INVENTORIES AND THE BUSINESS CYCLE

Darren Flood and Philip Lowe

Research Discussion Paper
9306

June 1993

Economic Research Department

Reserve Bank of Australia

We are grateful to Tom Rohling and Richard De Abreu Lourenco for helpful research assistance and to participants at the Reserve Bank Research Seminar for helpful discussions. Any errors are ours alone. The views expressed herein are those of the authors and do not necessarily reflect those of the Reserve Bank of Australia.

ABSTRACT

This paper examines the relationship between the inventory cycle and the business cycle. It uses both macro-economic data and data from surveys of individual firms' actual and expected inventory accumulation. It is argued that over the past decade and a half, the amplitude of the inventory cycle has been reduced. This reduction in amplitude reflects the decline in the stocks to sales ratio and the decline in the relative importance of unintended inventory investment. In part, these changes have been made possible by the application of increasingly sophisticated inventory management techniques.

The paper also argues that the behaviour of inventories is consistent with demand shocks being a principal source of business cycle fluctuations. This is in contrast to a number of recent papers that have argued that shocks to the cost of production are the driving force of the inventory and output cycles. We find that demand factors dominate cost factors in explaining both expected and unexpected changes in inventory investment.

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1. INTRODUCTION

On average, over the past 30 years inventory investment has accounted for just 0.7 per cent of the level of Gross Domestic Product (GDP). In contrast, on average, quarterly *changes* in the level of inventory investment have accounted for 59 per cent of the change in GDP.[1] In recessions, inventory investment has played an even more important role, often accounting for over 100 per cent of the fall in output. Clearly, while the accumulation of inventories has little impact on long-run economic growth, it is an extremely important part of the business cycle. This importance has led to a considerable research effort by both policy makers and business-cycle theorists into the behaviour of inventories. This research has failed to arrive at a consensus. Paralleling the ongoing debate concerning the source of shocks generating the business cycle, there are basically two broad schools of thought. One school argues that the inventory cycle is driven by shocks to demand while the other argues that it is driven by shocks to supply.

In this paper we examine the role of inventory investment in the Australian business cycle and use a previously unexplored dataset to examine the sources of fluctuations in inventories. The data are from the ACCI/Westpac Survey of Industrial Trends and consist of firms' expected and actual experience with inventories, costs and demand. By providing a direct measure of expectations, the survey results allow us to distinguish between expected and unexpected changes in these variables. Our results suggest that demand factors are of critical importance in driving the inventory cycle. In addition, they suggest that an increased ability of firms to manage their inventories has meant that unexpected changes in demand no longer generate the same pronounced inventory cycle that they once did.[2] This conclusion is supported by the macro-economic data.

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1 This figure is obtained by dividing the average absolute change in inventory investment by the average absolute change in Gross Domestic Product.

2 It is important to distinguish between inventories and inventory investment. In this paper the term inventories is used to refer to the *level* of stocks while inventory investment is used to describe the *change* in the level of stocks.

The demand side models of inventory investment were pioneered by the work of Metzler (1941) who argued that desired inventories were proportional to *expected* sales. This link between expected sales and inventories reflects two factors. The first is that marginal cost increases with output and the second is that firms hold inventories to reduce the probability of being unable to meet unexpectedly high demand. With increasing marginal costs, firms can minimise production costs by keeping a constant level of production, equal to expected sales. With production decisions being made before demand is known, a positive unanticipated shock to demand is met, in the first instance, by running down inventories. This fall in inventories, however, increases the probability of running out of stock and so leads to some additional increase in output in the subsequent period to rebuild stocks. A stock cycle is the result; inventory investment is negative in the first period and then positive in the second period.

In contrast, the supply side models focus on cost shocks. These models are based on the premise that the principal type of shock generating the business cycle is a shock to the production function. When a favourable but temporary productivity shock occurs, it reduces costs and induces the firm to increase output while costs are temporarily low. This extra output is stored as inventories and sold when output is temporarily low as the result of a bad productivity shock. Work by West (1989) has provided support for the cost-based models suggesting that cost shocks are the primary source of variation in inventories. This result mirrors the results of work by Prescott (1986) who estimated that cost shocks have accounted for more than 75 per cent of the variation in GDP.

In recent years, these supply side models have received increased attention. This interest primarily reflects two stylised facts. The first is that the variance of production exceeds the variance of sales. The second is that inventory movements are pro-cyclical.[3] The first of these "facts" is often interpreted as evidence against production smoothing and demand-based models of the inventory cycle. If firms are attempting to smooth production in the face of varying demand, why does the variance of production exceed the variance of sales? Proponents of cost-based theories argue that this greater variance reflects the high variance of productivity shocks relative to the variance of demand shocks. The positive correlation between

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[3] For evidence on the relationship between the variance of production and the variance of sales see Blanchard (1983), Blinder (1986), West (1988) and Blinder and Maccini (1991). For evidence on the pro-cyclical nature of inventory investment see Summers (1981), Blanchard and Fischer (1989) and West (1989).

inventory investment and output also suggests support for the cost-shock model. If costs are temporarily low, *both* output and inventories should increase, generating a positive correlation between the two variables. The demand-production smoothing based theories predict a negative correlation.

Given the role of inventory cycle in determining the amplitude of the output cycle it is important to understand the factors driving inventory investment. This is the task of the remainder of this paper. We begin in Section 2 by presenting a simple model of inventory behaviour that provides a framework for discussing the impact of various types of shocks on inventories and output. In the following section, we use macro-economic data to present some basic facts about inventory investment in Australia. We examine the contribution of inventory accumulation to the business cycle, the relationship between the variance of sales and the variance of production and the correlation between changes in inventories and changes in sales. In Section 4, we turn to the survey data to analyse the relationship between changes in demand and costs on the one hand, and expected and unexpected changes in inventories of finished goods and raw materials on the other. Finally, in Section 5 we summarise and conclude.

2. A MODEL OF INVENTORY INVESTMENT

In this section we present a simple model of inventory investment. The model allows an exploration of the factors that determine the relationship between inventories, productivity, output and sales. It is similar in spirit to the model presented in Blanchard and Fischer (1989).

The focus of the model is on a single firm's cost-minimisation problem. It is assumed that the future demand for the firm's product is uncertain, the firm is risk-neutral and that production decisions must be made before demand is known. The firm holds inventories to meet unexpectedly high demand and to smooth production. The problem for the firm is to minimise the present discounted value of its costs given expected demand. The firm's expected costs have two components. The first is standard production costs. The second component is the cost of having inventories depart from a target level. Holding too many inventories leads to undesirably high storage costs while holding too few inventories creates an unacceptably high probability of being unable to meet demand.

Given this structure, the firm's problem can be written as follows:

$$\min_{\{Y_t\}} E\left[\sum_{i=0}^{\infty}(1+\theta)^{-i}\left\{\frac{\gamma}{2}(Y_{t+i}-u_{t+i})^2+\frac{\beta}{2}(I_{t+i}-I^*_{t+i})^2\right\}\middle|\Omega_t\right] \tag{1}$$

where:

$$I^*_t = \delta E\left[S_t \middle| \Omega_t\right] \tag{2}$$

$$I_t = I_{t-1} + Y_t - S_t \tag{3}$$

$$\Omega_t = \left\{S_{t-1}, S_{t-2}, \ldots\ldots, u_t, u_{t-1}\right\} \tag{4}$$

Y_t denotes production in period t, S_t denotes sales in period t and I_t denotes inventories in period t. Desired inventories in period t are given by I_t^*, θ is the discount rate, u_t a productivity parameter and Ω_t denotes the information set. The larger is u_t, the higher is productivity and the lower is marginal cost.

The first term in (1) represents the convexity of the cost function. The larger is γ the faster marginal cost increases with increases in production.[4] If γ is zero, marginal cost is constant. The second term captures the costs associated with inventories being away from their target level. These costs include holding costs and costs associated with being unable to meet unexpectedly high demand. The larger is β the greater are these costs. The target level of inventories is equal to a linear function of expected sales. This is given in equation (2) where δ is the target ratio of inventories to sales. Equation (3) is the inventory accumulation identity and equation (4) defines the information set. Note that when deciding the level of current production the firm knows its current level of productivity but it does not know the current level of sales.

Taking expectations of equation (3) and re-arranging we can define actual production in period *t* by:

$$Y_t = E\left[I_t \middle| \Omega_t\right] - I_{t-1} + E\left[S_t \middle| \Omega_t\right] \tag{5}$$

Further, it can be shown that the expected stocks at the end of period t are defined by:

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4 As in Blanchard and Fischer (1989) we ignore linear terms as they simply affect the constant term in the solution.

$$E\left[I_t \middle| W_t\right] = a + lI_{t-1} - l\left(xS_t - u_t\right) + \left(1 - lx\right)\sum_{i=1}^{\infty}\left[\frac{l}{1+q}\right]^i E\left[S_{t+i} \middle| W_t\right] - \left(1 - l\right)\sum_{i=1}^{\infty}\left[\frac{l}{1+q}\right]^i E\left[u_{t+i} \middle| W_t\right] \quad where \quad x = \frac{g - b\,d}{g} \tag{6}$$

Here, 0 ≤ λ ≤1 and is a function of γ, β and θ. If γ = 0 (that is, marginal cost is constant and production smoothing is not important) then λ = 0, while if β = 0, λ = 1.

2.1. Productivity Shocks

We are now able to explore the impact of shocks to productivity on inventories and output. First, suppose that the firm observes a favourable shock (e_t) to productivity and that productivity follows the following process:

$$u_t = r\,u_{t-1} + e_t \tag{7}$$

where ρ ≤ 1. If ρ < 1, then shocks to productivity are only temporary while if ρ = 1 shocks to productivity represent permanent changes. For ease of exposition, initially assume that the increase in productivity does not affect expected sales. In this case, production and inventories will be expected to increase by:

$$DI_t = DY_t = \left[\frac{l\left(1 - r + q\right)}{1 + q - l\,r}\right] e_t \quad \geq \quad 0 \tag{8}$$

A productivity shock will lead to a positive correlation between changes in production and inventories. The intuition is straightforward. With productivity temporarily high, the firm wishes to increase production while costs are temporarily, relatively low. It will store this extra production as inventories and sell it when productivity and production are below normal levels.

The extent to which inventories increase in response to a productivity shock depends upon the need to smooth production, the discount rate and the persistence of the shock. To remove complications caused by the discount rate assume that θ = 0. In this case, the greater is the cost of holding excess inventories, the smaller will be the increase in inventories following the productivity shock. Similarly, the greater is the convexity of the cost function, the smaller will be the increase in output and inventories. Finally, the size of the inventory response is decreasing in the persistence of the shock. In the limit if ρ = 1, (that is, the improvement to productivity is permanent) there will be no increase in inventories as the lowering of costs is expected to be permanent. There is no advantage in producing more today as production costs are expected to be permanently lower.

The above discussion assumes that sales are unaffected by the productivity shock. However, higher productivity will increase income in the economy and this should lead to an increase in sales. Thus, a more general model in which sales are a function of permanent income would predict that innovations in inventories, driven by productivity shocks, should be positively correlated with both innovations in output and sales.

2.2. Demand Shocks

We now consider the effect of shocks to demand. To do this assume that sales are generated by the following process:

$$S_t = fS_{t-1} + h_t \tag{9}$$

where $\phi \leq 1$. Given the assumption that production must be determined before sales are known, any unexpected change in demand is, in the first instance, reflected in inventories. Thus, in the case of shocks to demand there will be a negative correlation between innovations in demand and innovations in inventory investment. Inventories are essentially used as a buffer stock.

Setting the productivity parameter to zero, the relationship between the following period's output and the current shock to sales is given by:

$$Y_t = a + (l - 1)I_{t-1} + \left[\frac{r(1+q)(1-lx)}{1+q-lr}\right]S_{t-1} \tag{10}$$

By iterating forward, it is possible to calculate the path that inventories and output take through time in response to the shock. From the path of inventories, the level of inventory investment can be calculated. This path depends on the parameters of the model. In Figures 1 to 3 we present the demand cycle, the inventory cycle and the output cycle, respectively, for three sets of parameter values. In each case the discount rate is set to zero, ξ=1 and the initial demand shock is one unit. In the first two examples the demand shock is quite persistent ($\rho = 0.9$) while in the third example it shows little persistence ($\rho = 0.3$). The three paths for inventory investment are distinctly different. In case 1 inventory investment amplifies the cycle in output while in cases 2 and 3 it tends to dampen the output cycle.

First consider case 1 in which shocks are relatively persistent and the need for production smoothing is relatively small ($\rho = 0.9$ and $\lambda=0.2$). In this case, faced with an unexpectedly high demand in period one and unexpectedly low inventories, the firm wishes to re-establish its desired level of inventories in the following period. With little convexity in the cost function, the extra production needed to satisfy higher demand and to rebuild inventories increases marginal cost by a relatively small amount. Thus, the firm is willing to substantially increase output to rebuild stocks. The inventory cycle thus amplifies the output cycle. This can be seen in Figure 3.

Now consider an increase in the convexity of the cost function so that production smoothing is very important (Case 2: $\rho=0.9$ and $\lambda=0.9$). In this case, inventory disinvestment not only occurs in the period in which demand is unexpectedly high, but it continues for a number of periods. The cost function is so convex that some of the higher demand is met for the following nine periods out of inventories.

Figure 1: Demand Shock (of one unit)

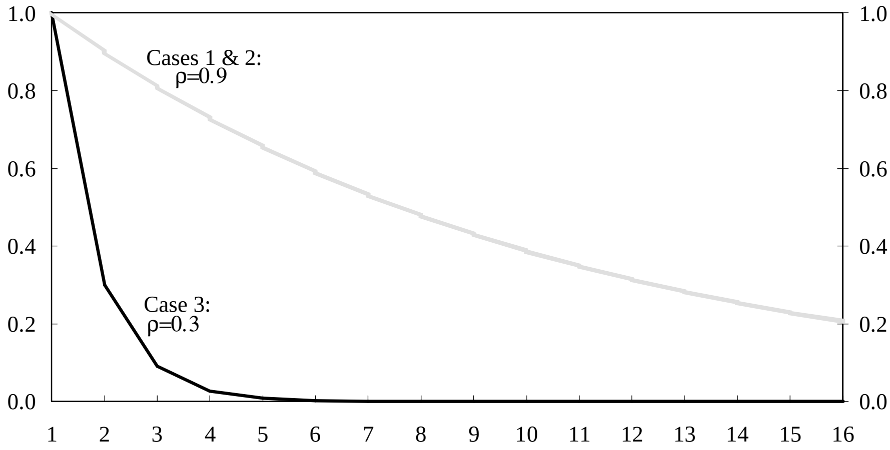


Figure 2: Inventory Investment in Response to the Demand Shock

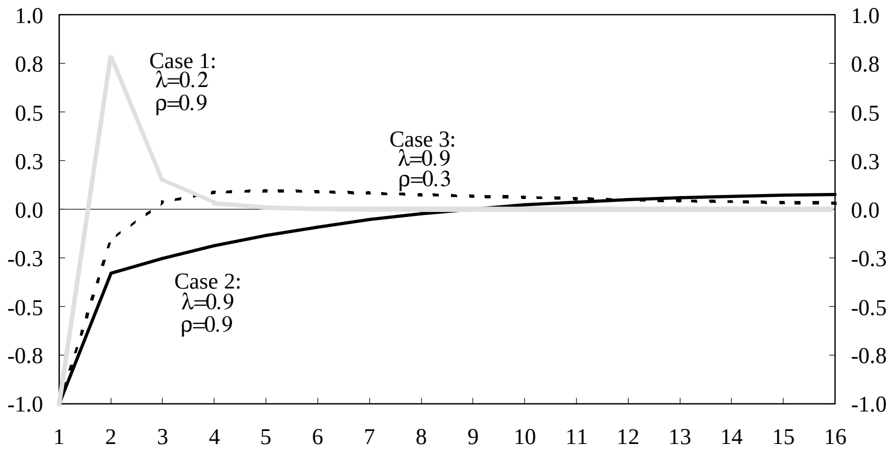
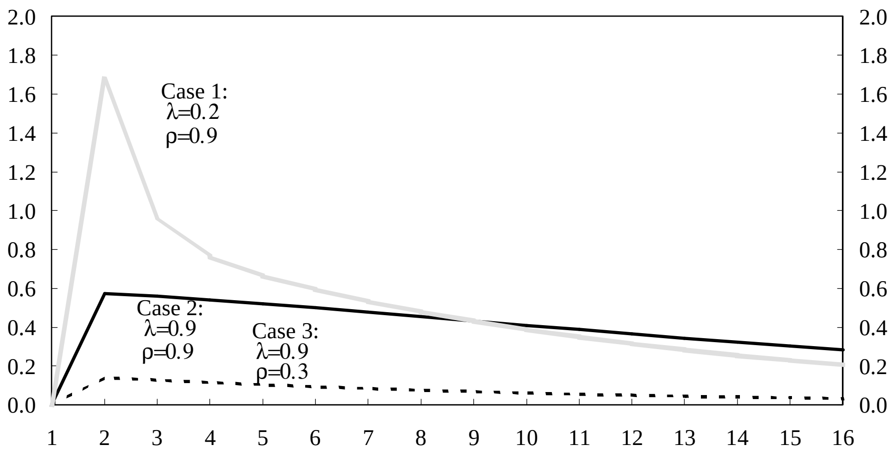


Figure 3: Output Cycle in Response to the Demand Shock



This reflects the fact that even though demand is high, the firm is only willing to increase production by a very small amount because marginal cost increases very quickly. It is only after 10 periods when demand is two-thirds of the way back to its original level, that inventory investment again becomes positive and stocks begin to increase. In this particular case, the inventory cycle tends to dampen the output cycle. This can be seen in Figure 3.

The third case presented is where there is little persistence in shocks to demand and where production smoothing is quite important (ρ = 0.3 and λ=0.9). In this case, there is only a small cycle in output. Some relatively small inventory disinvestment takes place after the initial shock, followed by a period of sustained but gradual accumulation of inventories. Here the production smoothing is important in stopping the firm from instantly rebuilding its inventories following the initial increase in demand.

There are two important points to be gained from the above examples. First, if the business cycle is driven by demand shocks and inventories act as a buffer-stock, there should be a *negative* contemporaneous correlation between innovations in inventory investment and innovations in demand. Second, the extent to which the inventory cycle will be important in driving the business cycle depends upon the persistence of shocks to demand, on the extent to which firms wish to smooth production and on the costs of holding inventories. If marginal costs are constant and production smoothing is unimportant, the inventory cycle will amplify the business cycle. If, in contrast, marginal costs increase quickly with production, the inventory cycle is likely to reduce the amplitude of the business cycle.

Finally, we consider the impact of improvements in inventory management techniques on the inventory and output cycles. The implementation of improved techniques might be expected to reduce the target ratio of inventories to expected sales (that is, to reduce δ and thus increase ξ). From equation (10) it can be seen that an increase in ξ reduces the output response for any given shock to demand. The intuition is simple. Given an increase in demand, the amount by which desired inventories increase, depends on the target stocks to sales ratio. The higher the ratio, the greater will be the desired increase in inventories, and thus the greater the desired increase in output. This suggests that any improvement in inventory management techniques that reduces the target stocks to sales ratio should see unexpected changes in demand produce smaller inventory and output cycles.

2.3. Expected Changes in Demand

Above we considered *unexpected* shocks to sales. Now we consider the case in which the firm actually *expects* an increase in sales. Again, suppose that sales follow the process given in equation (9) but that the firm expects that in the next period η_t will equal one, rather than zero. In this case if the discount rate is zero, the firm will initially change production by the following amount:

$$\Delta Y_t = \left[\frac{1-\lambda\xi}{1-\lambda\rho}\right] \tag{11}$$

This expression can be greater than, or less than one (the size of the expected demand shock). Thus, expected inventories and expected demand may be either positively or negatively correlated. If production smoothing is relatively important ($\xi>\rho$), then the firm will be willing to meet some of the extra demand out of inventories. As a result, output will rise by less than the increase in demand and inventories will fall. However, the greater is the persistence of the expected demand shock (the higher is ρ) the lower is the likelihood that the expected increase in demand will be associated with a fall in inventories.

The intuition for this result is as follows. As expected sales increase, the desired level of stocks also increases. Now suppose that the shock to demand is expected to last only one period and that marginal cost increases rapidly with output. In this case, the achievement of a higher stock level to reduce the probability of running out of stock would lead to a substantial increase in production costs. The firm is unlikely to be willing to incur these costs. Instead, it tolerates some run down in inventories and an increase in the probability of running out of stock. In contrast, if marginal costs increase by only a small amount when output increases, the saving in production costs from tolerating an increase in the probability of running out of stocks is small. Consequently, the firm will be more willing to increase output. In addition, the more permanent is the increase in sales the greater is the increase in the probability that stocks will be depleted if output is not expanded.

As was the case for *unexpected* changes to demand, the output response to an *expected* change in demand is decreasing in the target ratio of stocks to sales (this can be seen by recalling that ξ is a decreasing function of the stocks to sales ratio (δ)). If the stocks to sales ratio falls, the desired inventory response following an increase in expected demand is smaller, and as a result, the output cycle is less pronounced.

3. INVENTORY INVESTMENT IN AUSTRALIA

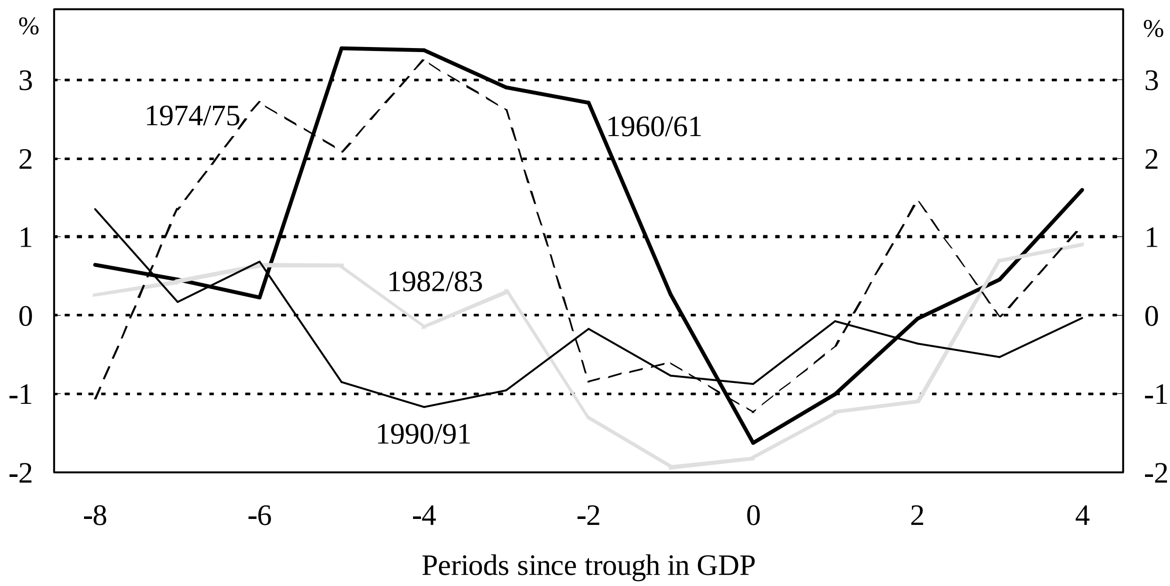
In this section we set out some of the characteristics of inventory investment in Australia. First, we examine the nature and size of the stock cycle. We then concentrate more specifically on the Australian evidence on the ‘stylised facts’ discussed in the Introduction. The results show a large degree of similarity with those from overseas studies. They also point to a marked change in the nature of the inventory investment cycle and its impact on the business cycle in Australia over the past decade and a half.

3.1. Inventory Investment Over the Cycle

Four major downturns in economic activity have occurred since the beginning of the 1960s. These occurred in 1960/61, 1974/75, 1982/83 and 1990/91. Graph 1 illustrates the pattern of private non-farm inventory investment during these downturns. In each case the reference point ‘0’ on the bottom axis represents the trough in Gross Domestic Product (GDP).

It is clear from this graph that during the 1960s and early 1970s inventory behaviour followed a quite marked cyclical pattern. A sharp increase in inventory accumulation occurs as activity slows. At its peak, inventory investment accounts for around 3 per cent of domestic final demand. After several quarters of strong build-up, inventories begin to be run down again. This run-down in stocks ceases after several quarters and gradual inventory accumulation resumes. This pattern of inventory investment is similar to that illustrated in Figure 2 (case 1). It is consistent with negative shocks to demand causing inventories to first rise and then to fall as firms attempt to work off the additional unwanted stocks. It suggests a degree of permanence to the demand shocks and a fairly small role for production smoothing.

Graph 1: Stock Cycles
Increase in Private Non-Farm Stocks, % of Domestic Final Demand



Note.

1. The troughs in GDP are in September 1961, September 1975, June 1983 and September 1991 respectively. The choice of September 1975 is somewhat arbitrary since this period was characterised by slow growth rather than a clear recession.

While the cycles in inventory investment in 1960/61 and 1974/75 are pronounced, this is certainly not the case in 1982/83 and 1990/91. At no stage in the latter episodes is there substantial inventory accumulation, but rather, inventory investment declines gradually as the economy slows. The running down of stocks is at its greatest at around the time activity bottoms. As activity increases, inventory investment also gradually recovers. This change in pattern suggests that firms have an increased ability to avoid the large swings in unplanned inventory investment that characterised the business cycle of the 1960s and 1970s.

Movements in inventory investment have potentially large effects on short-run GDP growth and hence this apparent change in the nature of the inventory cycle has major implications for the business cycle more generally. Table 1 shows the contribution of private non-farm stocks to GDP growth during the past four major downturns. The first column shows the peak-to-trough change in GDP and the second shows the contribution to GDP growth from private non-farm stocks over the relevant periods. The third and fourth columns show corresponding figures for the first year of recovery.

During the first two downturns, the decline in stocks made large negative contributions to GDP - in 1960/61 the contribution from stocks was nearly double the fall in GDP, while in 1974/75 stocks fell by 4 per cent of GDP during a period when GDP rose by 1.6 per cent. In the first year of recovery from the 1960/61 and 1974/75 episodes, the contribution from stocks was around half the rise in GDP. In contrast, during the 1982/83 and 1990/91 episodes, the contribution from stocks during the downturn is less than the total decline in GDP and the contribution during the first year of recovery is a relatively small fraction of the total. This marked difference between the two periods confirms the smaller role stocks appear to have played in the business cycle in recent years.

Table 1: Contribution of Inventory Movements to GDP Growth

	Peak to Trough		**First Year of Recovery**	
Peak - Trough	Change in GDP	Contribution From Stocks	Change in GDP	Contribution From Stocks
Sept. 60 - Sept. 61	-2.9%	-5.0%	+6.9%	+3.4%
Mar. 74 - Sept. 75	+1.6%	-4.0%	+4.5%	+2.5%
Sept. 81 - June 83	-2.4%	-2.3%	+9.9%	+2.9%
Mar. 90 - Sept. 91	-2.4%	-1.4%	+2.4%	+0.4%

Notes.

1. The period from March 1974 to September 1975 was not technically a recession. A clear cycle in stocks is, however, evident.

2. The contribution from private non-farm stocks to growth in GDP over the period shown is calculated as the difference between inventory investment in the later period and investment in the earlier period, expressed as a percentage of GDP in the earlier period.

One reason for firms' improved ability to avoid the large swing in stocks during the cycle is that they are able to respond more effectively and quickly to changes in activity. This quicker reaction reduces any unanticipated build-up or run-down in stocks in response to an unexpected change in demand. A likely cause of this change in the speed of adjustment is the spread of improved inventory management techniques. These improvements reflect the application of inventory management systems such as "just in time" and the spread of computer technology that allows better monitoring of stocks and sales levels.[5] Improved inventory management could also be expected to lead to the holding of lower stock levels, since a more rapid response means that the likelihood of running out of stocks is reduced. Increases in real interest rates are also likely to have reduced desired stock levels. Over the period from 1960:1 to 1982:2 the real prime rate averaged 2.2 per cent while over the period from 1982:3 to 1992:3 it averaged 8.7 per cent. This increase in real interest rates made the holding of inventories more expensive and is likely to have played some role in the development of new inventory management techniques.[6]

Graph 2 shows the traditional private non-farm stocks to sales ratio (SSR) from the National Accounts. Over the course of the 1960s and 1970s, the stocks to sales ratio fluctuated around a level of about 0.7. From the early 1980s, however, there was a marked decline in the ratio to a level just above 0.5. At least part of this decline is the result of changes in composition. The measure of sales used to derive this stocks to sales measure includes expenditure on services. Given that the service sector holds relatively small stocks and that the share of services in GDP has been increasing in recent times, it is natural that the stocks to sales ratio should have declined.

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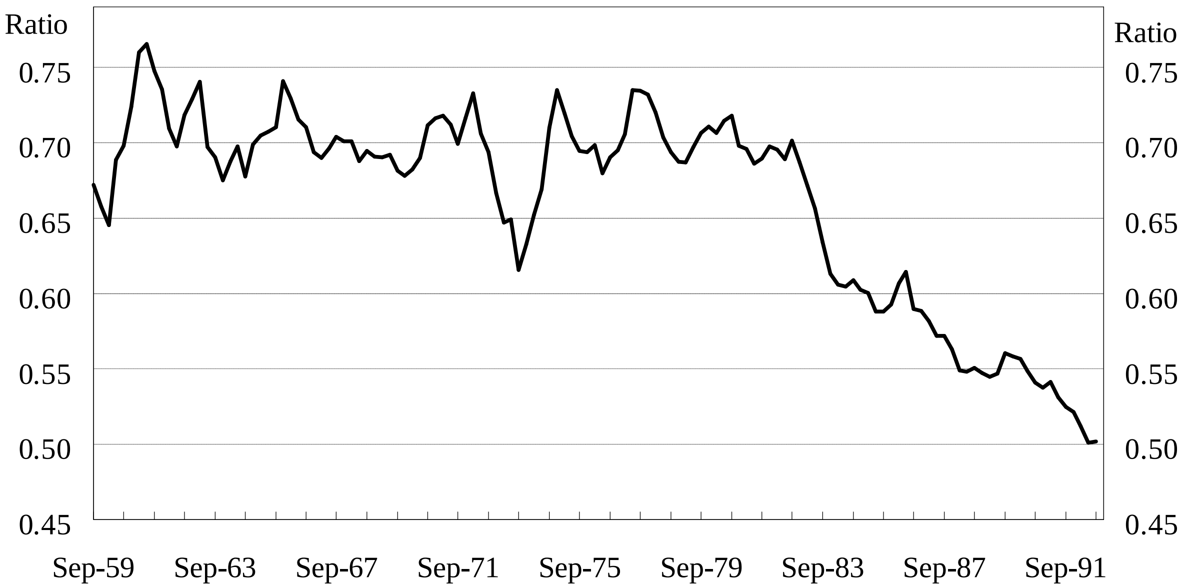
5 "Just in time" systems involve the minimisation of stocks by producing and ordering in small quantities, as required. Such a system requires flexible production processes which can be rapidly switched between purposes. There is little documentary evidence of the spread of just-in-time inventory management in Australia. Morgan (1991) provides a summary of the evidence of its spread in the United States.

6 The Australian Treasury (1991) also suggest that lower levels of industrial disputes, higher levels of import penetration and increased competitive pressures have also acted to reduce the stocks to sales ratio.

Graph 2: Non Farm Stocks to Sales Ratio

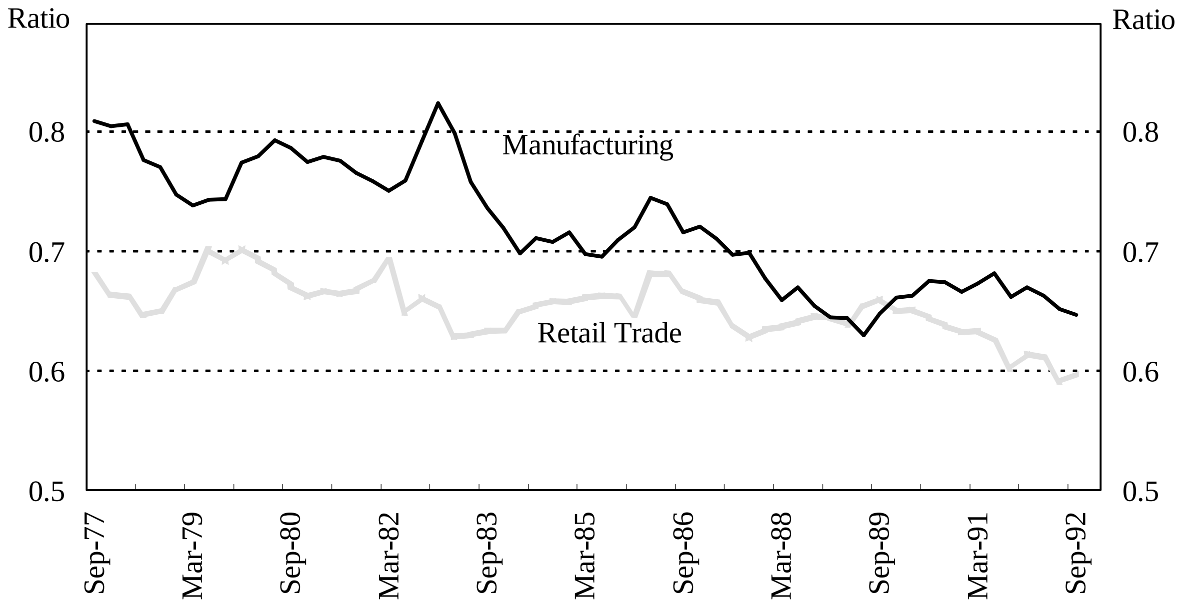


The Australian Bureau of Statistics has recently begun publishing a new stocks to sales ratio that excludes services from the definition of sales. This ratio also shows a decline during the 1980s, falling from around 1.2 in 1982 to just over 0.9 at the end of 1992. This downward trend in the stocks to sales ratio can also be seen in those sectors for which stocks to sales ratios can be derived. This is illustrated in Graph 3 which shows the stocks to sales ratio in the manufacturing and retail sectors since 1977.

A marked decline is evident during the 1980s in the ratio for manufacturing, while a more modest decline has occurred in the retail sector. It is unlikely that the wholesale trade ratio has declined as markedly as these other sectors, if at all, since the real increase in wholesale inventory levels since 1977 has been far greater than the increases in these other two categories. It would appear, then, that the manufacturing sector is primarily responsible for the decline in the overall stocks to sales ratio. This is in line with the findings of Morgan (1991) for the United States. He concluded that this decline was consistent with the spread of "just-in-time" inventory management throughout the manufacturing sector.

The discussion in Section 2.2 suggested that a decline in the stocks to sales ratio should reduce the impact of inventories on the business cycle. A lower stocks to sales ratio means that firms will change production by a smaller amount when demand changes, as the required inventory response is smaller. This decline in the stocks to sales ratio has helped contribute to the smaller inventory cycle seen in Graph 1.

Graph 3: Stocks to Sales Ratio



3.2. The Relationship Between Stocks, Output and Sales

Blinder and Maccini (1991), in their comprehensive survey of the inventory investment literature, point to three stylised facts that are important for understanding the forces driving the inventory cycle. These are:

(i) manufacturers' stocks of finished goods are less variable than wholesalers' and retailers' inventories and manufacturers' inventories of raw materials;

(ii) the variance of production exceeds the variance of sales; and

(iii) sales and changes in stocks are not negatively correlated.

Below we present Australian evidence on these issues.

3.2.1. The Variance of Inventory Investment

Blinder and Maccini find that retail stocks and manufacturers' stocks of raw materials make the greatest contributions to the overall variability in stocks in the United States. Manufacturers' stocks of finished goods are the smallest component.

Table 2, below, presents similar data for Australia using constant 1984/85 price measures of inventories. The first two columns show average inventory levels in 1991/92 while the third and fourth show the variance of inventory investment over the period from September 1977 to September 1992.

The table indicates that in terms of levels, wholesale stocks is the largest single category, followed by retail stocks - together they account for more than half of overall stock levels. Manufacturers’ stocks of finished goods rank third, with 18 per cent of the total. More importantly, in terms of the variance of inventory investment, manufacturers’ stocks of finished goods rank behind wholesale and retail trade stocks and stocks of raw materials. The variance of finished goods inventory investment accounts for only 6 per cent of the total variance. Blinder and Maccini note that while the variability of manufacturers' stocks of finished goods is relatively small, this is the area that has been the subject of the most intensive theoretical and empirical work. They call for further work into the behaviour of other categories of stocks.

The fact that the variance of wholesalers' and retailers' stocks is greater than the variance of manufacturers’ stocks of finished goods may, to some extent, reflect the fact that wholesale and retail stocks capture stocks of imports as well as stocks of domestic finished goods. In particular, the bunching of import deliveries may increase the variance of wholesalers' stocks. Nonetheless, the share of finished goods inventory investment in the total variance of inventory investment seems small given the level of finished goods stocks relative to wholesale and retail stock levels. A possible explanation is that manufacturers are able to push their stocks onto wholesalers with the result that wholesalers' stocks are more volatile than the finished goods stocks of manufacturers.

Table 2: Inventory Levels and the Variance of Inventory Investment

	Average Inventory Level 1991/92 $m	% of Total	Variance of Detrended Inventory Investment $m	% of Total
Mining	2,636	6.6	5,139	2.6
Manufacturing	15,845	39.4	45,139	22.4
Raw materials	5,404	13.4	17,637	8.8
Work in Progress	3,180	7.9	7,318	3.6
Finished Goods	7,269	18.1	12,010	6.0
Wholesale	12,004	29.8	58,841	29.2
Retail	9,357	23.3	19,900	9.9
Other	389	1.0	347	0.2
Total	40,231	100.0	201,252	

Notes.

1. In calculating the variance we have detrended inventory investment. If inventory investment is a constant share of GDP and GDP is growing, an unadjusted variance would be positive. The variance would, however, simply reflect the increasing size of the economy. To remove any distortion of the results from possible trend movements we followed the following procedure. First, log values of inventory levels were regressed on a constant and time trend. The exponential of the fitted value was then subtracted from the actual value to produce a detrended levels series. Finally, detrended inventory investment was calculated as movements in this series. The data are in constant 1984/85 prices.

2. The shares of the total variance do not sum to 100 per cent as we have not reported the covariance terms.

3. The data for the three components of manufacturing stocks are only available in current prices. To obtain constant price estimates, the current price data have been deflated by the deflator for manufacturing stocks.

3.2.2. Variance of Sales and Output

The second point noted by Blinder and Maccini is that in virtually all cases the variance of output exceeds the variance of sales.[7] This was shown to be the case

[7] Output here refers to gross output rather than the National Accounts measure which deducts costs. It is calculated in this case as sales plus the change in finished goods stocks.

for the wholesale, retail and manufacturing sectors, and for all sub-categories of manufacturing. Australian data do not allow the calculation of such a comparison for wholesale trade, but data are available for manufacturing and retail trade.[8] The first three columns of Table 3 compare the variance of output and sales for the retail trade and manufacturing sectors, and for the sub-components of manufacturing since September 1977.

The Australian data are consistent with the US data. In every case, the ratio of the variances is greater than 1; that is, the variance of output exceeds the variance of sales. This evidence weighs against the basic production smoothing model. If firms really do attempt to maintain constant production in the face of stochastic sales, then production should be considerably less variable than sales. In fact, the ratio of the variances for the manufacturing sector as a whole is higher than Blinder and Maccini's ratio of 1.03 for the US, implying that the evidence against production smoothing is even stronger in Australia than in the United States. It should be noted that the data presented in this table begin in 1977. This is the period over which the inventory cycle appears to be more muted.

It is of some interest that two components of the manufacturing sector stand out as having much greater variability in output than sales. These are transport equipment[9] and textiles. In the case of transport equipment, the higher level of variability in output relative to sales may well reflect the periodic necessity to shut down production in order to change models, while sales continue relatively unaffected.

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[8] Both manufacturing sales and manufacturing stocks are taken from *Stocks, Manufacturers' Sales, Australia* (ABS 5629.0) whereas retail sales are taken from *Retail Trade, Australia* (ABS 8501.0) and have a slightly different coverage to the stocks data.

[9] In examining the behaviour of the US automobile industry Blanchard (1983) also finds that the ratio of the variance of production to the variance of sales is high, ranging between 1.23 and 1.43.

Table 3: Variance of Sales and Output

	Variance of Detrended Sales (S)	Variance of Detrended Output (Y)	Y / S	Correlation Between Detrended Sales & Detrended Inventory Investment
Retail Trade	**104,093**	**129,019**	**1.24**	**0.08**
Manufacturing	**842,771**	**938,450**	**1.11**	**0.41****
Food & Beverages	47,236	48,625	1.03	0.01
Textiles	1,401	2,062	1.47	0.05
Clothing	6,691	7,755	1.16	0.33**
Wood & Furniture	11,072	12,128	1.10	0.13
Paper & printing	7,708	7,981	1.04	0.04
Chemicals & Petrol	33,567	37,674	1.12	0.17
Non-metallic Minerals	22,145	22,850	1.03	0.07
Basic Metal Products	31,434	33,166	1.06	0.01
Fabricated Metal Products	24,863	26,855	1.08	0.18
Transport Equipment	36,911	45,001	1.22	0.29*
Other Machinery	36,834	42,144	1.14	0.24
Miscellaneous	8,140	9,183	1.13	0.12

Notes.

1. See Note 1 of Table 2 for a discussion of the detrending procedure.

2. * (**) indicates that the correlation coefficient is statistically different from zero at the 5 (1) per cent level. The significance levels are calculated by regressing sales on inventories and using the White correction for the variance-covariance matrix.

3.2.3. The Correlation Between Sales, Output and Inventory Investment

The fourth column of Table 3 provides Australian evidence on the third characteristic identified by Blinder and Maccini; that sales and changes in stocks are positively, rather than negatively, correlated. In the case of retail trade there exists a fairly weak positive correlation, whereas for the manufacturing sector the correlation is much stronger. Rather than run down stocks as sales increase, stocks are actually built up. Within manufacturing, all sub-groups have positive correlations, although only those for transport equipment and clothing are significantly different from zero.

This third piece of evidence is often seen as damaging to demand shock driven models of inventories and the business cycle. As the discussion in Section 2 highlighted, if stocks are being used as a buffer against stochastic sales, the change in stocks should be negatively correlated with sales. However, in Section 2 it was also noted that if the changes in demand were *expected* then sales, output and inventories might reasonably be expected to be positively correlated. To answer the question of whether *unexpected* changes in demand are correlated with *unexpected* changes in stocks it is necessary to have observations on expected outcomes. In the absence of direct observations on these expectations, a popular method of generating estimates of the expected change is to estimate a time series model. The residuals of this model are then treated as the unexpected change.

The justification for this approach is as follows. Denote demand by D and inventory investment by I. Suppose that both D and I can be represented by simple ARMA(1,1) processes:

$$D_t = j\,D_{t-1} + e_t + r e_{t-1} \tag{12}$$

$$I_t = pI_{t-1} + m_t + q m_{t-1} \tag{13}$$

where e_t and m_t are serially uncorrelated error terms with zero mean and are independent of both *D* and *I*. At time *t-1*, the expected value of demand at time *t* is $j\,D_{t-1} + r e_{t-1}$. Thus, the forecast error, or the innovation in demand is e_t. Similarly, the forecast error for inventory investment is m_t. If ε_t and μ_t are positively correlated, then surprises in demand can be said to be typically associated with surprises in inventory investment of the same direction.

To examine the relationship between innovations in inventory investment and demand we follow a similar procedure to that used by Blanchard and Fisher (1989). This involves estimating ARMA models of transformed series for real seasonally adjusted domestic final demand and inventory investment. The transformation of inventory investment is made necessary by the fact that as the size of the economy increases over time, the absolute value of inventory investment might be expected to also increase. To remove any possible effect of this increase on the estimated model we first regress the absolute value of real seasonally adjusted inventory investment on a constant and a time trend.[10] We then divide the actual level of inventory investment by the predicted values of this equation. An ARMA model is then estimated for the adjusted inventory investment series. After some experimentation the selected model is an ARMA(2,2). For domestic final demand we estimate an ARIMA(1,1,2) model. The estimation period runs from 1960:3 to 1992:3. The correlations between I_t and D_{t-j} are shown in Table 4 for various

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[10] This regression yielded an insignificant coefficient on the time trend. The subsequent results are essentially unchanged when the unadjusted inventory series is used.

values of *j*. Positive values of *j* represent innovations in inventories leading innovations in demand while negative values imply that innovations in inventories lag demand. The table also shows separate correlations for both the first and second halves of the sample period.

The contemporaneous correlation between innovations in inventory investment and innovations in demand are positive but not statistically significantly different from zero. Further, the results suggest that innovations in demand lead innovations in inventory investment. That is, an unexpected increase in demand will result in an increase in inventory investment in subsequent quarters. In contrast, there is no evidence that innovations in inventory investment lead innovations in demand.

These results provide little support for models which emphasise the role of demand shocks and production smoothing. They provide no evidence that unexpected falls (increases) in demand lead to unexpected increases (decreases) in inventory investment. While these results are consistent with international findings using the same technique, the technique has a potentially important flaw. That is, it assumes that the ARIMA innovations are a good measure of the true unexpected changes. Below we argue that this assumption is invalid, as the information set used in constructing the ARIMA forecasts is much smaller that the information set used by firms. Using a superior measure of unexpected changes, we show that unanticipated falls in demand have, in fact, historically lead to unanticipated increases in inventory investment.

Table 4: Co-Movements in Demand and Inventory Investment: Correlations between Innovations

	Correlations between innovations in domestic final demand and innovations in inventory investment at time t =:						
Sample period	-3	-2	-1	0	1	2	3
1960:3 - 92:3	0.28**	0.21*	0.03	0.08	-0.04	-0.12	0.06
1960:3 - 76:3	0.26*	0.03	-0.12	0.10	-0.14	-0.26*	0.11
1976:4 - 92:3	0.30**	0.40**	0.16*	0.02	0.03	-0.01	-0.08

Notes.

1. * (**) indicates that the correlation coefficient is statistically different from zero at the 5 (1) per cent level. The significance levels are calculated by regressing the domestic final demand innovations on the inventory innovations and using the White correction for the variance-covariance matrix.

2. The model for the adjusted inventory investment series is $I^A = 0.60 + 1.28I^A_{-1} - 0.64I^A_{-2} + e_t - 0.79e_{t-1} + 0.41e_{t-2}$. The model for demand is $\Delta D = 0.01 + 0.50\Delta D_{-1} + m_t - 0.43m_{t-1} + 0.16m_{t-2}$

3. Positive values of *j* indicate that inventory investment *leads* demand. Negative values indicate that inventory investment *lags* demand.

4. DEMAND, COSTS AND INVENTORIES: EVIDENCE FROM SURVEY DATA

One way to overcome the problems induced by estimating expectations from an econometric model is to use actual surveys of firms' expectations. Since 1961 the quarterly ACCI/Westpac Survey of Industrial Trends has asked over 200 firms a number of questions concerning their actual and expected changes in production, stocks, orders, prices and costs etc. Specifically, the survey asks the following question for a range of variables:

"excluding normal seasonal changes, what has been your company's experience over the past three months and what changes do you expect during the next three months?"

Companies are asked to answer *increase*, *decrease* or *remain the same*. Our interest is in the answers to the questions regarding actual and expected changes in costs, new orders, stocks of finished goods and stocks of raw materials. Unfortunately, the survey does not publish the responses of individual firms. It does, however, publish the percentage of firms that answer "increase", "decrease" and "remain the same" to each question.

Since the survey asks whether the firm *expects* an increase in the relevant variables there is no need to use a model to estimate the expected changes and innovations. They are directly observable. For example, the innovation in demand at time t can be calculated by taking the difference between the percentage of firms that actually report an increase in new orders at time t and the percentage that, at time $t-1$, thought new orders would increase. If the percentage of firms that report an increase in demand exceeds the percentage that thought demand would increase, a positive shock to demand can be said to have occurred. Similar calculations can be performed to obtain the shocks to inventories of both *raw materials* and *finished goods*.

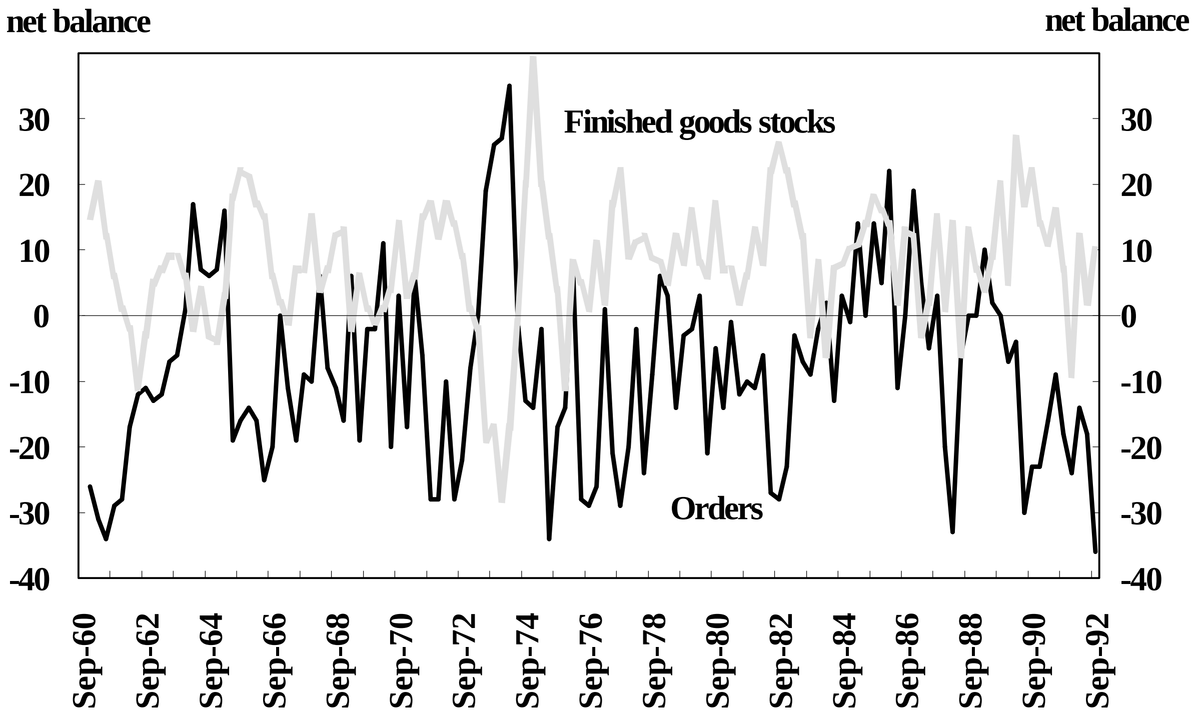
In addition to using the difference between the percentage of firms that experience and expect an *increase* in orders, stocks etc., we also use the difference in the percentage that actually report a *decline* in orders, stocks etc., and the percentage that expected a decline. Finally, we also use the *net balance* figures. The actual (expected) net balance is the difference in the percentage of firms that report (expect) an increase and the percentage that report (expect) a decrease. All three measures of the shocks should provide similar results.

Graph 4 shows the calculated shocks to both orders and the stocks of finished goods calculated using the "net balance" figures. There are two interesting points to note. First, the shocks to orders are typically unfavourable shocks. That is, the number of firms that actually report an increase in orders is generally less than the number that predicted an increase in orders. Over the entire sample period, the average "shock" is -8.5 per cent. If the forecasts are unbiased this average shock should be insignificantly different from zero. A test of the unbiased hypothesis is, however, overwhelmingly rejected.[11] Firms appear to be consistently excessively optimistic about their new orders. This optimism is also reflected in the fact that stocks of finished goods typically increase by more than was expected. The average

[11] The t-statistic for the test of the hypothesis that the average shock equals zero is 6.7.

expectation error is +7.9 per cent. Again, this is significantly different from zero. It is unclear why these persistent errors exist.[12]

Graph 4: Unexpected Changes in Orders and Stocks of Finished Goods



More interesting for the question at hand is the apparent negative correlation between the shocks to demand and inventories. A number of episodes clearly stand out. The unexpected declines in orders in the second half of 1974, 1982 and 1990 were all associated with an unexpected increase in inventories. Similarly, in the 1960s unexpected increases in inventories occur when demand is unexpectedly low. In Table 5 we present the correlation coefficients between the forecast errors for orders and the forecast errors for inventories of both finished goods and raw materials. Correlations are calculated using the "up", "down" and "net balance" figures. They are calculated using data from the entire period as well as data for each half of the sample.

[12] The t-statistic for the test of the hypothesis that the average shock to finished good inventories is zero is 9.3. The average shock to inventories of raw materials is 7.3 with a t-statistic of 9.2.

Table 5 : Correlations of Unexpected Changes in Orders and Inventories

	Sample Period		
Inventories Of:	60:3 - 92:3	60:3 - 76:3	76:4 - 92:3
Finished Goods			
• Up	-0.30**	-0.48**	-0.03
• Down	-0.30**	-0.49**	-0.06
• Net balance	-0.40**	-0.57**	-0.15
Raw Materials			
• Up	0.11	-0.01	0.27*
• Down	0.05	-0.17	0.29*
• Net balance	0.04	-0.12	0.23

Notes.

1. * (**) indicates that the correlation coefficient is statistically different from zero at the 5 (1) percent level.

2. The correlations for "up" are the correlations between the forecast errors calculated using only the "increase" responses for both orders and inventories. The "down" correlations use only the "decrease" responses.

Using data over the entire period we find a strong negative and statistically significant relationship between shocks to orders and shocks to inventories of final goods. Over the full sample period the correlation coefficient (using the net balance figures) is -0.40 which is significantly different from zero at conventional significance levels. In contrast, the correlation using the stocks of raw materials is small and is insignificantly different from zero. Similar results are obtained using both the "up" and "down" responses.[13] These results suggest that when demand for a firm's product is unexpectedly low, its stocks of finished goods are unexpectedly high, but that there is no unexpected change in the firm's stocks of raw materials. This indicates that when faced with an adverse shock to demand, firms do not reduce their production immediately but instead build up their stocks of finished goods. This is consistent with inventories of finished goods being used, in the first instance, as a buffer stock to demand shocks. Given that production and inventory accumulation initially continue in the face of the demand shock, it is hardly

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[13] Given this similarity, we report results using only the "net balance" figures in subsequent tables.

surprising that there is no immediate unexpected accumulation of raw materials stocks.

The results in Table 5 also suggest that there has been a change over time in the relationship between innovations in orders and innovations in inventories of finished goods. Over the first half of the sample period the correlation coefficient between demand forecast errors and finished goods inventory forecast errors is -0.57 while over the second half of the sample period the coefficient is just -0.15. The hypothesis that the coefficients are the same can be rejected at the 5 per cent level.

The above results for the stocks of finished goods stand in contrast to those reported in Table 4. Unlike the macro-results, the results from the survey suggest that unexpected falls in demand are reflected in unexpected increases in stocks. The difference in results may reflect the inability of the innovations from the ARMA models of inventories and output to accurately represent the true innovations. The forecasts from the ARMA models only use information contained in past values and the error terms. In contrast, while it is unclear to the econometrician what information goes into generating the firms' forecasts, these forecasts should be based on a much wider information set than that available to the time-series econometrician.[14] While, the forecasts from the ARMA models may be unbiased, the measured innovations may not be the true innovations. Suppose that the innovations from the ARMA models (e_t and μ_t) each consist of two components and that each of these components has a zero mean. That is:

$$e_t = f_t + j_t \tag{14}$$

$$m_t = n_t + z_t \tag{15}$$

and E(ϕ)=E(φ)=E(ν)=E(ζ)=0. Let the first component in each of the ARMA innovations represent the true innovation and the second component the error made by the econometrician through not being able to observe the complete information set. Assume that the errors induced by incomplete information are uncorrelated with the true innovations (E(ϕφ)=E(νζ)=E(φν)=E(ϕζ)=0). Given this assumption, the correlation between the two ARMA innovations is given by:

$$E[e_t m_t] = E[(f_t + j_t)(n_t + z_t)] = E[f_t n_t] + E[j_t z_t] \tag{16}$$

[14] Blinder (1986) also discusses the implications of the econometrician not using the full information set.

The results from the survey data suggest that the true innovations are negatively correlated; that is, E($\phi\nu$) is less than zero. However, the results in Table 4 show that E($\varepsilon\mu$) is approximately zero. This implies that E($\varphi\zeta$) is positive. Given that the same unobservable information is likely to be used in forecasting both demand and inventories it is not surprising that the errors induced by incomplete information are correlated. The fact that they are positively correlated suggests that when information, not included in the ARIMA model, leads firms to *expect* demand to be low, this same information leads firms to *expect* that inventories will also be low. This issue is examined in more detail below. More generally, the conflicting results from the aggregate and survey data suggest a general warning concerning the ability of ARMA models to generate true economic innovations.

The above results from the survey data suggest that firms have used their stocks of finished goods as a buffer against shocks to demand. The above reconciliation of the survey and the macro-data results also suggest that *expected* increases in demand are associated with *expected* increases in stocks. The model presented in Section 2 suggested such a positive correlation provided that changes in demand had reasonable degree of persistence. A negative correlation between the expected changes in demand and inventories is only predicted if production smoothing is extremely important and changes in demand are viewed as shortlived. We now turn to an examination of the relationship between expected changes in demand and inventories using the survey data.

Graph 5 shows the net balance figure for expected changes in both new orders and the stocks of finished goods. The most striking observation concerning this graph is the much higher volatility in expected orders than in expected stocks of finished goods. In some quarters the net balance figure for orders almost reaches 50 per cent while in others it exceeds -50 per cent. The swings in expected changes in inventories of finished goods are much smaller with the net balance figure ranging between -35 and 10.[15] Perhaps, more importantly there is a positive relationship between expected changes in orders and the expected changes in stocks of finished goods. This appears to be the case particularly when demand is expected to fall; 1982 and 1990 are good examples of this relationship. In both these years, firms expected to reduce their inventories in line with expected lower demand. This again questions the importance of production smoothing as an important determinant of

[15] The range in the net balance figure for expected changes in stocks of raw materials is -44 to 11.

the inventory cycle and suggests that firms typically believe that demand shocks have a considerable degree of persistence.

Graph 5: Expected Changes in Orders and Stocks of Finished Goods

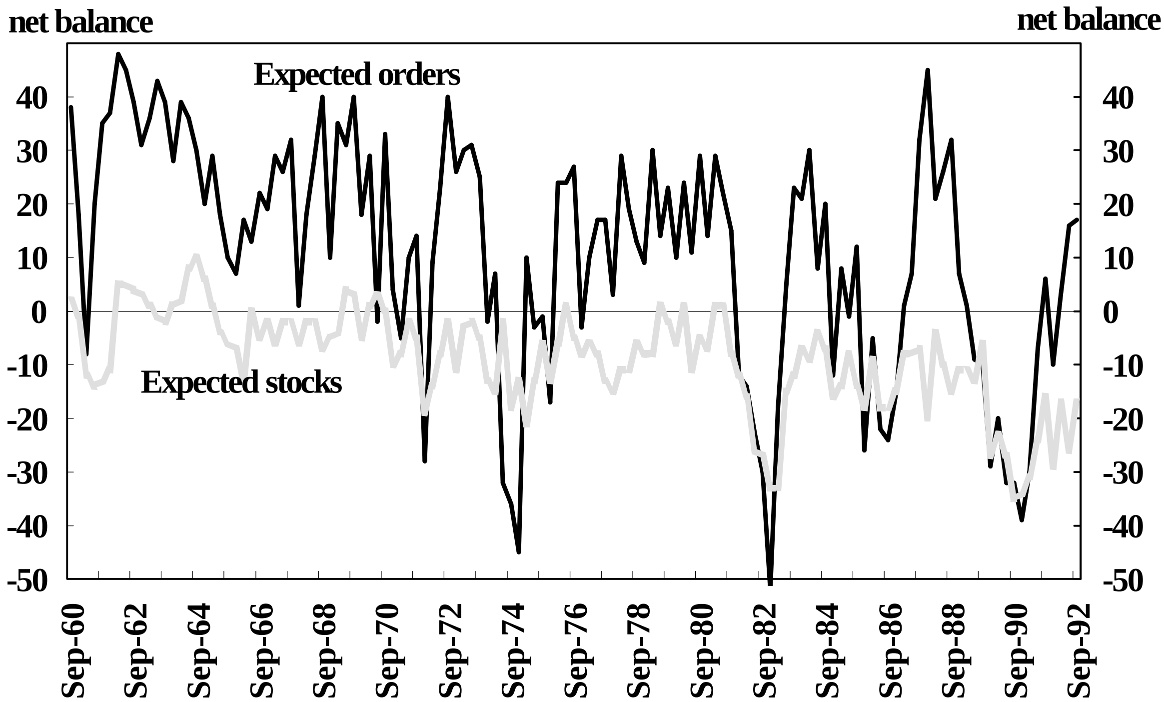

Table 6 presents the correlation coefficients between expected changes in demand and inventories of finished goods and raw materials. Each of the correlation coefficients in the table is positive and relatively large. In every case it is possible to reject the null hypothesis that the correlation coefficient equals zero. Higher expected demand leads firms to expect both higher stocks of raw materials and higher stocks of finished goods.

Table 6: Correlations between Expected Changes in Orders and Inventories (Net Balance Figures)

	Sample Period		
	1960:3-92:3	1960:3-76:3	1976:4-92:1
Inventories of Final Goods	0.71**	0.58**	0.72**
Inventories of Raw Materials	0.82**	0.78**	0.80**

Note.

1. ** indicates that the correlation coefficient is statistically different from zero at the 1 percent level.

We turn now to an examination of cost shocks. Ideally, we require some measure of shocks to real production costs per unit of output. While there is no direct measure of these shocks, the survey does allow the construction of a proxy. This proxy is constructed from two questions. The first question asks firms whether they expect an increase or decrease in their *average costs per unit of output.* These costs are in nominal terms. In an attempt to control for increases in the price level we use a second question which asks whether the firm expects their *average selling price* to increase or decrease. We use the difference between the net balance response to the cost question and the net balance response to the price question as a measure of expected changes in real costs. A similar calculation is performed using the data on actual experience. Subtracting the expected experience from the actual experience provides us with our proxy for cost shocks.[16]

[16] This proxy for real cost shocks is less than perfect. For example, if a firm experiences no change in its cost of production but is able to increase its output price (with no change in the general price level) our measure would record a reduction in real costs. However, this would be incorrect as our measure would simply be picking up an increase in margins for the individual firm. This problem is less severe when we aggregate over a large number of firms as not all firms can increase their prices relative to the general price level.

In Table 7 we report the correlations between these cost shocks and the shocks to inventories of both final goods and raw materials.[17] We also report the correlations between our proxy for expected changes in real costs and expected changes in stocks.

Table 7: The Relationship between Inventories and Costs
(Net Balance Figures)

	Sample Period		
	66:3-92:3	66:3-76:3	76:4-92:3
	Correlation Between Unexpected Inventories and Unexpected Costs		
Inventories of Finished Goods	0.12	0.10	0.27*
Inventories of Raw Materials	-0.15	-0.19	-0.07
	Correlation Between Expected Inventories and Expected Costs		
Inventories of Finished Goods	-0.32**	-0.34	-0.58**
Inventories of Raw Materials	-0.29**	-0.16	-0.58**

Note.

1. *(**) indicates that the correlation coefficient is statistically different from zero at the 5 (1) per cent level.

For the sample period as a whole, the correlations between the cost shocks and the inventory shocks are small and insignificantly different from zero. In contrast, over the second half of the sample period the correlation between cost shocks and shocks to inventories of finished goods is positive and statistically significant. However, this correlation is opposite in sign to that predicted by cost-shock based inventory models; it suggests that when costs are unexpectedly high, inventories are also unexpectedly high.

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[17] The questions concerning costs and prices were introduced in June 1966. Consequently, the sample period used to calculate correlations between inventories and costs runs from June 1966 to September 1992.

In contrast, the negative correlations in the second half of the table provide at least some support for the cost-shock theories. This is particularly the case over the second half of the sample period. When costs are expected to increase, firms expect both stocks of finished goods and raw materials to fall.

In estimating and presenting the above correlations it has been implicitly assumed that cost shocks and demand shocks are uncorrelated. This assumption may not be valid. When demand is weak, the costs of production may fall and when demand is strong production costs may rise. If demand and cost factors are related, the above correlations may not reflect underlying independent influences. In an attempt to isolate the independent effects of demand and supply side factors we estimate two equations. The first equation explains shocks to inventories in terms of the demand and cost shocks. The second explains expected changes in inventories in terms of expected changes in demand and expected changes in costs.

In the discussion of Graph 5 it was suggested that there may be some asymmetry in the response of inventories to expected increases and decreases in demand. Rather than imposing the constraint that the inventory response is symmetric, we allow the response to vary depending upon whether expected inventory accumulation is greater, or less than, the mean expected inventory accumulation.[18] Separate estimates for the two cases are obtained by defining two dummy variables. The first dummy (D1) takes a value of one if expected inventory accumulation is greater than the mean expected accumulation. The second dummy (D2) takes a value of one if it is less than the mean. The expected demand series is then multiplied by these two dummy variables to create two "expected demand" regressors.

A similar procedure is followed for the inventory shock equation. In this case, the first dummy variable takes on a value of one if the shock to demand is greater than the mean shock. The second dummy takes on a value of one if it is less than the mean shock. The estimation results for the equations explaining shocks to inventories are presented in Table 8, while the results for the equation explaining expected changes in inventories are presented in Table 9.

Using the full sample period, the results confirm that demand shocks have had a statistically significant effect on inventories of finished goods. The effect is significantly stronger when demand is unexpectedly high than when it is

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[18] This mean is calculated using data for the full sample period. Similar results are obtained if seperate means are calculated for each sub-period.

unexpectedly low. The coefficient on the cost shock variable is extremely small and is insignificantly different from zero. Comparing the results for the two sub-samples, we find significant differences in the estimates and in the ability of the equation to explain shocks to inventories of finished goods. Over the first half of the period the $\overline{R}^2$ is 0.47; this falls to 0.05 over the second half. Over the second half of the sample period the coefficients on both demand shock variables are insignificantly different from zero. This suggests that *unexpected* changes in demand have come to play a significantly smaller role in the inventory cycle.

The equation explaining unexpected changes in the stocks of raw materials has very low explanatory power. Over the full sample period, the demand shock variables and the cost shock variable are insignificantly different from zero. In contrast, when the sample is split in two, the favourable demand shock is significant in both sub-samples. The sign is, however, not consistent across the two periods.

The equations explaining expected changes in stocks perform considerably better. Over the full sample period, both the expected demand variables have positive and statistically significant coefficients in both the stocks of raw materials and stocks of finished goods equations. That is, when firms expect demand to increase they also expect their stocks of raw materials and finished goods to increase. Again, in both equations the cost shock variable is insignificant when using the full sample period.

For finished goods the two sample periods again show different results. Over the first half of the sample, the coefficients on favourable and unfavourable changes in demand are not significantly different from one another. In contrast, over the second half of the sample, the coefficient on unfavourable changes in demand is significantly greater than on favourable changes. Over this second half of the sample, expected declines in demand have caused large expected declines in inventories while expected increases in demand have caused negligible increases in inventories of finished goods. In addition, over the second half of the sample, expected changes in costs have a significant effect on expected inventories of the sign predicted by the cost shock models.

Table 8: Explaining Unexpected Changes in Inventories

$$\begin{matrix} Inventory \\ Shock_t \end{matrix} = constant + b_1 \begin{bmatrix} demand \\ shock \end{bmatrix} * D1 \Bigg]_t + b_2 \begin{bmatrix} demand \\ shock \end{bmatrix} * D2 \Bigg]_t + b_3 \begin{matrix} cost \\ shock_t \end{matrix} + e_t$$

	STOCK OF FINISHED GOODS			STOCK OF RAW MATERIALS		
	66:3:92:3	66:3-76:3	76:4-92:3	66:3-92:3	66:3-76:3	76:4-92:3
CONSTANT	**8.86** (5.81)	**11.14** (2.91)	**6.68** (4.16)	**10.69** (4.93)	**13.07** (2.43)	**9.00** (3.81)
DEMAND SHOCK*D1 (favourable)	**-0.64** (2.30)	**-1.00** (7.45)	**0.22** (1.79)	**-0.14** (0.76)	**-0.40** (2.30)	**0.43** (2.61)
DEMAND SHOCK*D2 (unfavourable)	**-0.10** (1.03)	**-0.15** (1.03)	**-0.11** (1.03)	**0.10** (1.02)	**0.08** (0.69)	**0.08** (0.57)
COST SHOCK	**-0.02** (0.13)	**-0.39** (1.46)	**0.24** (2.22)	**-0.16** (1.12)	**-0.43** (1.16)	**0.01** (0.10)
$\overline{R}^2$	**0.19**	**0.47**	**0.05**	**0.01**	**0.06**	**0.03**
$H_0\!:b_1 = b_2 \quad (p-value)$	**0.06**	**0.00**	**0.08**	**0.27**	**0.03**	**0.19**

Table 9: Explaining Expected Changes in Inventories

$$\begin{matrix} Expected\ D \\ in\ \ Inventories_t \end{matrix} = constant + b_1 \begin{bmatrix} expected\ D \\ in\ demand \end{bmatrix} * D1 \Bigg]_t + b_2 \begin{bmatrix} expected\ D \\ in\ demand \end{bmatrix} * D2 \Bigg]_t + b_3 \Bigg[\begin{matrix} expected \\ in\ costs \end{matrix}$$

	STOCK OF FINISHED GOODS			STOCK OF RAW MATERIALS		
	66:3-92:3	66:3-76:3	76:4-92:3	66:3-92:3	66:3-76:3	76:4-92:3
CONSTANT	**-9.37** (5.64)	**-4.60** (1.49)	**-6.88** (3.60)	**-13.74** (8.40)	**-13.68** (2.45)	**-10.56** (6.28)
EXPECTED DEMAND*D1 (favourable)	**0.18** (2.48)	**0.20** (3.07)	**0.03** (0.29)	**0.33** (4.40)	**0.36** (4.28)	**0.19** (1.67)
EXPECTED DEMAND*D2 (unfavourable)	**0.37** (2.86)	**0.09** (1.12)	**0.47** (5.47)	**0.49** (4.40)	**0.31** (3.14)	**0.53** (5.93)
EXPECTED CHANGE IN COSTS	**-0.11** (0.92)	**-0.26** (2.05)	**-0.28** (3.30)	**-0.02** (0.13)	**0.07** (0.28)	**-0.26** (2.07)
$\overline{R}^2$	**0.47**	**0.33**	**0.62**	**0.63**	**0.57**	**0.68**
$H_0\!:b_1 = b_2 \quad (p-value)$	**0.30**	**0.40**	**0.01**	**0.33**	**0.75**	**0.04**

Note.

1. T-statistics appear in parentheses below coefficient estimates. Standard errors have been calculated using the Newey-West procedure with three lags.

The results in Tables 8 and 9 suggest that changes in stocks of finished goods have increasingly become driven by *expected* rather than *unexpected* changes in demand. The ability of demand shocks to explain unexpected changes in inventories is much lower over the second half of the period. In contrast, the ability of *expected* changes in demand to explain *expected* changes in inventories is considerably higher over the second half of the sample. For finished goods the $\overline{R}^2$ increases from 0.33 to 0.62 while for raw materials it increases from 0.57 to 0.68.

The above conclusions are robust with respect to the point at which the sample period is split. In Appendix 2 we present the estimation results for the case in which the sample period is split at the June quarter of 1982. This quarter marks the beginning of the period of a declining stocks to sales ratio (see Graph 2). The results are qualitatively the same as those in Tables 8 and 9.

Graph 5 suggests that over recent years there has been an increase in the number of firms reporting an expected decline in stocks of finished goods. This is consistent with the decline in the overall stocks to sales ratio. To remove possible distortions caused by trend movements in the expected inventory series, a linear time trend was included in the estimated regressions. The results are reported in Tables A3 and A4 in Appendix 2. The sample period is split at the June quarter of 1992. Again, the results are qualitatively similar to those presented in Tables 8 and 9. As expected the time trend variable in insignificantly different from zero in each of the "inventory shock" equations. In contrast, it is negative and significantly different from zero in each of the "expected inventory" equations. For both finished goods and raw materials, the absolute size of the coefficient on the time trend is larger in the second sample period. This again supports the proposition that the process of reducing stock levels accelerated over the 1980s.

The conclusion that expected changes in demand now play a more important role is also supported by a comparison of the variance of the expected changes in finished goods with the variance of the forecast error. Over the first half of the sample, the ratio of the variance of the forecast error to the variance of the expected change in inventories is 2.6; this compares with a ratio of 0.7 over the second half of the sample period.[19] In addition, not only has the relative variance of the forecast error declined but so has the absolute variance, while the absolute variance of the expected changes in inventories has increased.

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[19] If 1982:2 is used as the break point these ratios are 2.2 and 0.9 respectively.

5. SUMMARY AND CONCLUSIONS

In this paper we examine the interaction of the inventory cycle and the business cycle. In particular we discuss the influences driving the inventory cycle and the impact that inventory investment has on the business cycle. These issues are examined with the aid of both macro-economic data and data from surveys of individual firms.

In contrast to an increasing volume of literature supporting the view that changes in inventories are driven by shocks to the cost of production, we find that demand factors dominate. Using survey data rather than macro-economic data we show that unexpected increases in inventories have typically been associated with unexpectedly low demand. In contrast, when demand is *expected* to be low, inventories are expected to fall, not rise. This suggests that shocks to demand are viewed as having a considerable degree of persistence and/or that production smoothing is relatively unimportant. Further, changes in real unit costs of production appear to have little independent effect on the inventory cycle. In terms of the debate concerning the sources of business cycle shocks, these results provide considerably more support for models that focus on demand shocks than for models which emphasise shocks to the production function.

Perhaps more importantly, the results also show a significant change in the behaviour of inventories over the last decade. In the business cycles in the 1960s and 1970s, unexpected falls in demand led to a substantial increase in inventories. This was followed by a cut-back in production as firms attempted to wind back the excessively high level of inventories. As a result, the inventory cycle amplified the business cycle.

More recently, unexpected changes in demand have come to play a much smaller role in explaining the behaviour of inventories. The notion that production smoothing is very important and that firms use inventories to buffer production from changes in sales does not appear to be a good description of reality. Increasingly, inventories move positively in line with expected and actual changes in demand. In part, this reflects increasingly sophisticated inventory management techniques and greater production flexibility. The fact that firms can more effectively prevent unintended inventory accumulation in the face of adverse shocks, reduces the need for firms to subsequently cut back production to run down inventories. The reduction in the stocks to sales ratio has also made inventories less sensitive to demand shocks. The result of these changes is an inventory cycle which has a much smaller amplitude and a smaller impact on the output cycle.

APPENDIX 1: DATA

- Data on domestic final demand, private non-farm stocks and gross domestic product in Graph 1 and Tables 1 and 4 come from Australian National Accounts, National Income and Expenditure, (5206.0), Australian Bureau of Statistics. Domestic final demand is derived as the sum of all final consumption expenditure and gross fixed capital expenditure. Data are at constant 1984/85 prices and are seasonally-adjusted.

- The private non-farm stocks to sales ratio in Graph 2 also comes from the Australian National Accounts, National Income and Expenditure (5206.0). Prior to September 1969 imports rather than endogenous imports are used in the derivation of sales.

- Manufacturing and retail trade stocks and manufacturers' sales in Graph 3 come from Stocks, Manufacturers' Sales and Expected Sales (5629.0), Australian Bureau of Statistics. Retail sales come from Retail Trade Australia (8501.0), Australian Bureau of Statistics. Data are seasonally-adjusted and at 1984/85 prices.

- Data at the sectoral level in Table 2 are from Stocks, Manufacturers' Sales and Expected Sales (5629.0), Australian Bureau of Statistics and are seasonally-adjusted, at 1984/85 prices. The 'stage of processing' breakdown of manufacturing comes from unpublished data available in an unadjusted current price form from the ABS. We seasonally adjusted these series using the X11 package and deflated each series by the implied manufacturing stocks deflator.

- Retail trade sales in Table 3 are from Retail Trade Australia (8501.0), Australian Bureau of Statistics. Manufacturing sales and components, as well as retail stocks, are from Stocks, Manufacturers' Sales and Expected Sales (5629.0), Australian Bureau of Statistics. These data are seasonally-adjusted and at 1984/85 prices. Inventory investment data are for finished goods stocks only and are based on unpublished data from the ABS. The ABS data are not seasonally-adjusted and are at current prices. We have deflated and seasonally-adjusted these in the manner described above for 'stage of processing' data. Output is calculated as sales plus the increase in stocks.

- The survey data are from the "Survey of Industrial Trends" currently undertaken by the Australian Chamber of Commerce and Industry and Westpac Banking Corporation.

APPENDIX 2: ALTERNATIVE REGRESSION RESULTS

The tables in this appendix present similar results to those presented in Tables 8 and 9. The results in Tables A1 and A2 use the second quarter of 1982 as the break point in the sample. This quarter corresponds to be beginning of the period in which the stocks to sales ratio declines (see Graph 2). Tables A3 and A4 use the new sub-samples and include a time trend in the regressions.

Table A1: Explaining Unexpected Changes in Inventories
Dependent Variable: Inventory Shock

	FINISHED GOODS		RAW MATERIALS	
	66:3-82:2	82:3-92:3	66:3-82:2	82:3-92:3
CONSTANT	**10.06** (5.46)	**6.11** (2.89)	**12.94** (5.25)	**7.06** (2.20)
DEMAND SHOCK*D1 (favourable)	**-0.97** (9.63)	**0.22** (1.58)	**-0.41** (2.71)	**0.53** (2.71)
DEMAND SHOCK*D2 (unfavourable)	**-0.20** (1.76)	**-0.02** (0.15)	**0.06** (0.54)	**0.13** (0.69)
COST SHOCK	**-0.30** (1.99)	**0.37** (3.39)	**-0.34** (1.79)	**0.07** (0.36)
$\overline{R}^2$	**0.47**	**0.04**	**0.09**	**0.07**
$H_0: b_1 = b_2 \quad (p-value)$	**0.00**	**0.27**	**0.03**	**0.23**

Table A2: Explaining Expected Changes in Inventories
Dependent Variable: Expected Inventories

	FINISHED GOODS		RAW MATERIALS	
	66:3-82:2	82:3-92:3	66:3-82:2	82:3-92:3
CONSTANT	**-6.45** (4.37)	**-8.09** (3.89)	**-12.07** (4.83)	**-12.20** (6.87)
EXPECTED DEMAND*D1 (favourable)	**0.22** (4.47)	**-0.06** (0.74)	**0.35** (5.62)	**0.12** (1.02)
EXPECTED DEMAND*D2 (unfavourable)	**0.12** (1.14)	**0.41** (4.75)	**0.36** (3.01)	**0.44** (5.51)
EXPECTED CHANGE IN COSTS	**-0.22** (2.33)	**-0.30** (3.58)	**-0.03** (0.21)	**-0.30** (2.69)
$\overline{R}^2$	**0.36**	**0.61**	**0.54**	**0.70**
$H_0: b_1 = b_2 \quad (p-value)$	**0.46**	**0.00**	**0.94**	**0.03**

Note.

1. T-statistics appear in parentheses below coefficient estimates. Standard errors have been calculated using the Newey-West procedure with three lags.

Table A3: Explaining Unexpected Changes in Inventories
Dependent Variable: Inventory Shock

	FINISHED GOODS		RAW MATERIALS	
	66:3-82:2	82:3-92:3	66:3-82:2	82:3-92:3
CONSTANT	**8.45** (1.81)	**20.65** (1.20)	**5.76** (1.02)	**14.01** (0.62)
DEMAND SHOCK*D1 (favourable)	**-0.96** (9.02)	**0.21** (1.33)	**-0.38** (2.54)	**0.53** (2.43)
DEMAND SHOCK*D2 (unfavourable)	**-0.19** (1.73)	**-0.06** (0.46)	**0.09** (0.90)	**0.11** (0.65)
COST SHOCK	**-0.27** (1.42)	**0.41** (3.25)	**-0.19** (0.79)	**0.09** (0.47)
TIME TREND	**0.02** (0.47)	**-0.13** (0.85)	**0.10** (1.65)	**-0.06** (0.33)
$\overline{R}^2$	**0.46**	**0.05**	**0.11**	**0.05**
$H_0 : b_1 = b_2 \quad (p - value)$	**0.00**	**0.27**	**0.02**	**0.20**

Table A4: Explaining Expected Changes in Inventories
Dependent Variable: Expected Inventories

	FINISHED GOODS		RAW MATERIALS	
	66:3-82:2	82:3-92:3	66:3-82:2	82:3-92:3
CONSTANT	**5.38** (1.45)	**24.37** (3.27)	**-2.43** (0.37)	**20.50** (2.89)
EXPECTED DEMAND*D1 (favourable)	**0.16** (3.15)	**-0.12** (1.85)	**0.30** (4.28)	**0.07** (0.82)
EXPECTED DEMAND*D2 (unfavourable)	**0.09** (1.21)	**0.40** (7.41)	**0.34** (3.40)	**0.43** (7.78)
EXPECTED CHANGE IN COSTS	**-0.44** (4.37)	**-0.41** (3.52)	**-0.21** (1.26)	**-0.40** (3.69)
TIME TREND	**-0.12** (3.15)	**-0.27** (4.46)	**-0.10** (1.59)	**-0.27** (4.45)
$\overline{R}^2$	**0.45**	**0.74**	**0.56**	**0.80**
$H_0 : b_1 = b_2 \quad (p - value)$	**0.56**	**0.00**	**0.78**	**0.00**

Note.

1. T-statistics appear in parentheses below coefficient estimates. Standard errors have been calculated using the Newey-West procedure with three lags.

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