

On the paradox of efficiency improvement at the micro level and Productivity Slowdown at the macro level: The case of Efficient Inventory Control

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Summary

Last decades show a Productivity Slowdown at the macro level, but at the micro level we have seen a huge attention for business economics and operations management and we now have a decade of booming stock markets. This paper tries to tackle that paradox by singling out the issue of Efficient Inventory Control. This seems to be the part of the business process that comes closest to the problem of the Productivity Slowdown. Namely, when inventories are reduced, then this normally means that part of demand is serviced from inventories, and this means lower production. Estimating stylized relationships for the US, we find that inventories in 1997 are 25% lower than they would have been otherwise, and the level of production is 0.56% lower at an annual basis. However, real GDP growth is not really affected, since the annual change in inventory is a very small percentage of GDP. Thus, business success stories that are based upon inventory reduction - which is regarded as efficiency improvement at the micro level - can be reconciled with stagnation at the macro economic level.

Introduction

The economic shocks of the early 1970s had huge consequences for Western economies. The break-down of 'Bretton Woods', bad harvests, the Oil Crises, turbulent labour markets, and other developments, apparently caused a serious reduction of growth and productivity - the latter phenomenon being called the Productivity Slowdown. The major aspects of these developments have been discussed in widely known books like Maddison (1982), Bruno & Sachs (1985) and textbooks like Dornbusch & Fischer (1994), just to name a few.

Though much is explained, there still appears to be room for a paradox. Namely, at the same time while the macro economy suffered a Productivity Slowdown, firms grew more conscious of the teachings of business economics and operations management, and started a boom of activities targetted at improved efficiency. Management guru's became the most popular of people, and books on business re-engineering and the like became the things to read. Indeed, in the 1990s we see highly profitable companies and soaring stock markets, but the economy as a whole still suffers its problems. And thus there arises a paradox: for we apparently see an increase in efficiency at the micro level while there is a reduction in productivity growth at the macro level.

This paper tries to tackle that paradox by singling out the issue of Efficient Inventory Control. This seems to be the part of the business process that comes closest to the problem of the Productivity Slowdown. Namely, when inventories are reduced, then this normally means that part of demand is serviced from inventories, and this means lower production.

My interest in this topic was spurred by some serious arguments from the side of business economists and operation managers that concerned the important costs of inventories. Indeed, the decade of the 1970s made companies much more aware of their costs, and, especially, for our story, high interest rates caused companies to reconsider their policies on inventory. Managers discovered that huge sums of their capital were locked in inventories of raw materials, finished products and work in progress. By methods like Material Requirements Planning and by implementing Just In Time approaches and other operations management techniques - see for example a modern textbook like that of Krajewski & Ritzman (1996) - they succeeded in the course of time into a sizeable reduction of that dead capital.

Thus, when business economists and operation managers told me that they had become very efficient, especially in inventory control, I thought the situation rather paradoxical in the light of the macro economic data, and in need for an explanation.

The explanation provided by this paper has some subpoints:

- The great effort and success of managers at the micro level to reduce inventories appears to be a 'Much Ado About Nothing' for the macro economy. At the macro level it does not seem to matter how much inventory a country has.
- But this does mean that the micro success and the macro stagnation can be consistent. This is a similar argument as the point that redistributing income can require a lot of effort, but without effects on growth. Since many of the micro success stories are about inventory control which is without macro economic interest, much of the paradox evaporates. (Only that part remains, where managers improve efficiency outside of inventories - not looked into here. Because of our analysis this part would be even more paradoxical.)

In other words, the story of the Productivity Slowdown concerns topics like the labour market - see the references above and for example also my own work, Cool (1994) - and *it can do without a discussion of inventories*. Inventories can be important for the business cycle, but appear rather unimportant for the Productivity Slowdown as a structural process covering many years.

That said, there still is a story about Efficient Inventory Control. This story is alike to the well-known one of business cycle analysis, but differs as a result of the fact that we are not discussing the business cycle but structural developments. That story is, basically, that the gradual reduction of the inventory level has allowed a lower level of production than would have been the case before. Part of demand has been serviced from inventories rather than production. While demand would have caused higher levels of inventories before, this is no longer so.

Indeed, our analysis below estimates that the level of US inventories now is 25% lower lower than it otherwise would have been. Also, the level of US production now is 0.56 % lower than it otherwise would have been. However, the latter is just a level effect, and does not really affect economic growth. Since the annual change in inventories is rather small, the effect on growth can only be measured in single digit base points. The discussion below appears to be an exercise in very very small numbers. And hence it is rather awkward to link the increased efficiency in inventory control to the Productivity Slowdown.

The paper is structured as follows. We first look at the National Accounting definitions and the economics basics, and present US data for a better understanding of sizes and development. Then we discuss ‘production’ versus ‘productivity’, and clarify our stylized approach to ‘efficient inventory control’. Then we estimate some simple relations and use the estimated parameters for a counterfactual analysis. The counterfactual is: ‘How would the world look now if inventory control had not moved to a higher level of efficiency?’ We conclude with some final points that arise when looking back at our discussion.

I must emphasize that the discussion below is cursory. The search is for stylized facts. The mathematics, the data and the estimation technique are sound, of course, but it obviously is problematic to apply a micro inventory model to macro data, as we do below, and there is a score of other equally obvious objections.

National Accounting

We can best develop the model starting with real terms. With y production (real GDP), yd demand, s inventories and Δs inventory formation, we have:

$$y = yd + \Delta s = yd + s - s(-1)$$

Useful statistics are s / yd for the *period of available supply*, and yd / s for *turnover*.

We take common deflator P , and thus find $Y = P y$, $YD = P yd$, $S = P s$, and:

$$Y = YD + P \Delta s = YD + S - P s(-1)$$

It follows that $\Delta S = S - S(-1) = (P\Delta s + P s(-1)) - S(-1) = P\Delta s + (P/P(-1) - 1) S(-1)$.

In words, the value change in the stock consists of the volume change, measured at current prices, plus the price update of the whole old volume. (The latter is considered only in the capital account and not included in current production.) Due to the common deflator for YD and S , we can use S / YD for the period of available supply and YD / S for turnover, too.

Below we have a timeseries only for Δs and not for s . Cumulation of Δs provides us with a ‘base series’ sb , that equals s up to a constant $s(0)$:

$$sb = \sum_{t=1}^T \Delta s = s - s(0)$$

Economics

Economic causality within these relationships is that companies have expectations about demand, yd^* , and then set inventories s^* and production y plans based upon these expectations - so that y is 'effective demand' (Keynes' original definition). The (unanticipated) stock formation is the result of actual demand, as $\Delta s = y - yd$. It follows that the proper production equation is:

$$y = yd^* + s^* - s(-1)$$

Only yd^* and s^* need not satisfy optimality due to forecast errors. Our problem is that yd^* , s^* and also $s(-1)$ are not measured in the NA.

The business cycle story is - as Dornbusch & Fischer state:

“The role of inventories in the business cycle is a result of a combination of unanticipated and anticipated inventory change. (...) In the quarter before the 1981-1982 recession began, GDP increased rapidly, recovering from the previous recession. From the beginning of 1981 firms began to accumulate inventories, as output exceeded their sales. Firms were probably anticipating high sales in the future and decided to build up their stocks of goods for a future sale. Thus there was intended inventory accumulation. Final sales turned down in the middle of 1981, but GDP stayed above sales until the end of 1981. Then firms realized their inventories were too high and cut production to get them back in line. In the first quarter of 1982 (...) sales exceeded output.” (p359)

A similar business cycle discussion is the recent Financial Times article by Tett & Harney (1998).

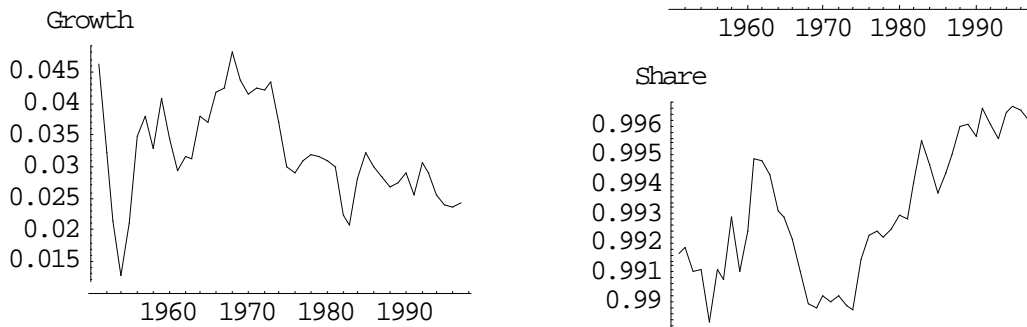
As opposed to the business cycle, however, we now look into the long run effect of a gradual improvement in inventory control.

US data

Before we continue our analysis, it may be useful to clarify what developments we are looking into.

Figure 1 plots data on the slowdown in US real GDP growth ($y/y(-1) - 1$) and the share of demand in output (yd/y). Both data series have been smoothed in order to see the 'big picture'. Note that the vertical axis for growth starts at 0.01 (1%) and that the vertical axis for the share ends at 1 (100%). Also note that the share of US demand in GDP now is about 99.6%, so we are discussing small effects. Nevertheless, a small build up of inventories over a longer period of time may still involve huge quantities - as we shall see below.

Figure 1: US data 1950-1997
Left: Real growth of GDP, 10 year geometric average
Right: Share of Demand in GDP, 10 year moving average



In these graphs we see that growth in the 1960-1973 period averaged about 3.5%, while this average falls to below 3% in the subsequent period. The share of demand dropped in the 1960-1973 period, and rose again later on. Conversely, the share of inventory formation rose in the 1960's and dropped subsequently. Obviously, the higher the share of demand in GDP, the greater the contribution of demand growth to GDP growth. The growth of production will nowadays follow the growth of demand more closely, if only because of the statistical reason that they are so close together.

NB: Dornbusch & Fischer p357 contain an 'inventory to final sales ratio' graph (i.e. a period of supply graph) with an approximate 20% (of a year) value in 1990, and they refer to DRI. I don't have these data, and surmise, since level data are less reliable, that I may as well proceed along the lines below. My data are from the Bureau of Economic Analysis at the US Department of Commerce, at <http://www.bea.doc.gov/bea/dn1.htm>.

Production versus Productivity

Production obviously differs from productivity. If production is given by the production function $y = A f(n, k)$, with labour n and capital k , then labour productivity is y/n and total factor productivity growth is $d \log(A)$ or $A/A(-1) - 1$. If production is reduced in this model, the null hypothesis is that a level of productivity already attained remains the same, so that only less resources are required.

The 'Productivity Slowdown' is defined as the reduction since 1970 of total factor productivity growth $d \log(A)$. Thus Figure 1 above gives only information about the reduction in growth but no information about the productivity slowdown.

One point to note is that inventories most likely do not enter the production function as such. Inventories are part of costs, but not of production per se. With wages w and user cost of capital c and unit inventory costs v , the objective is to minimize $w n + c k + v s$, subject to $y = A f(n, k)$, and $y = yd + s - s(-1)$, but there is no reason to think that s is part of A . (It would then be very simple to link declining s to declining A (the Productivity Slowdown).) Inventories compete with other activities for space, but this does not seem a crucial link for our analysis.

In other words: Efficiency in inventory control basically makes companies profitable on their capital account, but not necessarily on their current income account - where common productivity is measured.

A common approach in the literature is to explain the reduction in growth *as caused by* the Productivity Slowdown, and to explain the latter in terms of other factors. For data and a discussion of the Productivity Slowdown in these terms one is referred to Dornbusch & Fischer p268.

Alternatively, however, we may consider the possibility that a reduction of growth may in some ways result into a reduction of productivity. Possible causes are:

- If output growth is reduced since companies eat into their inventories, they may still retain some of their productive resources (capacity). Part may be unintentional since change takes time, part may be intentional since they want to be able to respond when demand rises.
- The ‘learning by doing effect’ is that growth itself results into higher productivity. There may be causes that makes this process symmetric. Then lower output would cause less learning by doing.
- If high productivity comes from increasing returns, and the adequate level of production is not attained, then this high productivity does not materialise.
- If the reduction of output growth feeds into the system, by the macro economic multiplier and accelerator effects, and e.g. makes investments less attractive, then productivity is affected, not directly at the micro level, but by macro economic interaction.

Of course, we should be cautious about these suppositions.

Economic Order Quantity

We will use the ‘Economic Order Quantity’ (EOQ) theory to analyse inventories, see Krajewski & Ritzman (1996). We will use the format of this micro economic theory as a simple theory for macro economic developments (and as such the EOQ is the simplest model).

Let q be the lot size quantity that is demand when an order is made. The number of orders per annum then will be yd/q . Associated with orders are the order costs per order o , so total order costs are $o yd/q$. With order quantity q , the average level of inventories is $s = q/2$. With holding costs per unit product h , total inventory costs are (with v unit costs as above):

$$C = (q/2) h + (yd/q) o = v s$$

Minimising C with respect to q only, gives optimal order quantity q^* :

$$q^* = \sqrt{\frac{2 yd o}{h}} = \alpha \sqrt{yd}$$

For our time series analysis we might assume that the ratio o/h does not change over time, so that α is a parameter indeed. Assuming optimality, $s = q^*/2$ and we find $s = \alpha \sqrt{yd}$ for some unknown α . Alternatively, we may note that holding costs increased relatively with the real rate of interest, and we should make a distinction between a ‘pre-crisis’ period of unawareness of inventory costs and a ‘post-crisis’ period of acute awareness of such costs. For this paper we stick to the first approach, and thus arrive at:

$$y = yd^* + \alpha \sqrt{yd^*} - s(-1)$$

Estimation with Perfect Foresight

With perfect foresight (in levels):

$$\begin{aligned}\Delta s &= \alpha (\sqrt{yd} - \sqrt{yd(-1)}) \\ y &= yd + \alpha (\sqrt{yd} - \sqrt{yd(-1)})\end{aligned}$$

Alternatively, for the growth rate of production we find (rates):

$$\frac{y}{y(-1)} - 1 = \frac{yd + \alpha(\sqrt{yd} - \sqrt{yd(-1)})}{yd(-1) + \alpha(\sqrt{yd(-1)} - \sqrt{yd(-2)})} - 1$$

The ‘period of supply’ s/yd gives much less variation than yd , and we may be advised to take this for the estimation. We then find (ratio):

$$\frac{s}{yd} = \frac{s(0) + sb}{yd} = \frac{s}{yd} = \frac{\alpha \sqrt{yd}}{yd}$$

Reworking we find an estimation equation with unknown parameters α and $s(0)$:

$$\frac{sb}{yd} = \frac{\alpha}{\sqrt{yd}} - \frac{s(0)}{yd}$$

Estimation with a Prediction Scheme

It is more likely that agents don’t have perfect foresight. Estimation of α thus becomes complicated since we have to estimate forecast errors that agents make too.

Let $yd^* = (1 + g) yd(-1)$, with g the predicted growth rate according to some prediction scheme (e.g. a smoother). Then take $y = yd^* + \alpha \sqrt{yd^*} - s(-1)$ and divide both sides with $yd(-1)$:

$$\frac{y}{yd(-1)} = (1 + g) + \alpha \sqrt{\frac{1 + g}{yd(-1)}} - \frac{s(0) + sb(-1)}{yd(-1)}$$

In fact, an exponential smoothing predictor has been estimated on the growth rate of demand since 1951 and with a start value of 5%, and the best SSE smoothing coefficient is 0.88. We may allow agents a degree of ‘trendiness’ of β and a degree of foresight of $(1 - \beta)$. Then we get the scheme:

- the smoothed predictor: $yd' = 0.88 yd'(-1) + (yd(-1) / yd(-2) - 1)$
- expected growth by US firms: $g = \beta yd' + (1 - \beta) (yd / yd(-1) - 1)$

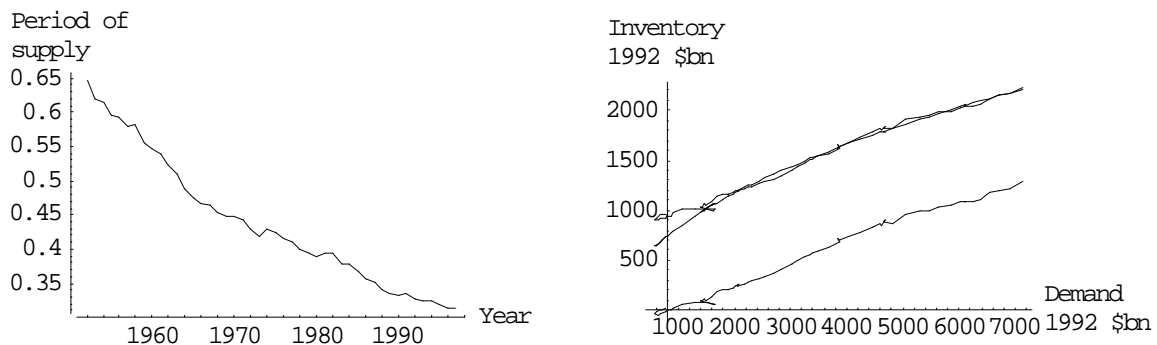
The estimation results for the 1952-1997 period are in Table 1.

Table 1: Estimation 1952-1997

Parameter	α	$s(0)$	β	R^2
Value	26.23	949.6	0.0959	0.99994
T-value	73.9	49.7	1.95	-

US firms have a degree of foresight of 90%. The outcome of $s(0)$ is in terms of 1992 \$ billion. As one can see in Figure 2 to the right, $s(0)$ lifts observed sb to a higher level, towards estimated s . Figure 2 to the right also plots the smooth $\alpha \sqrt{yd}$, which fits well with the proper estimate even though it differs of course from the estimated $s^* = \alpha \sqrt{yd^*}$. The estimated s implies a period of supply as plotted on the left. The 1990 value is about 35% and thus is notably higher than the 20% referred to by Dornbusch & Fischer (above), while the development is much smoother than in their graph.

Figure 2: Implied Period of Supply and Inventory Level



It must be remarked that this estimate is preliminary, since it does not take account of the trend change in the 1970s. Also, we look at the macro level, and might better disaggregate, e.g. to industry and services, and use quarters instead of years. Many other precautions apply.

Counterfactual

Though above estimate is preliminary, it still provides a stylized estimate of s , and thus we can proceed with our intended counterfactual.

That counterfactual is: What would have happened with production and growth in the post 1973 period when the supply period s / yd (or turnover yd / s) had remained constant ?

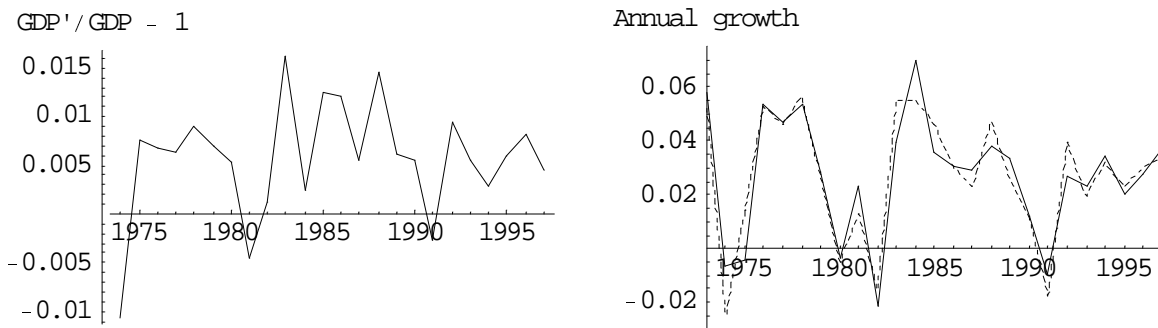
This counterfactual means that we maintain the actual development of demand. With demand given and with φ the period of available supply in 1973, we find the new level of inventories as $s' = \varphi yd$ and thus implied new production as $y' = yd + s' - s'(-1) = yd + \varphi \Delta yd$. Note that this approach is not uncommon in economic models, for example this relation was used in the Beta and later Athena midterm models of the Dutch Central Planning Bureau, see Eijgenraam & Verkade (1988).

Note that we are not suggesting a different forecast, $s^{*'} = \varphi yd^*$. If we have just a different forecast, then demand would quickly push inventories in line, since $s = s(-1) + y - yd$. So it is crucial that we now assume another level of inventories s' .

Since the periods of supply in 1973 and 1997 are approximately 0.42 and 0.32, according to our estimates above (see the graph), we find that the level of inventories in 1997 would have been higher at even 10% of demand, or \$bn 758.6 (in 1992 \$).

Distributing this increase over the 24 year period, by looking at $y' / y - 1$, we find an average annual increase in the level of production of 0.0056 or 0.56 %. Production growth $y' / y'(-1) - 1$ however is only marginally affected, in 1 digit base points (hundreds of percentages). Figure 3 plots this result.

Figure 3: Post 1973 counterfactual
Left: Relative difference of the counterfactual level with the actual real GDP level
Right: Annual GDP growth (drawn), and counterfactual growth (dashed)



Conclusion

We started out with the paradox that there has been a Productivity Slowdown at the macro level while firms had applied numerous efficiency improvements at the micro level. We registered the textbook explanations provided for the Productivity Slowdown, but still lacked a proper answer for that business economics and operations management argument.

For the sake of clarity, we did not regard all business improvements, but singled out Efficient Inventory Control since this is a process that would suit the paradox of reducing output. We found that inventories were reduced much from former levels, and that the level of production indeed has been less as a result of it. But we also found that the reduction of production was rather small, 0.56% at an annual basis, and that growth was barely affected because of the very

small size of the annual inventory change. So the effect of Efficient Inventory Control on the Productivity Slowdown was only very very small.

If a great deal of the effort of managers and their success stories concern the topic of inventories, then we also better understand the 'gap' between the micro success stories and the macro stagnation. For the level of inventories has been reduced, at great effort, without much macro economic effect.

Here we have not discussed managerial efforts directed at other business areas. Since it has been claimed that these improve efficiency too, the paradox of micro efficiency and macro productivity slowdown is not fully explained. However, my null hypothesis is that efficiency improvement before 1973 was relatively easy, and thus did not draw much attention, while now it is much more difficult, and thus more noteworthy. This explanation is little else than the 'efficiency frontier' and 'catch up' argument already common in the literature. However, it must be noted that the reduction in the inventory level since 1973 is sizeable, and thus, for inventories, one cannot really argue that these were already at their highest efficiency level.

It may be a point of macro economic policy making to consider whether the huge attention of firms for their inventories is wise, and whether the available intelligence and skill would not be more profitably applied, with real productivity improvement, when directed at other aspects of doing business. Note that this is a line of argument that implies that Efficient Inventory Control *could* be relevant for the Productivity Slowdown, namely via managers' attention.

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