the customer used the product.

The results identify the relevance of process complexity in modelling costs associated with logistic processes, both operating costs as well as cost associated with inventory turns and on-time delivery. These costs become relevant to business decisions where costs have a key role including continuous improvement, pricing policies, and budgeting processes.

A limitation of the present study is that we do not have quantitative data about the whole supply chain. The quantitative data allowed testing performance benefits only at the disk drive company. However, the interview data suggest that there was no shifting of costs or inventories from this firm to its supplier or customers. Cost and inventory changes at the manufacturing site were marginal, and the OEM customers did not hold inventories. Additional costs at the customers’ sites (because they needed to adjust their processes and perform certain configuration activities while assembling the drives into PCs) are likely to be less than the cost savings at the disk drive company, because these costs have been passed on to the company, who still found these acceptable and below their cost savings.

Using longitudinal data from one company makes it hard to generalize the results beyond one company; however it also keeps constant a large number of potentially confounding factors that may bias cross-sectional studies. It is also important to highlight the potential limitations of the study. Given the longitudinal nature of the data, any other initiative correlated in time with the Generic Drive Program is a potential omitted variable; including months as a control variable may mitigate some of this limitation although it also captures part of the implications of the program. During our interaction with the company, no other program was highlighted as happening simultaneously to the Generic Drive Program.

The study suggests several avenues for future research. Modelling and empirically examining the overall impact of postponement—including both the benefits as shown in this paper as well as costs—is an additional avenue for future research (Ramdas and Sawhney 2001, Desai et al. 2001, Krishnan and Gupta 2001).
Future research could also investigate the impact of process complexity on fixed costs. Modelling costs as they move up the activity hierarchy from unit to batch, product, and facility-sustaining costs requires certain assumptions regarding the pattern in which costs are avoidable. Our analysis did not show any impact of postponement upon fixed costs even if it is likely to have implications for capacity utilization. Thus, a more powerful test for fixed costs would involve some measure of capacity utilization. Future studies could also address implications of complexity in supply chains beyond costs, inventory, and service trade-offs investigated here, such as the effects of complexity on quality. Lower process complexity may eliminate the need to unpack, configure, and repack units and this may reduce quality problems.

Acknowledgements

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References


