

Who Holds the Bag?:
The Impact of Information Technology and Workplace Practices on Inventory

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Who Holds the Bag?:

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In recent years, firms in the U.S. retail sector have widely adopted bar-coding, scanning, and automated distribution systems in order to create systems of efficient product replenishment. Retailers place weekly orders based on actual sales and expect to receive replenishment within very short (4 -5 day) time periods. These changes in the retailing sector have led manufacturing suppliers in a variety of consumer industries to invest in information technology. As a result, manufacturers now have more timely information on demand at a detailed product level.

Firms which combine changes in their production process with more timely demand information from retailers may more closely match production with sales, and thereby reduce their need to hold inventories. These manufacturers can choose to use information as a substitute for inventories. On the other hand, manufacturers who do not adjust production strategies in response to replenishment orders may end up bearing much of the inventory risk formerly held by their retail customers.

This paper examines how the adoption of information technology and changes in workplace practices affect the level of inventories held by firms in the U.S. apparel industry. Other studies have found mixed effects of information technology on inventories (see Bechter and Stanley 1991; Blinder and Maccini 1991; Bechter and Stanley 1991; Little 1992; Filardo 1995). We hypothesize that apparel manufacturers will decrease the amount of inventories they hold as a deeper set of information technology and workplace practices are adopted in a manner that allows them to more closely respond to fluctuations in retail and therefore consumer demand.

The relationship between inventories and the business cycle makes the findings of this paper important from a macroeconomic perspective. The diffusion of information technologies spawned by new forms of retailing is affecting a wide variety of industries beyond apparel, from food to automobiles. If the significant reduction of inventories documented here for apparel are representative of more pervasive shifts in practices, information technology may contribute to

more profound changes in the length and depth of recessions and recoveries in the future.

Data

The study draws on a matched data set that links detailed, business-unit level information regarding firm-level practices collected by the authors with Department of Commerce micro-data from the Longitudinal Research Database. Information regarding adoption of specific practices among apparel firms arises from a comprehensive survey of 103 business units that measures a wide variety of practices and performance outcomes. The database provides information on practices in the area of information system, logistics, design, manufacturing, and supplier relations. Data were collected at the business unit level for 1988 and 1992 (see Hwang and Weil 1997 for a more detailed description).

Data from this survey are matched to corresponding establishment-level data from the U.S. Department of Commerce's Longitudinal Research Database (LRD). The LRD provides longitudinal data for establishments included in the Bureau of the Census Annual Survey of Manufacturing (see Davis and Haltiwanger 1991 for a complete description). In order to understand the relationship between technology / workplace practice adoption and inventory levels, we match the survey data on adoption decisions as of the beginning of 1988 with inventory observations for the period 1988- 1991 and adoption decisions as of the beginning of 1992 with inventory observations for the period 1992 – 1994.

Information Technology and Inventories

Information technologies form the basis of what has been called “modern manufacturing” (Milgrom and Roberts 1991) as well as modern retailing practices. Information technologies enable retailers to efficiently track products (via “bar-codes”), scan product identifications electronically at the check-out counter, use this product-specific, “real time” information for inventory control at the store-, regional-, and company-level, and then draw on that data for replenishing products (Abernathy *et.al.* 1995, Brown 1997). The advent of modern retailing practices represents the replacement of inventories for information at the distribution end of

production channels (Milgrom and Roberts 1988; Bental and Eden 1993). The availability of point of sale information to retailers changes the manner in which they relate to their suppliers. In particular, it reduces the lead time allowed by retailers for order replenishment, increases the frequency of orders, and reduces the size of a given order placed with suppliers relative to the order practices in a world of more limited demand information (Lee 1996, Fisher and Raman 1996).

New replenishment practices by retailers potentially change the level of inventories optimally held by suppliers. Part of the optimal level of inventories are affected by the frequency and variability of orders as well as by the level of uncertainty surrounding the underlying state of demand, including the accuracy of information concerning the true state of demand. Optimal levels of inventory also vary with the leadtime requirements of providing the products in question (see Arrow, Harris and Marschak 1951; Hadley and Whitin 1963 for classic treatments of optimal inventory policy).

We look at four technologies that affect these different parameters of a firm's optimal level of inventory. These practices represent a combination of technological innovations and business practices that affect how apparel suppliers acquire and use information concerning demand at the product level. The first practice area involves the adoption of standardized product identification systems (called the Uniform Product Code or "UPC") which provide unique, electronically scannable, identifiers (bar-codes) for classifying products at the detailed stock keeping unit (SKU) level. Adoption of this practice provides suppliers with the baseline ability to engage in more rapid exchange of information with retailers.

The second practice area involves the use of electronic data interchange as a means of transmitting data on orders between apparel suppliers and retailers ("EDI"). Like bar-codes, the use of EDI requires a set of investments by suppliers and customers (computer hardware and software capable of sending and receiving data rapidly) and conventions (a standardized system of data interchange for transmission). Adoption of EDI further augments the availability of data

on the state of demand from retailers as well as improves its accuracy.

The third practice area involves changes in the way business units prepare products for shipment (“SHIPPING”). Modern distribution centers of retailers are capable of rapidly identifying and sorting incoming shipments from suppliers through the use of scanning systems, automated sortation and conveyers, and computer controls. This requires that incoming shipments adhere to a set of technological and process standards. We measure this practice area as the percentage of shipments sent by business units with a bar-coded markers.

Finally, we look at workplace practices involving the assembly of apparel items through the use of team-based production, measured by the percentage of domestically produced sewing output produced using modular or related team assembly systems (“MODULAR”). Rather than breaking up assembly (sewing) into a long series of small steps, modular production entails grouping tasks and assigning those tasks to a team as a means of reducing the elapsed throughput time required to assemble a given product. Adoption of this assembly technique entails altering the physical layout of sewing machines and human resource systems. While the three information technologies (UPC, EDI, and SHIPPING) change the inventory problem by providing more frequent and precise information on the state of demand, instituting alternative assembly systems alters the lead time (throughput) required to manufacture products once ordered. This improved flexibility potentially reduces the level of inventories (or the speed of inventory adjustment to changes in demand) required given the state of information on demand.

Firms responding to frequent orders from retailers potentially benefit from combinations of these practices (Hwang and Weil 1997). In particular, more extensive adoption of the practices should allow an apparel supplier not only to respond to retail orders, but to lower its exposure to inventory risk by using demand information for planning purposes. More importantly, by adopting information technology practices (UPC, EDI, and SHIPPING) in tandem with new manufacturing practices (MODULAR), apparel suppliers should increase their capabilities at handling incoming orders with more limited levels of inventory and to adjust to demand shocks

more rapidly. We capture these interactive benefits in the following empirical analysis by examining the impact of specific combinations of the practices and through an adoption variable (INDEX) that captures specific sequences of adoption.

Empirical Analysis

The overall pattern of inventory / sales (I/S) ratio for the matched sample of business units shows little change over the time period under study. I/S ratios for three periods, 1984-87, 1988-91, and 1992-94, do not vary much from a mean of 1.5. The trend (or lack thereof) in I/S ratios is consistent with the reported I/S ratios for the category “other non-durable goods” reported by the Bureau of the Census over the same time period (U.S. Department of Commerce 1996). We explore the possibility that greater information technology impacts I/S ratios in Table 2. The results show that average inventory/sales ratios fall as business units adopt more of the four technologies during both time periods under study. In the 1988-91 period, firms which adopted none of the four technologies by 1988 had an average I/S ratio of 1.9 while firms which adopted UPC, EDI, and either SHIPPING or MODULAR or both had an average I/S ratio of only 1.1 in the 1988-1991 period. These differences between low- and high-level adopters is even more dramatic for the 1992-94 period, where the lowest level of technology adopters had more than twice the inventory / sales ratio of the high level adopters (2.46 versus 1.22).

A reduction in the I/S ratio means that changes in sales will be matched by a smaller change in inventories. Therefore a lower I/S ratio should imply lower inventory volatility (Filardo 1995). This, in turn, implies lower volatility of total inventories and I/S ratios for firms which have adopted more technology. Table 3 employs the standard deviation of inventory levels and I/S ratio for the period 1992-94 as a metric for volatility. Firms which adopted all four technologies had a standard deviation in total inventories of \$1.2 million (in 1994\$) relative to firms with low levels of adoption which held inventories of \$1.5 million. This comparison obviously suffers from the different scales of firms in the different technology groups. However, the standard deviation in I/S ratios (which controls for differences in firm size) of firms with low levels of

adoption were more than double those of the high adopters (1.22 versus .50) in the same period.

Regression Analysis

The relationship between technology adoption and inventory may be an artifact of some other unmeasured variable. One particular confounding factor is product diversity. A business unit's absolute and relative level of inventory will be affected by the number of different products provided by the supplier. Specifically, product diversity and inventory should be positively correlated, all else equal. If units with higher levels of technology adoption also tend to have more limited product mixes than those units that have adopted few or no technology, the relationships in Tables 1-3 may be more directly attributed to this factor than to information technology / workplace practices.

We control explicitly for product diversity by including a variable measuring the number (log) of individual stock keeping units (SKUs) provided by the apparel supplier in 1988 and 1992. Table 4 tests the null hypothesis that technology adoption, defined both as adoption of the four individual technologies and using the index of adoption, does not affect inventory/sales ratios. No matter which technology adoption index is used, and holding constant product diversity, we find that information technology results in significantly lower I/S ratios.

Table 5 examines the impact of information technology and workplace practice adoption on the growth of inventory in the subsequent study period. Specifically, we test the hypothesis that firms which adopt more technology experience faster declines in their total inventory levels than those which do not. Table 5 presents OLS regression of the growth rate in total inventories between 1992 and 1994. Adjusting for inflation, the coefficient of the INDEX variable for 1992 indicates that the absolute growth rate of inventories between 1992-94 decreases as a greater number of the four information technologies are adopted by a business unit by 1992. This suggests firms with more technology make the transition to lower inventory levels more quickly, after controlling for the effects of product diversity. This relationship did not seem to hold, however, in relating the impact of information technology adoptions in 1988 on growth of

inventories between 1988-92.

Conclusion

We believe that this preliminary evidence is consistent with the notion that information technology acts as a substitute for inventories in the manufacturers' production processes. Firms supplying products to a retail sector increasingly characterized by rapid replenishment need not "hold the bag" for the retailers if they adopt a set of technologies that allow them to collect, use, and adapt production. These results provide evidence consistent with earlier empirical findings regarding the negative impact of information technology on inventory levels by Bechter and Stanley (1991) and Little (1992). Future work will attempt to model the determinants of inventory levels more formally and control for other confounding factors explicitly.

More generally, these results suggest that one of the major impacts of information technologies may arise from their impacts on inventory levels at both the retail and manufacturing level. The adoption of deeper information technology by these sectors reduces the level of "safety stock" held by firms to deal with unanticipated demand fluctuations, thereby lowering the "band width" implied by (S, s) inventory models. The resulting reduction in inventory levels arising from the diffusion of modern retailing practices in concert with the responses seen here among suppliers impacts the relationship between inventory and production levels and the business cycle. This macroeconomic link may prove to be the most profound implication of the adoption of firm-level information technology and workplace practices.

Table 1
Average Inventory/Sales Ratio for Sample, by Time Period

Time period	Mean	Std Dev	Nobs
1984-87	1.504	1.707	690
1988-91	1.491	1.996	921
1992-94	1.562	2.617	654

Table 2
Average Inventory/Sales Ratios, by technology indices

1988-1991				1992-1994			
Index88	Mean	Std Dev	Nobs	Index92	Mean	Std Dev	Nobs
0	1.931	2.425	203	2	2.464	4.986	92
1	1.718	1.984	215	3	1.850	2.354	162
2	1.117	1.318	393	4	1.222	1.736	379

INDEX88 = 0 if, none of four technologies adopted by 1988.

INDEX88 = 1 if only UPC adopted, or both UPC and EDI adopted by 1988.

INDEX88 = 2 if UPC and EDI adopted and either SHIPPING or MODULAR adopted, or all four technologies adopted by 1988.

INDEX92 = 2 if none adopted by 1992, only UPC was adopted by 1992, or both UPC and EDI were adopted by 1992.

INDEX92 = 3 if both UPC and EDI were adopted, and either SHIPPING or MODULAR were adopted by 1992.

INDEX92 = 4 if all four technologies were adopted by 1992.

Table 3
Inventory volatility (1992-1994) by technology index

	INDEX92	2	3	4
Standard deviation of Total inventories (000s, 1994\$)	mean (std dev)	1483 (4785)	1130 (2148)	1172 (2193)
Standard deviation of Inventory/Sales Ratio	mean (std dev)	1.22 (4.33)	0.63 (1.40)	0.50 (1.07)
	Nobs	32	56	130

INDEX92 = 2 if none adopted by 1992, only UPC was adopted by 1992, or both UPC and EDI were adopted by 1992.

INDEX92 = 3 if both UPC and EDI were adopted, and either SHIPPING or MODULAR were adopted by 1992.

INDEX92 = 4 if all four technologies were adopted by 1992.

Table 4: Regression Analysis of Average Inventory/Sales Ratio (using Total Inventories)

Average I/S	1988- 1991	1992- 1994							
UPC(yy)	-0.641*				-0.632*				
	(-2.025)				(-2.157)				
	[0.022]				[0.016]				
EDI(yy)		-0.603*			-0.826*				
		(-1.781)			(-2.698)				
		[0.038]			[0.004]				
SHIPPING(yy)			-0.686*				-0.575*		
			(-2.000)				(-2.172)		
			[0.024]				[0.015]		
MODULAR(yy)								-0.891*	
								(-3.149)	
								[0.001]	
INDEX(yy)				-0.466*					-0.574*
				(-2.995)					(-3.078)
				[0.001]					[0.001]
SKUs(yy)	0.021	0.068	0.033	0.001	-0.039	-0.012	-0.089	0.002	-0.007
(log of total # SKUs in the buisness unit)	(0.238)	(0.725)	(0.378)	(0.012)	(-0.517)	(-0.160)	(-1.217)	(0.032)	(-0.093)
	[0.812]	[0.469]	[0.706]	[0.990]	[0.606]	[0.873]	[0.225]	[0.974]	[0.926]
Constant	1.904*	1.455	1.567*	2.150*	2.360*	2.280*	2.698*	2.108*	3.604*
	(2.426)	(1.860)	(2.022)	(3.400)	(3.553)	(3.457)	(3.903)	(3.205)	(4.402)

	[0.016]	[0.064]	[0.044]
Adjusted R2	0.008	0.005	0.008
# observations	261	261	261
YY=88 for 1988-1991 regressions			
YY=92 for 1992-1994 regressions			
(t-statistics in parentheses), [p-values in brackets]			
* denotes significance at the 5% level			

The 1988-1991 regressions test the null hypothesis that the adoption of technology in 1988 has no effect on the average inventory/sales (I/S) ratio in the 1988-1991 period against the alternative hypothesis the adoption of technology reduces the I/S ratio in the 1988-1991 period. UPC88, EDI88, SHIPPING88, and MODULAR88 = 1 if firm used that technology at all in 1988, else = 0.

INDEX88 = 0 if none of four technologies adopted by 1988,

INDEX88 = 1 if only UPC adopted, or both UPC and EDI adopted by 1988.

INDEX88 = 2 if UPC and EDI adopted and either SHIPPING or MODULAR adopted, or all four technologies adopted by 1988.

The 1992-1994 regressions test the null hypothesis that the use of technology in 1992

has no effect on the average inventory/sales (I/S) ratio in the 1992-1994 period against the alternative hypothesis the use of technology reduces the I/S ratio in the 1992-1994 period. UPC92, EDI92, SHIPPING92, and MODULAR92 defined to be 1 if firm used that technology more than the median amount in the HCTAR survey in 1992, else 0.

INDEX92 = 2 if none adopted by 1992, only UPC was adopted by 1992, or both UPC and EDI were adopted by 1992.

INDEX92 = 3 if both UPC and EDI were adopted, and either SHIPPING or MODULAR were adopted by 1992.

INDEX92 = 4 if all four technologies were adopted by 1992.

Table 5: OLS Regression of Growth Rates in Total Inventories (1992-1994)

	1988-1991	1992-1994
INDEX(yy)	0.0189	-0.1604*
	(0.8430)	(-2.8160)
	[0.2000]	[0.0025]
Sales	-0.0072	0.0257
	(-0.4410)	(0.7320)
	[0.6600]	[0.4650]
# SKUs	0.0042	0.0111
	(0.4280)	(0.5140)
	[0.6690]	[0.6080]
Constant	-0.0089	0.3763
	(-0.1000)	(1.8510)
	[0.9210]	[0.0660]
Number obs	215	228
Adjusted R2	-0.0100	0.0265

The 1988-1991 regression tests the null hypothesis that the adoption of more technologies in 1988 has no effect on the growth rate of total inventories in the 1988-1991 period against the alternative hypothesis that the adoption of more technologies in 1988 induces greater rates of decline in the total inventory level in the 1988-1991 period.

INDEX88 = 0 if none of four technologies adopted by 1988,

INDEX88 = 1 if only UPC adopted, or both UPC and EDI adopted by 1988.

INDEX88 = 2 if UPC and EDI adopted and either SHIPPING or MODULAR adopted, or all four technologies adopted by 1988.

The 1992-1994 regression tests the null hypothesis that the adoption of more technologies in 1992 has no effect on the growth rate of total inventories in the 1992-1994 period against the alternative hypothesis that the adoption of more technologies in 1992 induces greater rates of decline in the total inventory level in the 1992-1994 period.

INDEX92 = 2 if none adopted by 1992, only UPC was adopted by 1992, or both UPC and EDI were adopted by 1992.

INDEX92 = 3 if both UPC and EDI were adopted, and either SHIPPING or MODULAR were adopted by 1992.

INDEX92 = 4 if all four technologies were adopted by 1992.

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