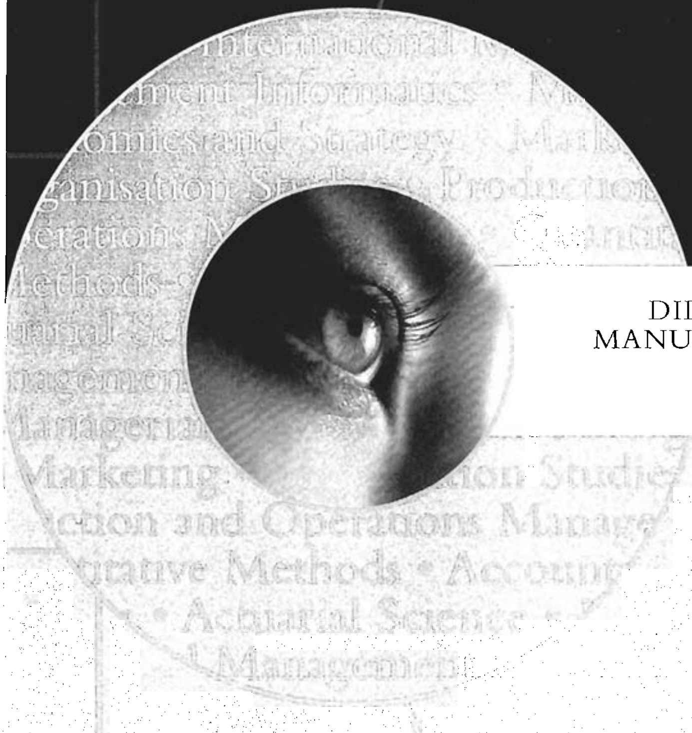
DEPARTMENT OF APPLIED ECONOMICS



RESEARCH REPORT

DID INVENTORIES DECREASE IN THE BELGIAN MANUFACTURING SECTOR BETWEEN 1979 AND 2000 ?

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OR 0352

Did Inventories Decrease in the Belgian Manufacturing Sector Between 1979 and 2000 ?

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Abstract

It is almost unquestionably accepted by most observers that inventories decreased over time. There are so many Enterprise Resource Planning systems implemented and so many Just-In-Time ideas successfully introduced in companies that we almost automatically conclude that inventories went down. This conclusion, however, is somewhat hasty. Finished product inventories did actually not decrease, whereas the work-in-process and raw materials inventories did go down in most industrial sectors. This is the main conclusion from our econometric study performed on industry data (15 industrial sectors) during the period 1979-2000. In this paper we focus on the econometric model of our study, we interpret the results and we conclude with a number of managerial insights.

Keywords: Manufacturing; Inventory; Empirical Study; Time Series

1 Introduction

There is ample anecdotic evidence that inventories went down in the period 1979-2000. In the beginning and mid eighties we experienced the Just-In-Time revolution, characterized by a strategy to ban inventories, the root cause of all evil. Over the same period we observed that numerous companies introduced Manufacturing Resources Planning (MRP) and more recently, Enterprise Resources Planning (ERP) systems were introduced in many large corporations. The focus on supply chain collaboration is now well accepted and many companies managed to implement lead-time reduction programs. The focus on quality needs no further explanation. High inventory holdings are commonly identified as poor management. All of these operational improvement tools, undoubtedly, must have resulted in less inventories and improved efficiencies. Many handbooks and seminar gurus will paint this rosy picture and illustrate their gospel with appealing examples and successful stories. Moreover, there is a well known theoretical argument why inventory ratios (e.g. Total Inventory / Cost of Goods Sold) must decrease over time: the economic order quantity (EOQ) tells us that inventories change proportionally to the square root of sales. If sales increase by 10%, then the average inventory will increase only by a few percentages, and as a consequence the inventory ratio will decrease. As we will argument later on in this text, there are other factors forcing inventory ratios to increase.

In this paper we ask about basic patterns observed in inventory holdings. Did inventories actually fall? Was there an equal effect on raw materials, work-in-process and finished goods? In section 2 we review the literature and summarize the major findings. In section 3 we present our econometric model and discuss the data used. In section 4 we interpret the results and we focus on a number of important managerial insights. In section 5 we conclude.

2 Literature Review

There are a lot of papers dealing with the question whether inventories went down, especially focusing on the before/after JIT introduction effect. Balakrishnan, Linsmeier and Venkatachalam (1996) conclude that JIT had no effect on reported return on assets. Huson and Nanda (1995), however, conclude that JIT adopters decreased inventories. Sakakibara, Flynn, Schroeder and Morris (1997) found mixed evidence. The three studies mentioned are all based on relatively small samples of firms, surveys of managers or questionnaire studies. So, caution is needed and the results are hard to generalize.

It is possible to study the problem at the industry level or at the firm level. Our study reported in this paper is on the industry level, consequently we use aggregate industry level data published in the national statistics. The best known study on the industry level was published by Rajagopalan and Malhotra (2001) focusing on the U.S. manufacturing sector. They used the two-digit SIC code comprising 20 manufacturing industry sectors during the period 1961 to 1994. They found that raw material and work-in-process inventories did decrease in a majority of the two-digit industry sectors. Finished-goods inventories decreased in some industry sectors, increased in a few others but did not show a significant trend in more than half of the sectors. The analysis provides in other words a somewhat mixed picture about the results of the U.S. manufacturing inventory-reduction efforts. In this paper we repeat the same study for the Belgian industrial sector. Rajagopalan and Malhotra (2001) also study whether greater improvement was seen in the post-1980 period as compared with the pre-1980 period. 1980 is seen as a momentum for inventory reduction due to the introduction of JIT. Amazingly enough, total manufacturing inventory ratios did not improve at a higher rate during the post-1980 period as compared with the pre-1980 period in any of the inventory categories. For certain industrial sectors however, we do observe a greater improvement. An analogue study was done by Ginter and La Londe (2001). They came to the conclusion that of the fourteen industries studied, the finished goods inventory level (finished goods inventories over cost of goods sold) increased in seven of them (apparel, chemicals, electrical/medical equipment, food products, furniture/home furnishings, medical products and other consumer packaged goods). They observed decreased inventory levels for raw materials and work-in-process in a large majority of industries.

Finally we would like to review an excellent study by Chen, Frank and Wu (2003) based on firm level data. They analysed balance sheet data from 6077 manufacturing firms (USA) over a twenty-year period (1981-2000). A key metric the authors use is inventory days. It measures the length of time that goods are held.

Inventory days, ID_{it} of firm i in year t is:

$$ID_{it} = \frac{(I_{it} \times 365\ days)}{COGS_{it}}$$

I_{it} : firm i's inventory in year t

$COGS_{it}$: cost of goods sold by firm i in year t

Replacing I_{it} with raw material inventory, work-in-process inventory or finished goods inventory in the above equation gives measures of how long each of these components of inventory are being held.

The main conclusion from their analysis is that inventories did fall (we give the overall industry numbers, not differentiated by sector). In 1981 the median days inventory was about 98 days (3.72 inventory turns per year). By 2000 this had fallen to a median of 80 days (4.56 turns per year). Raw material accounts for 35 days (median) in 1981 and dropped to 27 days. Work-in-process came from 23 days to 9 days. Finished goods dropped from 32 days to 30 days (not statistically significant). We again can conclude that finished goods inventories seem to be hard to manage. A major improvement can be found in work-in-process. We observe minor improvements in the management of raw materials. A detailed analysis of individual industries will give a more differentiated picture.

Another interesting metric is AID_{it} denoting abnormal inventory days of firm i in year t. It measures the extent to which a firm's inventory deviates from the industry norm. It is defined as (where σ denotes the standard deviation):

$$AID_{it} = \frac{(ID_{it} - \text{mean inventory days of firm } i\text{'s industry in year } t)}{\sigma\,(\text{inventory days of firm } i\text{'s industry in year } t)}$$

If $AID_{it} > 0$ then in year t firm i is holding inventory longer than do other firms in the same industry. If $AID_{it} < 0$ then the firm holds inventory for a shorter period. Chen, Frank and Wu (2003) relate the above metric to the financial performance of the firm. If firms reduce inventories, can we then conclude that the financial position will improve? The authors conclude after extensive analysis that inventory does not seem to matter much for the market-to-book ratio. However, firms with abnormally high inventories do have poor stock returns over time. More surprising, firms with the lowest levels of inventory did not have good performance either. This may mean that the super lean companies operate in commodity type of businesses with low profit margins. This argument was raised by Oliver and Hunter (1994) who argue that lean businesses operate in sectors where the competition is stiffer and hence profit margins are lower.

3 Evolution of inventory levels in the Belgian manufacturing sector

In this section we report on the Rajagopalan and Malhotra methodology applied to the Belgian manufacturing sector. We choose to use sector level data simply because of data availability. The data were obtained from the National Bank of Belgium and we therefore adopted their definition of industrial sectors. This definition is based on the NACE-70 classification until 1995 and afterwards on the NACE-BEL classification. This change does not affect the results for the sectors we analysed; it only means that we had to be careful in collecting the data. We defined three main sectors "non-energetic minerals & chemicals", "metal processing & optics" and "other manufacturing sectors". These main sectors can be further split up in sub-sectors, which can be analysed separately. Non-energetic minerals & chemicals are split up in iron & steel, non-ferro metals, non-metallic minerals and chemicals. For the metal processing & optics sector, we only consider electronics & ICT. The "other manufacturing sectors" consist of food & tobacco, textile, apparel, wood & furniture, paper & printing and rubber & plastics. Finally, we also analyse the total manufacturing sector as a whole. This results in 15 sectors, including different levels of aggregation.

In order to analyse the evolution of the inventory ratio over time (materials and supplies, work-in-process, finished goods and total inventory), we estimate the following regression equation for each sector and the manufacturing industry as a whole. In a technical note we describe the technical details needed to estimate this equation.

$$\text{Inventory ratio} = \beta_0 + \beta_1 \times \text{time} + \beta_2 \times \text{output growth}$$

As dependent variable we use inventory ratios (see table 1). It is clear that we cannot use absolute values of inventory in euro; instead we have to use relative measures because it corrects for inflation and sector size.

Table 1: inventory ratios

Inventory Type	Ratio
Raw Materials	$\frac{\text{inventory raw materials}}{\text{material cost}}$
Work In Process	$\frac{\text{inventory work in process}}{\text{material cost}+0.5\times\text{value added}}$
Finished Goods	$\frac{\text{inventory finished goods}}{\text{material cost}+\text{value added}}$

The raw material inventory ratio is quite obvious (changes in prices of raw materials will not affect the analysis because we use ratios). In the work-in-process inventory ratio we use the coefficient of 0.5 for the value added. Although this coefficient is commonly used, it is quite arbitrary since we use the same factor in all years and we are more interested in comparisons over time within an industry rather than across sectors. In the finished goods inventory ratio we use value added + material cost instead of the more classical cost of goods sold. Value added is defined as value of shipments minus material cost. The denominator of the finished goods inventory ratio is in other words equal to value of shipments. It is of course preferable to use cost of goods sold instead, but these data are not available. We also introduced a fourth ratio, which refers to the total inventory position. The total inventory ratio equals:

$$\frac{\text{inventory raw materials, work in process and finished goods}}{\text{value added + material cost}}$$

As independent variables we use time and sector growth. The use of time is obvious since we are interested in the rate of change in inventory ratios over time. The second independent variable (sector growth) is included to correct for the impact of economic swings. This variable is measured as the percentage change in the value of shipments (output) in a sector from year $(t-1)$ to t. When output growth is high, companies will experience high demands, depleting the inventory and consequently the inventory ratio will be lower. We expect that inventory ratios should be negatively correlated with growth rates.

The results of the regression analysis for raw materials and work-in-process for Belgian manufacturing sectors (the sector names are followed by the National Bank codes) are given in table 2. Those for finished goods and total inventory are given in table 3. In case the evolution is statistically significant, it is followed by the significance level at which the null hypothesis of no significant evolution ($H_0 : \beta_1 = 0$) is rejected[1].

[1] * 0.1 level, ** 0.05 level,*** 0.01 level, **** 0.001 level

Table 2: Regression results for raw materials and work in process

	Raw Materials		Work In Process	
	time	**output growth**	**time**	**output growth**
Total Manufacturing Sector (PU290)	-0.0011	-0.0125	0.0014	-0.0180
non-energetic minerals & chemicals (PU2311)	-0.0012*	-0.0353*	0.0002	-0.0064
iron & steel (PU2303)	0.0012	-0.099***	0.0040**	0.0290
non-ferro metals (PU2304)	0.0012	-0.0038	-0.0065	-0.0557
non-metallic minerals (PU2302)	-0.0053**	-0.0395*	-0.001***	-0.0009
chemicals (PU2312)	-0.0009*	-0.0354**	0.0000	-0.0104**
metal processing & optics (PU2511)	0.0023	-0.0031	0.0022	-0.0735
electronics & ICT (PU2611)	0.0000	0.0516	-0.0011	0.0229
other manufacturing sectors (PU2850)	-0.002****	0.0135	-0.001****	0.0033
food & tobacco (PU270)	-0.001****	0.0217*	-0.001****	-0.0004
textile (PU2801)	-0.003****	0.0012	-0.0004	-0.0005
apparel (PU2802)	0.0044	0.0056	0.0005	-0.0055
wood & furniture (PU2803)	-0.0009	-0.021***	-0.001****	-0.015***
paper & printing (PU2811)	-0.003****	0.0442**	-0.001****	0.0048
rubber & plastics (PU2301)	-0.002****	-0.0271**	-0.001****	-0.0001

Table 3: Regression results for finished goods and total inventory

	Finished Goods		Total Inventory	
	time	**output growth**	**time**	**output growth**
Total Manufacturing Sector (PU290)	-0.0001	-0.016****	0.0025	-0.0391*
non-energetic minerals & chemicals (PU2311)	0.0000	-0.025**	-0.0003	-0.0421**
iron & steel (PU2303)	0.0000	-0.0375**	0.0093	-0.101***
non-ferro metals (PU2304)	0.0017***	-0.0327	-0.0032	-0.071***
non-metallic minerals (PU2302)	-0.0008	-0.0024	-0.0029	-0.059****
chemicals (PU2312)	-0.0008**	-0.0138	-0.0012	-0.039***
metal processing & optics (PU2511)	-0.0001	-0.0087	0.0050	-0.0712*
electronics & ICT (PU2611)	-0.001***	0.0091	0.0016	0.0550
other manufacturing sectors (PU2850)	0.0000	-0.0101	-0.002****	0.0058
food & tobacco (PU270)	0.001****	-0.0086	-0.0006**	0.0022
textile (PU2801)	-0.0007**	-0.015****	-0.003****	-0.0045
apparel (PU2802)	0.0000	-0.0023	0.0017***	-0.0053
wood & furniture (PU2803)	0.0004	-0.0162*	-0.0010*	-0.0270
paper & printing (PU2811)	-0.0001	-0.0121	-0.002****	0.0372*
rubber & plastics (PU2301)	-0.001***	-0.0114	-0.002****	-0.0151

In figures 1 through 4 we graphically represent the evolution of inventory ratios for four sectors (iron & steel, chemicals, food & tobacco and textile). We refer to Lambrechts (2003) for the complete data set. Note that we plot the inventory ratios over time and this is not what we measure in the regression model (which includes the growth variable).

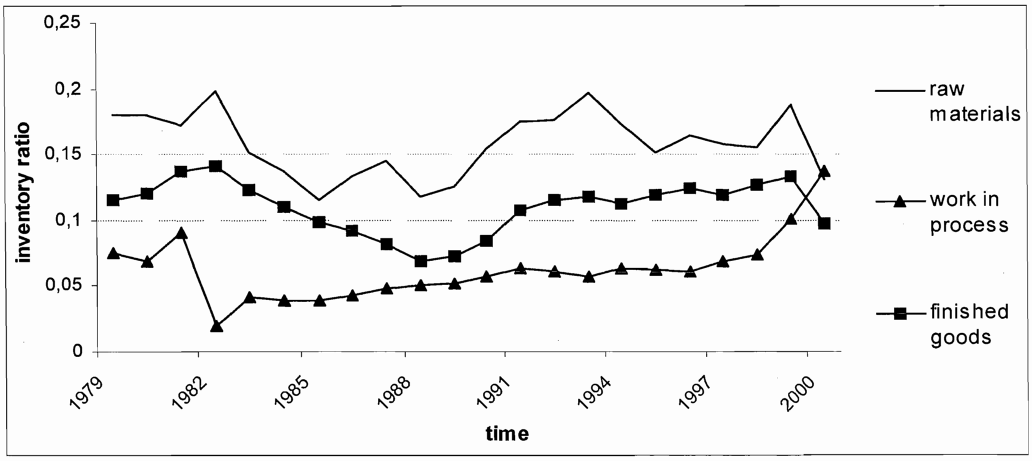

Figure 1: Evolution of inventory ratios for the iron & steel sector

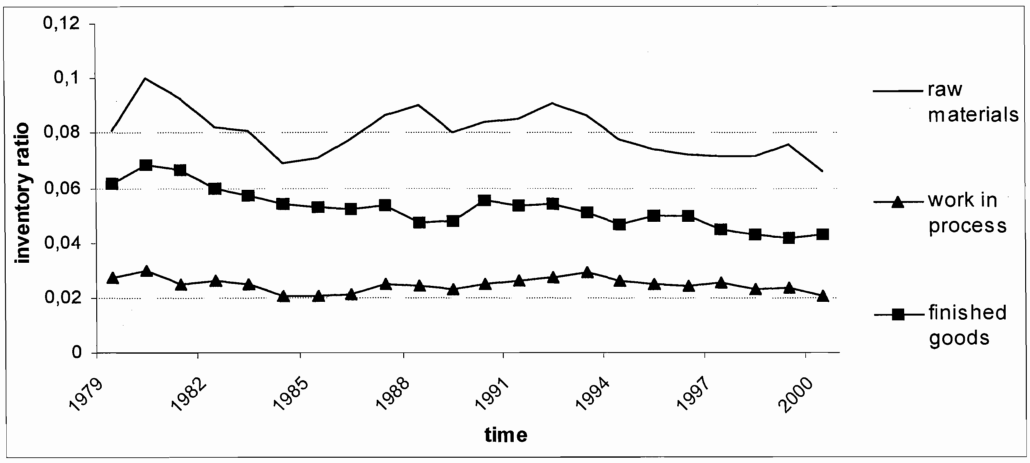

Figure 2: Evolution of inventory ratios for the chemicals sector

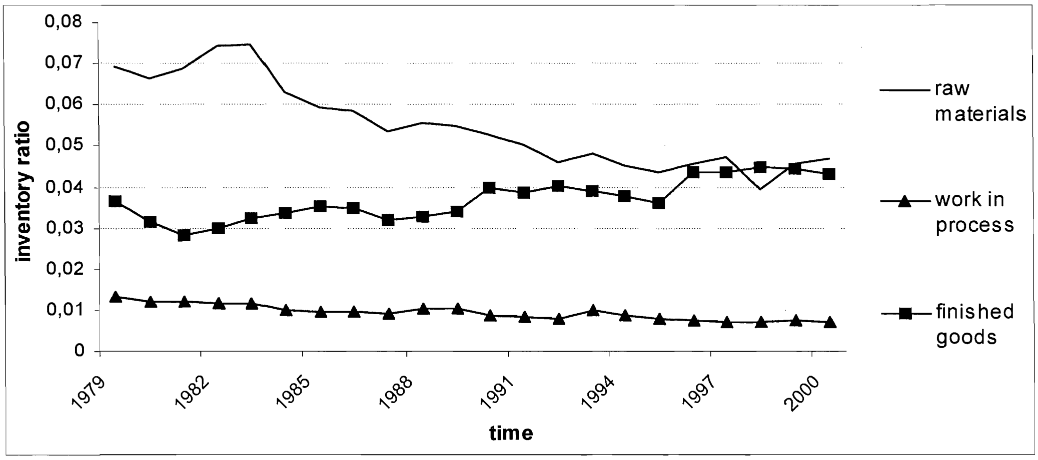

Figure 3: Evolution of inventory ratios for the food & tobacco sector

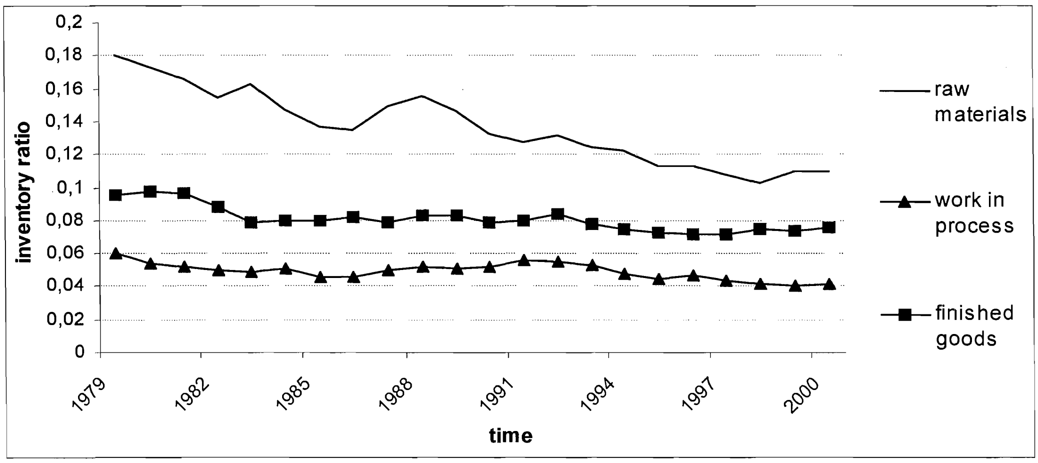

Figure 4: Evolution of inventory ratios for the textile sector

In figure 5 we plot the total inventory ratio for the six sectors showing a significant (throughout the text we interpret at 0.1 level, unless mentioned otherwise) decrease in total inventory holdings: other manufacturing sectors, food & tobacco, textile, wood & furniture, paper & printing and rubber & plastics. We observe a positive trend for the apparel sector and for the remaining sectors no significant trend was detected.

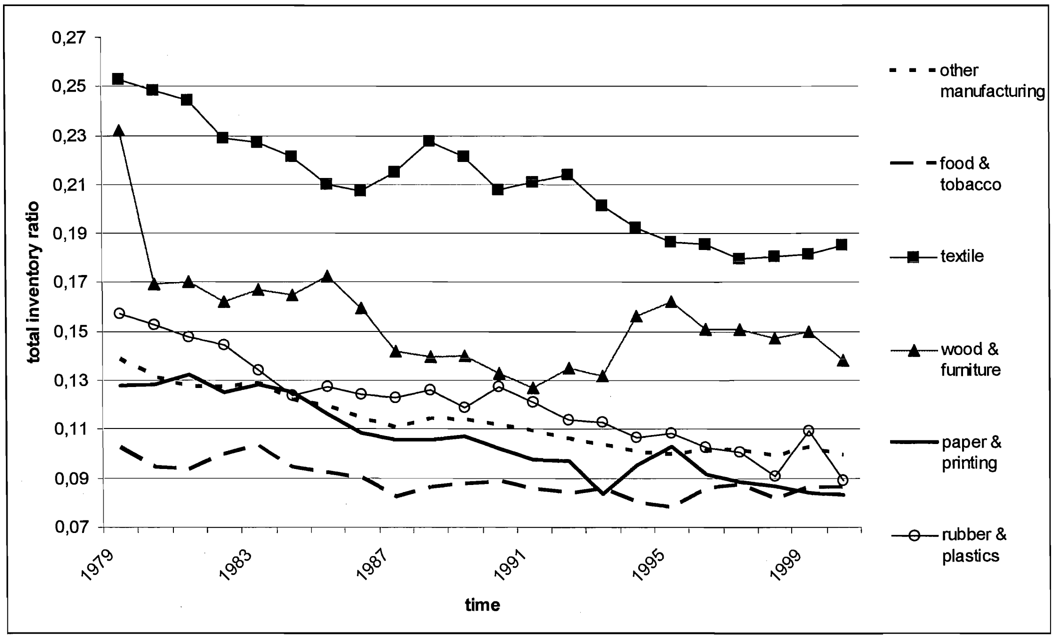

Figure 5: Evolution of total inventory ratios for 6 manufacturing sectors

Let's further interpret the results. If we look at the total manufacturing industry, we did not observe a significant trend for any of the inventory ratios. These results are not in line with the Rajagopalan and Malhotra (2001) study (who did observe a decrease in raw materials and work in process).

The raw material inventory ratio significantly decreases in eigth sectors and we observe a decrease in work in process inventories in six sectors. As expected, the finished goods segment is not performing very well. Only four sub-sectors (chemicals, textile, electronics & ICT and rubber & plastics) show a significant decrease. Overall we can conclude that we observe the same patterns as in Rajagopalan and Malhotra (2001), but the number of Belgian manufacturing sectors in the category "statistically significant decrease" is smaller compared to the U.S.A.

At first sight, this seems to be a disappointing performance. Indeed, there is still plenty of room for improvement, but we must interpret the results with care. This will be done in the next section.

4 Interpretation of the results and a number of managerial insights

In this section we will speculate on potential causes of the mixed picture of the state of inventory reduction we observed both in the U.S. and in the Belgian study.

Let's start with a general remark. MRP and ERP systems are meant to lower the inventory investments, to free cash for other uses, etc. According to our experience, we believe that managers are somewhat overoptimistic concerning the potential savings. Reducing inventories is much more than installing a piece of software; the whole incentive system has to change as well. A number of operational metrics, used to measure performance, do not go in the same direction. Obtaining high utilization rates on equipment and people is still a dominating performance criterion, no need to say that inventory reduction requires in many cases just the opposite. Revenue enhancing strategies require higher availability of products, more product variety and fast response, which may cause inventories to increase. Cost reduction programs on the other hand will focus on high utilizations (which means more waiting), outsourcing to low wage regions (and consequently creating more inventory) and this results in inventory increases. A good inventory strategy has to balance both views. Inventory holdings are not always bad, inventories do have a return as well. We have to develop a profit view of inventory management and not just a cost view. We also observe that "crude inventory" policies are used in many companies, while there are so many powerful tools to better determine e.g. lot sizes, that unfortunately did not find their way to implementation.

We either observe a statistically significant increase or no trend in finished goods inventories in a number of sectors (see e.g. the food industry). Schonberger (2001) analysed 585 companies in 18 countries and found among other things that many retailers (supermarket chains) turn out to be among the worst performing sectors. This is a highly finished goods inventory intensive business. How come we observe increased finished goods inventories?

Let's therefore analyse the finished goods inventory ratio (Finished Goods Inventory / Value of Shipments) for the Belgian wholesaling and retailing sector. The results are given in table 4. We observe a significant decrease[2] in finished goods inventories for retailing and no significant trend in the wholesale sector (we analyse the period 1978-2000). One possible interpretation is that retailers managed to push the inventory upstream to wholesalers and manufacturers. The finished goods inventory ratio for retailing was 11.39%

[2] * 0.1 level, ** 0.05 level,*** 0.01 level, **** 0.001 level

in 1978 and went down to 9.62%; wholesalers on the other hand have an average ratio of 8.17%. Wholesalers do experience a slightly lower ratio probably due to less variety in the assortment.

Table 4: Regression results for the finished goods inventory ratio for the Belgian wholesaling and retailing sector

	time	**output growth**
Retail	-0.0007***	-0.0056
Wholesale	-0.0004	-0.0170

More customer service means more finished goods inventories, especially in an environment characterized by a tremendous increase in product variety. In many industries, we are facing an explosive growth in the number of new product introductions. Companies want to avoid the commodity trap and therefore explore new markets and increase product variety. According to theory this results in higher inventory ratios (especially finished goods). The revenue enhancing strategy requires buffered production systems. This is an example of what we mentioned before: inventories do have a return as well. Therefore, the disappointing results obtained from our study do not necessarily mean that operations managers did a bad job. Avoiding the commodity trap also means that we will have to face more demand uncertainty, it becomes harder to forecast sales, etc. More uncertainty and more variability automatically means more buffers (see Lambrecht (2003)).

The strategy to focus on core competencies led many companies to increase the level of outsourcing. In table 5 we show the degree of outsourcing for the 15 sectors studied. For every sector, we measure the ratio: Amount Outsourced (materials+services) / Value of Shipments. We observe a higher degree of outsourcing for all sectors except for chemicals. On average 75% of the value of shipments is outsourced. Contract manufacturing is becoming very popular in certain industries, more and more companies relocate their operations to low wage countries. This strategy inevitably results in loosening the Just-In-Time principles.

We are facing longer (and sometimes more variable) lead times, since products have to be shipped over long distances requiring more coordination in the supply chain. All this will result in additional stocks. Add to that the strong export orientation of the Belgian economy. For a number of industries, higher exports mean less frequent deliveries and consequently higher finished product inventories.

Table 5: Outsourcing in Belgian manufacturing sectors

	1980	**1990**	**2000**
Total Manufacturing Sector (PU290)	69.59%	71.83%	75.41%
non-energetic minerals & chemicals (PU2311)	69.98%	68.75%	72.20%
iron & steel (PU2303)	69.64%	66.81%	74.47%
non-ferro metals (PU2304)	78.77%	79.13%	82.56%
non-metallic minerals (PU2302)	56.87%	63.68%	67.20%
chemicals (PU2312)	71.77%	68.80%	71.56%
metal processing & optics (PU2511)	62.98%	70.20%	73.19%
electronics & ICT (PU2611)	55.59%	66.81%	69.71%
other manufacturing sectors (PU2850)	74.18%	76.04%	78.11%
food & tobacco (PU270)	80.89%	80.80%	81.28%
textile (PU2801)	67.63%	70.17%	73.74%
apparel (PU2802)	68.38%	75.67%	80.43%
wood & furniture (PU2803)	64.23%	71.07%	74.52%
paper & printing (PU2811)	64.25%	67.81%	70.86%
rubber & plastics (PU2301)	66.81%	71.46%	77.09%

5 Conclusion

Anecdotal evidence suggests that inventories undoubtedly decreased in all sectors of the economy. Especially the manufacturing industry must be flagship of this efficiency improvement. This conjecture is not confirmed if we analyse the inventory holdings in greater detail. In this paper we report on an econometric study of the Belgian manufacturing sector. The results are encouraging but we get a mixed picture, since the inventory reductions are limited to a number of sectors, and the finished goods inventory did overall not decrease. A similar conclusion was obtained by U.S. researchers. What does that mean? Does it mean that operations managers did not manage their businesses properly? This conclusion would be far too brutal and totally unjust. The business strategy and the business model pursued by many companies include forces that potentially may increase inventory ratios. Increased product variety, commodity trap avoiding, outsourcing and contract manufacturing, profit enhancing strategies all have a potential to increase stocks. With roughly the same inventory holdings (and sometimes less) we do more and consequently the operations efforts contribute to the business model. This is the positive interpretation of our study. Of course we can still improve, we have to develop inventory management tools to better manage inventories in an international environment, with innovative products in uncertain and rapidly changing business conditions and develop performance measures that fit the business strategy.

Technical Note

In order to analyze the rate of change in inventory ratios over time, we use a simple linear regression model with time or year as an explanatory variable. We take a linear model instead of a non-linear model, because it allows an easy interpretation of the regression parameters. Remember that this is the objective of our regression (e.g. it is not to be used for prediction analysis). The output growth in each sector, measured as the percentage change in the value of output in a sector from year $(t-1)$ to t, is included in our model as a control variable. Basically, our regression model boils down to

$$\text{Inventory ratio} = \beta_0 + \beta_1 \times \text{time} + \beta_2 \times \text{output growth}$$

or

$$y_t = \beta_0 + \beta_1 \times t + \beta_2 \times og_t + \varepsilon_t$$

A common finding in time series regressions is that the residuals ε_t are correlated with their own lagged values, which is known as autocorrelation or serial correlation. In general, the error term ε_t picks up the influence of those variables affecting the dependent variable that have not been included in the model. Persistence of the effects of excluded variables is therefore a frequent cause of autocorrelation. This serial correlation violates the standard assumption of regression theory that disturbances may not be correlated with other disturbances. Although OLS still yields unbiased estimates in this case, its routinely computed standard errors are based on the wrong expression. Therefore, standard $t-$ and $F-$tests will no longer be valid and statistical inferences will be misleading.

Since our goal is to study whether the time trend is a significant factor in the inventory evolution, we have to eliminate this serial correlation in order to make correct judgments. An appropriate method for removing serial correlation is to create an autoregressive moving average model (see Hanke and Reitsch (1998)). We do this by including autoregressive (AR) and moving average (MA) terms in our original model, which correspond to respectively lagged values of our independent variable and lagged values of the residual term. The advantage of these AR and MA terms is that the estimated coefficients, the coefficient standard errors and the t-statistics of our original parameters may be interpreted in the usual manner. We add as many AR and MA terms as needed, such that the residuals reveal a white noise process. The Akaike information criterion (AIC) may also be used as a guide to select the appropriate lag order. In our case, a first order autoregressive term suffices in the majority of the regression models and in some cases an additional moving average term is required to have white noise residuals. The Breusch-Godfrey Lagrange multiplier test for general, high-order, ARMA errors, gives evidence that there is no serial correlation anymore in the residuals. The model we actually estimate is then as follows (with L denoting the lag or backshift operator):

$$(1 - \Theta L) \times y_t = \beta_0 + \beta_1 \times t + \beta_2 \times og_t + (1 + \alpha L) \times \epsilon_t$$

Another phenomenon that may keep us from drawing correct statistical inferences is the presence of heteroskedasticity. The consequences are similar to those of serial correlation: OLS remains unbiased, but its standard errors are calculated in the wrong way. An effective way to overcome this problem is to replace the standard formula for computing the OLS covariance matrix and to make use of heteroskedasticity-consistent standard errors or White standard errors (see Verbeek (2000)). This is exactly what we have done. In this way, we do not have to adapt our regression model.

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