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3 Inventory Fluctuations in the United States since 1929

Alan S. Blinder and Douglas Holtz-Eakin

3.1 Introduction

Inventory fluctuations are of great importance in business cycles. Indeed, to a surprisingly large extent, business cycles *are* inventory fluctuations—especially during recessions and in the early stages of recoveries. This basic feature of business cycles has been known for a long time, at least since the seminal work of Abramovitz (1950).

But inventory fluctuations are fundamentally a short-period phenomenon. Stocks of all types of inventories typically amount to about three months' sales, and even large changes in inventories amount to only a week's sales or less. Consequently, annual data may shed relatively little light on the nature of inventory fluctuations; most of the "action" may be played out within the year. For this reason, economists know precious little about inventory behavior before World War II.

This paper seeks to lift this veil of ignorance in two ways. First, we create—from some admittedly incomplete and imperfect data—monthly time series on inventory holdings in manufacturing, durables manufacturing, and nondurables manufacturing. To our knowledge, these are the first such series ever made available. We offer these data in the data appendix to this volume (appendix B) in the hope that others will find them useful. Second, we apply to the prewar data certain statistical

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procedures and models that are in common use with postwar data. In this way we can address the central issue of this conference: Has the business cycle changed?

While we do not wish to overstate the case, we were struck more by the similarities in inventory behavior between the prewar and postwar periods than by the differences. Considering the tremendous changes in the nature of American industry, in inventory management practices, in forecasting, and in the amplitude of business cycles, we found the degree of similarity surprising. But the relevant stylized facts are displayed below, and each reader can make up his or her own mind.

The rest of the paper is organized into three main sections. Section 3.2 documents the dominant role of inventories in recessions. Here the facts are fairly well known. Section 3.3 investigates some less well known aspects of the variances of production, sales, and inventory investment that Blinder (1981b, 1984) has recently emphasized using postwar data. In section 3.4, stock adjustment models similar to those popularized by Lovell (1961) are fit to data covering 1929–83 and subperiods. At least qualitatively, the results are rather similar in the prewar and postwar periods. Section 3.5 is a brief conclusion.

3.2 Inventories in Recessions

In a previous paper, Blinder (1981b) documented the dominant role of inventory swings in cyclical contractions. The data presented there are repeated and extended in table 3.1. Panel A shows the peak-to-trough movements in real GNP and real inventory investment in the eight postwar recessions, using quarterly data.[1] With the single exception of the "minirecession" of 1980, which some people think should never have been designated a recession, the important role of inventory movements is evident. Taking each recession as one observation, inventory changes have accounted, on average, for 101% of the total peak-to-trough change in real GNP. Or keeping score in a different way, the mean peak-to-trough change in inventory investment is 68% of the mean peak-to-trough change in GNP.[2]

Panel B, which is restricted to annual data, shows that a similar pattern prevailed in prewar recessions. In fact, the dominance of inventory fluctuations looks even more dramatic here. However, this

1. Peaks and troughs are defined by movements in real GNP, which sometimes differ a bit from NBER reference cycle peaks and troughs.

2. Naturally, trough-to-peak movements, which generally cover far longer periods, show no such dominance by inventory behavior. Hence these data are not shown. However, it is well known that GNP movements in the first few quarters of recoveries are dominated by inventory movements.

Table 3.1 **Changes in GNP and in Inventory Investment during Recessions**

Period	Change in Real GNP[a]	Change in Inventory Investment[a]	Change in Inventory Investment as Percentage of Change in Real GNP	Change in Inventory Investment as Percentage of GNP Gap at Trough[b]
	A. Postwar Recessions (peak and trough)[c]			
1948:4 to 1949:4	−7.1	−13.0	183	71
1953:2 to 1954:2	−20.2	−9.2	46	90
1957:3 to 1958:1	−23.0	−10.5	46	41
1960:1 to 1960:4	−8.6	−18.0	209	68
1969:3 to 1970:4	−7.3	−12.3	168	60
1973:4 to 1975:1	−60.7	−38.0	63	52
1980:1 to 1980:2	−35.0	−1.6	5	3
1981:3 to 1982:4	−45.1	−38.8	86	25
	B. Interwar Recessions			
1920–21	−3.6	−4.2	117	30
1923–24	1.5	−3.7	—[d]	336
1926–27	1.0	−0.8	—[d]	—[e]
1929–32	−32.0	−5.6	18	17
1937–38	−3.1	−2.9	94	11
	C. Postwar Recessions (peak and trough)[c]			
1953–54	−7.5	−3.7	49	71
1957–58	−2.9	−3.3	114	14
1969–70	−2.0	−7.3	365	365
1973–75	−22.7	−23.9	105	37
1979–80	−4.4	−11.7	266	23
1981–82	−28.4	−17.9	63	13

Source: Postwar data are from the national income and product accounts; interwar data are adapted from Abramovitz (1950, table 84, 476–77).

[a]Billions of 1972 dollars for postwar data, billions of 1929 dollars for interwar data.

[b]GNP gaps are based on Gordon's (1984) natural GNP series.

[c]Peaks and troughs of real GNP, not official dates of the National Bureau of Economic Research.

[d]Real GNP rose during this recession.

[e]No GNP gap in "trough" year.

may be an artifact of using annual data. As can be seen in panel B, several "recessions" display no decline in GNP on an annual basis. To get a cleaner prewar/postwar comparison, panel C puts the postwar data on an annual basis. (Two of the eight recessions disappear in the process.) Comparing panels A and C shows that annual data make inventory fluctuations look even more important than quarterly data, as we suspected. Comparing panels B and C suggests that inventory fluctuations played a more predominant role in postwar than in prewar recessions.

But in any case the main conclusion is obvious: there is really no hope of understanding the dynamics of recessions without analyzing inventory behavior. Lest we be accused of false advertising, we hasten to point out that inventories play their main role in *propagating* business cycles, not in *causing* them. We do not claim, and we do not believe, that business cycles are typically initiated by autonomous movements in inventory investment. In fact, as we shall show later, a crude measure of the impulses originating in the inventory sector suggests that they are rather small.

Another well-known fact about business cycles is that much of the cyclical action comes in the manufacturing sector, and more particularly in the durables manufacturing subsector. For this reason we tried to use our more detailed monthly data on manufacturing to conduct a peak-to-trough analysis of inventory investment in manufacturing and in the durables and nondurables subsectors.

This, however, proved impossible to do in any systematic way. One minor problem was that monthly data on manufacturing output display so much volatility that picking out peaks and troughs was no easy matter. But the major problem was that month-to-month gyrations in inventory investment are so large that—for most recessions—a strategic choice of endpoints can make inventory change appear to be either a large or a small fraction of the decline in production. Though it is hard to quantify, we did cull one basic impression from this effort: inventory swings seems to be a less dominant force in contractions in the manufacturing sector than in the whole economy. This observation underscores the importance of retail inventory movements—a point emphasized in Blinder (1981b).

3.3 Decomposing the Variance of Output

So far we have considered only periods of recession, which are, almost by definition, special cases. A more general impression of the importance of inventory movements in business cycles can be obtained by asking how much of the variance of output is attributable to changes in inventory investment.

3.3.1 The Whole Economy

An identity relates production, sales, and inventory investment. For the whole economy, if Y is GNP, X is final sales, and ΔN is inventory investment, the identity is:

$$(1) \qquad Y_t = X_t + \Delta N_t.$$

If we then detrend each time series and take the variances of both sides, we obtain:

$$(2) \qquad \mathrm{var}(y) = \mathrm{var}(x) + \mathrm{var}(\Delta n) + 2\mathrm{cov}(x,\Delta n),$$

which is a convenient way to decompose the variance of GNP around trend.

Estimates of the elements of equation (2) invariably lead to the conclusion that var(y) exceeds var(x); in this sense, inventory fluctuations are "destabilizing." This is well known. But to go further, or to be more precise, a serious data problem must be confronted. The period 1929–46 contains nothing but aberrant observations—the Great Depression followed by World War II. While the precise procedure used to detrend postwar data has little effect on equation (2), quite different results can be obtained by applying different detrending procedures to the momentous ups and downs of the earlier data. Thus we really must decide how to "detrend" the depression and the war.

We experimented with two procedures and ultimately settled on one. We first developed a purely statistical definition of trend by regressing the log of each time series in (1) on a constant, time, and time squared—omitting the years 1930–39 and 1941–46 on the grounds that they were obviously far from trend. Two problems quickly became apparent. First, the choice of which years to omit from the regression is somewhat arbitrary. Second, since each time series is detrended separately, and in logs, the identity (1) does not add up in the detrended data, and so (2) does not hold exactly. This discrepancy never amounted to much in previous work on postwar data by Blinder (1981b, 1984). But in this application, the left-hand side of equation (2) turned out to be 16% smaller than the right-hand side. That is quite a discrepancy.

So we rejected the purely statistical approach. Instead, we defined trend GNP as Robert Gordon's (1984) "natural" GNP, which he computes by applying an Okun's law conversion to a series for the natural rate of unemployment. "Natural" final sales and "natural" inventory investment were defined, essentially, by assuming that the mean value of X/Y observed in the sample was the "natural" ratio of final sales to GNP. (Details are in appendix 3.3.)

Table 3.2 shows the elements of equation (2), plus some related statistics, for the whole period and for several subperiods. Several dramatic differences between the periods 1947–83 and 1929–46 can be observed.

First, notice that the variance of detrended GNP in the postwar period is less than one-third as large as it was in the earlier period (col. 1), and the variance of detrended final sales is less than one-fourth as

Table 3.2 **Decomposition of the Variance of Real GNP (Annual Data, in Billions of 1972 Dollars)**

Period	Var (y) (1)	Var (x) (2)	Var (Δ n) (3)	2Cov (x, Δ n) (Corr (x, Δ n)) (4)	Var (y)/Var (x) (5)	Var (Δ n)/Var (x) (6)
1929–83	3123.7	2821.7	41.8	260.2 (.38)	1.11	.015
1947–83	1746.3	1327.1	48.7	370.5 (.73)	1.32	.037
1929–46	5992.9	5935.3	29.5	28.0 (.03)	1.01	.005
1929–41	1355.1	1109.6	28.0	217.6 (.62)	1.22	.025

Note: Entries are the *variances* of the differences between the actual and "natural" times series, not merely the squared deviations of actual from natural.

large (col. 2). In contrast, the postwar variance of inventory investment is actually larger than its value in the earlier period (col. 3). Thus the remarkably more stable postwar economy did not have more stable inventory behavior. In consequence, inventory fluctuation played a much more important role in the postwar economy than it had previously (col. 6).

Since the covariance between inventory investment and final sales rises tremendously after the war (col. 4, top number of each row), x and Δn are much more positively correlated in the postwar period (col. 4, bottom number). With cov(x,Δn) and var(Δn) both growing larger relative to var(x), the ratio var(y)/var(x) increased from 1.01 before 1947 to 1.32 after—a large increase.

A natural question to ask is, How much of these differences can be attributed to the war years? And the answer, as table 3.2 shows, is most of it. Naturally the variances of GNP and final sales are much smaller when the war years are excluded. What is striking, however, is that the variance of inventory investment hardly changes. If we compare the period 1929–41 with the period 1947–83, we find that both the ratio var(y)/var(x) the correlation between sales and inventory change are quite similar in the two periods (see cols. 4 and 5).

Thus, if we exclude the war years, a clear picture of continuity in the stylized facts emerges between the prewar and postwar periods. This is an important link to earlier work with postwar data. Blinder (1981b, 1984) called attention to two salient features of the variance decomposition that seem to cast doubt on the major prevailing theory of inventory behavior: the production smoothing/buffer stock model. These features are: (a) The variance of production exceeds the variance of sales, in apparent contradiction of the idea that inventories are used to smooth production in the face of fluctuating sales. (b) Final sales and inventory change actually covary positively (or not at all), not negatively, in contrast to the alleged role of inventories as a buffer stock.

Blinder (1984) shows that these two facts are not literally inconsistent with an elaborate version of the production smoothing model that includes cost shocks and allows for a complicated structure of demand disturbances. Specifically, cost shocks lead to intertemporal substitution possibilities in production that can make it optimal for var(y) to be greater than var(x) for a value-maximizing firm. And a particular type of persistence in demand shocks can make it optimal for a firm to build inventories when it experiences a positive sales shock.

Nonetheless, the facts do suggest that the theory is barking up the wrong empirical tree in that these appendages, not the basic theory itself, carry all the explanatory power. The central idea of the theory is that a firm with a concave production function and sales that vary over time (either deterministically or stochastically) will find it optimal to smooth production relative to sales. Yet, in fact, output is more variable than sales. The buffer stock motive emphasizes the role of inventories in cushioning the effects of sales "shocks" on output. Yet inventories rise, rather than fall, when sales rise.[3]

Table 3.2 shows that these two troublesome features of the postwar data also characterize the earlier data, and to a remarkably similar degree if the war years are excluded. Thus the problems with conventional inventory theory emphasized by Blinder (1981b, 1984) did not originate in the postwar period.

3.3.2 The Manufacturing Sector

Manufacturing output is the most volatile component of GNP, so it is worth seeing how a variance decomposition like equation (2) looks using monthly data for manufacturing. Before looking at the results, we should say something about how the prewar data on manufacturing output, shipments, and inventories were constructed, although the details are reserved for appendixes 3.1 and 3.2.

In this context it is important to note that when the identity (1) is applied to the manufacturing sector, Y denotes production, X denotes shipments, and N denotes the stock of finished goods plus works in progress. Inventories of materials and supplies are excluded.[4] Unfor-

3. Deviations of sales from trend include both anticipated and unanticipated components. Thus the observed covariance between inventory investment and deviations of sales from trend is a composite of two effects that presumably differ in sign. The evidence suggests that the anticipated component of sales fluctuations is dominant, whereas the buffer stock model stresses the unanticipated component.

4. Let y_t be goods that are fully produced within the period, z_t be goods that are started, and q_t be works in progress that are completed. Then the change in finished goods inventories is $y_t + q_t - X_t$, while the change in works in progress is $z_t - q_t$. Adding these up and noting that $Y_t = y_t + z_t$ gives the conclusion stated in the text.

tunately, the data available to us did not distinguish among finished goods, works in progress, and raw materials, but lumped all inventories together. Consequently, our inventory data are not quite appropriate. Because our general procedure was to piece together two of the three time series needed for equation (1) and then use the identity to infer the third,[5] this data problem introduced some unavoidable errors into our constructed series.

For the whole manufacturing sector, we used the Federal Reserve Board index of industrial production to create a monthly series on output (Y) in 1929 dollars. Then we combined annual end-of-year inventory data from Abramovitz (1950) with monthly index numbers from the *Conference Board Economic Record* to create a monthly inventory stock series (N). (Details are in appendix 3.1.) From these, X was created by using equation (1). Thus our synthetic series on shipments is actually "true" shipments minus the change in raw materials inventories (which is unobserved). Our constructed series on production is displayed in figure 3.1. The underlying data, as well as corresponding data on shipments and inventories, are in the data appendix to this volume.

For the durable and nondurable subsectors, the situation was just the reverse. Conference Board data on monthly shipments and inventory stocks were used to create a synthetic "production" series from equation (1). (Details are in appendix 3.2, and the data are in the data appendix to the volume, appendix B.) Thus our series on Y_t is actually the "true" Y_t plus the change in raw materials inventories.

With these provisos understood, let us look at the data. Because our prewar inventory data include changes in raw material inventories (ΔM) even though (1) excludes them, our measured series for manufacturing are related to the conceptually "true" series by:

$$\Delta\hat{N} = \Delta N + \Delta M$$

$$\hat{X} = X - \Delta M,$$

where "hats" denote measured time series. Hence our measured series will almost certainly overstate var(Δn)[6] and can overstate or understate var(x) and cov($x,\Delta n$) depending on how strongly X and ΔM covary.[7] The output series (Y) is constructed independently and hence is not

5. This is actually what is done with the postwar data as well. The Bureau of Economic Analysis provides data on inventories and shipments, from which we create production data to satisfy equation (1).

6. Only if ΔM and ΔN were strongly negatively correlated, which is emphatically untrue in the postwar data, could measured inventory change display less variation than true inventory change.

7. With the magnitudes that characterize the postwar period, var(x) and cov($x,\Delta n$) might actually both be biased down by the measurement error. But we cannot be sure.

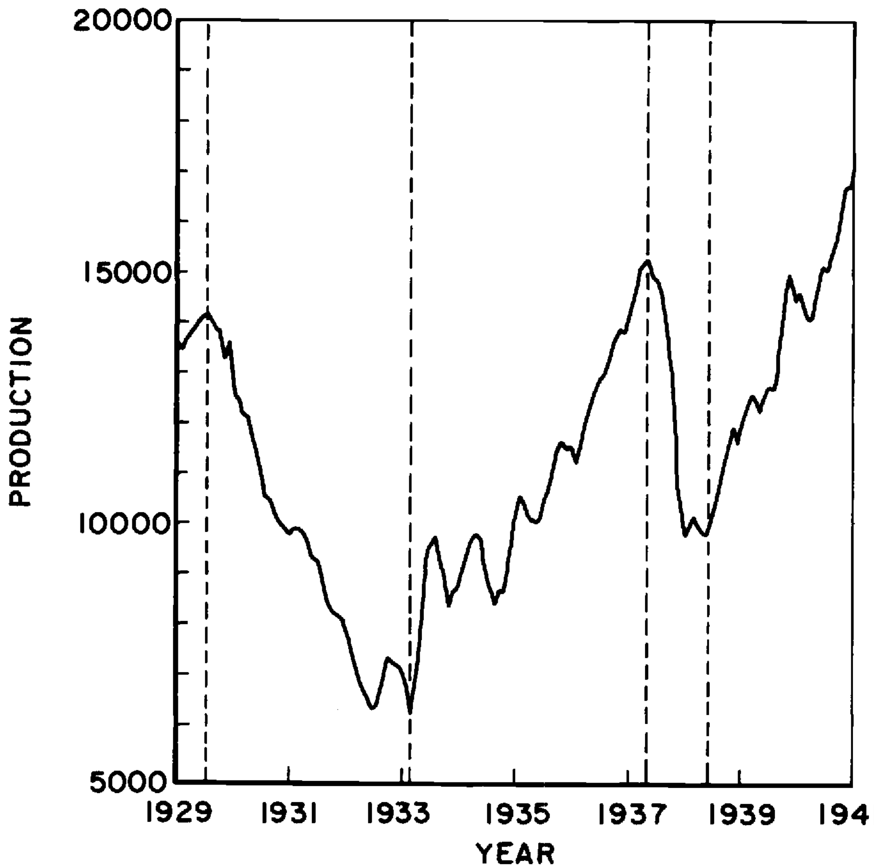

Fig. 3.1 Total manufacturing production, 1929–41. Vertical lines mark turning points.

affected by this particular measurement problem. Some evidence presented in appendix 3.1 suggests that these measurement errors are not too severe if we stick to the levels of the variables rather than the first differences. So that is what we do.

But there remains the problem of "detrending" the Great Depression and World War II, a period in which manufacturing output first sank like a stone and then rose like a rocket (see fig. 3.1). For manufacturing we have no "natural output" series, analogous to Gordon's natural GNP, to fall back on. So a statistical procedure was imperative. We tried three alternatives: (*a*) peak-to-peak interpolation (in logs), using 1929 and either 1940 or 1941 as "peak" years; (*b*) estimating the 1929–41 trend by fitting a log-linear regression line to the monthly data.

Notice that either version of procedure (*a*) treats essentially the whole period as "below trend." (The monthly data end in 1941.) This is a strange way to define a trend, but it is conceptually close to Gordon's "natural GNP." By contrast, a regression line must pass through the point of means, so procedure (*b*) labels half the period 1929–41 as "above trend" and half as "below trend." Neither procedure is particularly appealing. Fortunately, as appendix 3.3 shows, although the choice of detrending procedure greatly affects the estimated variances, *ratios* of variances are relatively insensitive. Hence the tables that follow use one particular detrending procedure (peak-to-peak interpolation between 1929 and 1941) and report only the statistics that are "scale free."

Detrending the postwar data (1959–82) was easier. Each time series was detrended by the following model of the trend component:

$$\log Z_t = a + bt + cD_t + dA_t + e_t,$$

where t is time, D_t is a second time trend (for OPEC) beginning at 1 in October 1973, A_t is zero until January 1966 and 1 thereafter, and e_t is a white noise disturbance. (The variable A_t—used because the Bureau of Economic Analysis (BEA) has revised the data since 1966, but not before—is unimportant in practice.)

Finally, we are ready to look at the results. Panel A of table 3.3 shows that the prewar data share with the postwar manufacturing inventory and sales data the two outstanding characteristics emphasized above:

1. The ratio var(y)/var(x) is greater than one, in apparent contradiction of the idea that firms want to smooth production. This ratio is a bit smaller in the prewar period (1.08 versus 1.15) but still greater than one. As noted above, the model is not literally contradicted by the finding that var(y) exceeds var(x) because cost shocks can rationalize such a variance ratio. Nonetheless, some statement about the nature of shocks is part and parcel of any stochastic model of economic behavior, and there is no doubt that the traditional production smoothing model emphasizes demand shocks, not cost shocks.[8]

2. Cov(x,Δn) is not negative, as suggested by the buffer stock motive for holding inventories. In fact, the covariance is slightly more positive in the prewar period than in the postwar period.

8. McCallum's comment offers a numerical example in which demand shocks and cost shocks apparently have equal variances, and yet the optimal value of var(y)/var(x) for the firm is 18.7! This example is misleading, however. By picking numerical values that make the marginal revenue curve ten times as steep as the marginal cost curve, McCallum makes the Lagrange multiplier (the shadow value of inventories) ten times as sensitive to shifts in the MC curve as to shifts in the MR curve. Thus his choice of parameter values renders demand shocks totally unimportant, as can be seen in his equations (13). The tremendous coefficient of the cost shock (u) in the output (y) equation dominates all the others when variances are computed.

Table 3.3 **Analysis of the Variance of Manufacturing Output (Monthly Data)**

Period	Var (y)/Var (x) (1)	Corr (x, Δn) (2)	Var (Δn)/Var (x) (3)
	A. Total Manufacturing		
Prewar (1929–41)	1.08	0.25	0.012
Postwar (1959–82)	1.15	0.20	0.063
Postwar (with errors)	1.26	0.23	0.056
	B. Durables Manufacturing		
Prewar (1929–41)	1.11	0.46	0.014
Postwar (1959–82)	1.43	0.22	0.089
Postwar (with errors)	1.61	0.27	0.067
	C. Nondurables Manufacturing		
Prewar (1929–41)	1.05	0.12	0.035
Postwar (1959–82)	1.06	0.05	0.046
Postwar (with errors)	1.16	0.12	0.040

One noticeable difference between the two periods is the relatively greater role of inventory variability in the (more stable) postwar period. The variance of inventory investment is only about 1% of the variance of shipments in the prewar period, but it rises to 6% in the postwar period. This finding in the monthly manufacturing data echoes what we saw earlier in the annual economywide data for 1929–46, but not for 1929–41.

The third line in each panel of table 3.3 requires some explanation. Our postwar data have been corrected (by us, not by the BEA) to account for the facts that one 1972 dollar of finished goods in inventory represents more physical units than one 1972 dollar of shipments and, similarly, one 1972 dollar of works in progress represents more physical units than one 1972 dollar of finished goods.[9] These adjustments cannot be made to the prewar data. Also, the aforementioned problem with raw material inventories does not afflict the postwar data. To put the two time periods on a more equal footing, we created an "incorrect" set of postwar data in which we deliberately introduced the wrong

9. For a full explanation of the problem and an explanation of our corrections, see West 1983 and Blinder and Holtz-Eakin 1983.

treatment of raw material inventories (and calculated shipments incorrectly from the identity) and failed to make the corrections for physical units just mentioned.

Results with these erroneous data are presented in the third line of each panel of table 3.3. In general they suggest that the data errors are not of enormous import.

3.3.3 Durables and Nondurables Manufacturing

Data problems are a little different in the durables and nondurables sectors because here we have data on sales and inventories (including, once again, raw material inventories) and need to construct output. Hence our measured series are related to the "true" series by:

$$\hat{Y} = Y + \Delta M$$

$$\Delta\hat{N} = N + \Delta M.$$

This creates different statistical biases from those present in the data for manufacturing as a whole.

Results from decomposing the variance of output in durables and nondurables manufacturing are presented in panels B and C of table 3.3. The results for durables are rather similar to those for all manufacturing, except that the ratio var(y)/var(x) in the postwar period is much larger in durables than in manufacturing as a whole. Results for nondurables show a smaller var(y)/var(x) ratio and less covariance between sales and inventory change but are qualitatively similar.

Thus the findings of this section seem quite robust. Like the postwar data, the prewar data are characterized by a ratio of var(y)/var(x) that exceeds unity, a positive cov(x,Δn), and a small ratio of var(Δn)/var(x). The major difference between the two periods seems to be that var(y)/var(x) is higher after the war.

3.4 A Simple Characterization of the Inventory Cycle

How can we characterize the cyclical behavior of inventory investment in a simple way? The stock adjustment model pioneered by Lovell (1961) seems a good place to start, since it has become the workhorse of empirical research on inventories.

The model consists of two equations. The first states that inventory investment is some fraction of the gap between actual and desired inventories, minus a fraction of unanticipated sales; the latter represents the buffer stock role of inventories. Thus

$$N_{t+1} - N_t = b(N^*_{t+1} - N_t) - c(X_t - {}_{t-1}X^e{}_t) + e_t, \quad (3)$$

where N^*_{t+1} is desired inventories, ${}_{t-1}X^e{}_t$ is expected sales, and e_t is a stochastic error. The second equation is a specification of desired inventories, which are commonly taken to be a linear function of expected sales:

$$N^*_{t+1} = A + a_{t-1}X^e_{t+1}. \tag{4}$$

This model of inventory behavior has many defects, some of which have already been mentioned.[10] In addition, several other problems have emerged when equations like (3) and (4) have been estimated. One persistent problem is that the estimated speed of adjustment, b, usually turns out to be too slow to be believed.[11] Despite this apparently slow adjustment, the estimate of c normally turns out to be near zero (and is sometimes negative!), suggesting that production moves almost one to one with sales.[12] In addition, when such obvious "cost" variables as wages and interest rates are added to (4) as determinants of desired inventories, they often get the wrong sign. Finally, except for manufacturers' inventories of finished goods, the theoretical motivation for partial adjustment is not clear.[13]

Despite all these reservations, the stock adjustment model is a simple way of putting some structure on the data, summarizing the time series in a way that is more meaningful than an unrestricted vector autoregression. Obviously, the stock adjustment model is a vector autoregression that has been constrained in a particular way suggested by economic theory—which has the advantage of giving economic interpretations to the estimated coefficients.

Note, however, that the stock adjustment model is incomplete in that it tells us nothing about the path of final sales. Since the X_t process is autonomous, the model only describes how inventories (and implicitly output) fluctuate given autonomous fluctuations in sales. Explaining fluctuations in sales goes well beyond the purview of this paper; indeed, this volume contains several papers devoted to this task.

10. For a discussion of these defects, see Blinder 1981b, 1984.

11. Maccini and Rossana 1984 appears to be a prominent exception. But we believe their rapid adjustment speeds are artifacts of their estimation technique. Blinder 1984, using essentially the same data as Maccini and Rossana, reports that the likelihood function implied by the stock adjustment model with first-order serial correlation in the disturbance has two local maxima: one with rapid adjustment and high serial correlation, the other with slow adjustment and little serial correlation. Maccini and Rosanna use a two-step procedure that, in practice, selects the former. But Blinder 1984 finds that the latter is the global maximum in most industries.

12. Slow adjustment and low c have often been thought to be contradictory. However, Blinder 1984 shows that there is no necessary contradiction. He also shows that a negative value of c can be rationalized if the econometrician knows less about the firm's sales than the firm does and if demand shocks have a particular form of persistence.

13. For manufacturers' inventories of finished goods, Holt et al. 1960 and Blinder 1982 show that the model can be derived by maximizing discounted profits subject to quadratic revenue and cost functions.

3.4.1 Stock Adjustment Estimates for the Whole Economy

We begin with annual data for the whole economy. To "close" the model, we assume that expectations are formed rationally. There are several ways to estimate rational expectations models like this one.

One way, a limited information method suggested by McCallum (1976, 1979), is to substitute equation (4) into (3) and use an instrumental variable procedure to deal with the unobserved expectation. But as McCallum (1979) notes, this technique may not be very promising when both the actual and the expected value of sales appear in the equation—which is the case in (3).

Another way, a full information procedure suggested by Sargent (1978), is to posit an explicit stochastic process generating sales and then estimate the parameters of the stochastic process jointly with the parameters of (3) and (4), imposing the cross-equation restrictions implied by rational expectations. This paper is not an appropriate place to discuss the merits and demerits of limited versus full information econometric procedures. Suffice it to say that both have both.

We adopted the full information technique under the assumptions that the disturbance e_t in equation (3) is AR(1) and that final sales are generated by an autonomous AR(2) time series process around a quadratic time trend:

$$X_t = a_0 + a_1 t + a_2 t^2 + pX_{t-1} + qX_{t-2} + u_t: \tag{5}$$

As a check, we also estimated the system without the cross-equation constraints. Much to our surprise, the constrained estimates hardly differed from the unconstrained estimates, so we report only the constrained estimates (with asymptotic t-ratios in parentheses) for the whole period 1929–83 below:

$$\underset{}{N_{t+1} - N_t} = \underset{(2.1)}{.19}\,(\mathrm{N}^*_{t+1} - N_t) + \underset{(2.1)}{.075}\,(X_t - {}_{t-1}X^e_t)$$

$$\mathrm{N}^*_{t+1} = \underset{(0.8)}{44.1} + \underset{(1.9)}{.235}\ {}_{t-1}X^e_{t+1}$$

$$R^2 = .35,\ \rho = \underset{(1.8)}{.23},\ \mathrm{DW} = 1.96$$

$$X_t = \text{time trend} + \underset{(11.3)}{1.44}\,X_{t-1} - \underset{(3.3)}{.44}\,X_{t-2}.$$

$$R^2 = .996 \qquad \mathrm{DW} = 1.86$$

These estimates share the problems that are familiar from studies of less aggregative postwar data. The estimated speed of adjustment is quite low—only 19% per year. The coefficient of "unexpected sales" gets the wrong sign, indicating that unexpectedly high sales lead to inventory accumulation. More probably, this coefficient indicates that our unexpected sales proxy is not unexpected by firms, which is hardly surprising when using annual data.[14]

Since the constant in the desired inventory equation is small, the estimated marginal inventory/sales ratio is close to the historical average inventory/sales ratio, which is .25. The AR(2) process for final sales takes a familiar form: the coefficient of lagged sales exceeds unity, and the coefficient of X_{t-2} is negative.[15]

These results are less than awe inspiring. One possibility is that the stock adjustment model should be applied only to the sales of goods—or perhaps only to durable goods—rather than to all final sales, because there are no inventories in the service sector. However, when we did this, the only parameter estimate that changed much was "a"—which increased to reflect the rising inventory/sales ratio as we moved from goods and services to goods and then to durable goods. The parameter estimates may be unreasonable from a theoretical point of view, but they are robust.

The simple stock adjustment model tracks history surprisingly well, even during the Great Depression and World War II. The reason, of course, is that our simple AR(2) model of final sales fits the data quite well. The model underestimates sales at the start of World War II and overestimates them by more at the end. But considering that no special allowances were made for either the war or the depression, the tracking performance was good.

Since stock adjustment models have been estimated many times on postwar data, but never to our knowledge on prewar data, it is of interest to split the data and estimate the model on 1929–46 and 1947–83 subsamples. In splitting the sample, the number of degrees of freedom drops precipitously—especially in the prewar period. So we eliminated the quadratic time trend. Table 3.4 reports the results for the whole period and for the two subperiods.[16]

14. Monthly regressions with manufacturing data produce the correct (positive) sign for c, as will be seen shortly.

15. Unfortunately, this particular AR(2) model has a root that is almost exactly unity.

16. Notice that the earlier sample is 1929–45, not 1929–46. At first we included 1946, but we discovered that this one year had an extraordinary effect on all the regression estimates. It happens that inventory investment shot up to an unusually high level in 1946, even though final sales plunged. Though this may sound like normal behavior, it is not. When 1946 is added to the regression reported in table 3.4, the coefficient of unexpected sales falls from .12 to .02, the speed of adjustment falls from .32 to .05, the marginal inventory/sales ratio falls from .17 to .04, and the R^2 of the equation drops from .71 to .19.

Table 3.4 Estimates of Stock Adjustment Model: Whole Economy

Parameter	1929–83	1929–45	1947–83
Inventory equation			
a (inventory accelerator)'	.23	.17	.21
	(18.4)	(3.0)	(7.0)
b (adjustment speed)	.15	.32	.10
	(2.4)	(2.4)	(1.0)
c (unexpected sales)	−.093	−.123	−.230
	(3.1)	(2.4)	(6.6)
Autoregression for sales			
p	1.44	1.91	1.23
	(11.4)	(8.8)	(11.5)
q	−.43	−1.06	−.23
	(3.3)	(3.9)	(2.1)
R^{2a}	.34, .996	.71, .98	.66, .996
ρ^{b}	.22	.37	.28
	(2.0)	(2.2)	(3.7)
DW[a]	1.97, 1.86	2.01, 1.71	2.14, 1.85
σ^2_e	30.3	8.51	16.2
σ^2_u	645.1	328.0	383.8

Note: The model is:

(3) $N_{t+1} - N_t = b(N^*_{t+1} - N_t) - c(X_t - {}_{t-1}X^e) + e_t$

(4) $N^*_{t+1} = A + a_{t-1}X^e$

(5) $X_t = \text{const.} + pX_{t-1} + qX_{t-2} + u_t$.

[a]The first number is for the inventory investment equation; the second number is for the final sales equation.

[b]For the inventory investment equation.

The results for the whole period are given only to provide a basis for comparison with the subsample results. They differ insubstantially from those given above, reflecting the fact that the best AR(2) sales model hardly changes when the time trend is omitted.

Despite the topsy-turvy nature of the economy during 1929–45, the estimates differ only moderately from those for the whole sample and the postwar subperiod. The main difference is that the estimated speed of adjustment is much faster in the period 1929–45 (32% per year) than in the period 1947–83 (10%). The marginal inventory/sales ratio is quite similar in the two periods, and the incorrectly signed buffer stock coefficient is smaller in the earlier period. In general, however, the 1929–45 and 1947–83 estimates of the stock adjustment are qualitatively similar.

Finally, and not surprisingly, the estimated AR(2) processes for final sales are quite different in the two subperiods. (Remember: no special allowances were made for the Great Depression or World War II.) Figure 3.2 shows how the simple AR(2) model of final sales copes with the Great Depression and World War II. Notice in particular that the beginning of the war comes as a large positive sales surprise to the model. Nevertheless, the fit is surprisingly good.

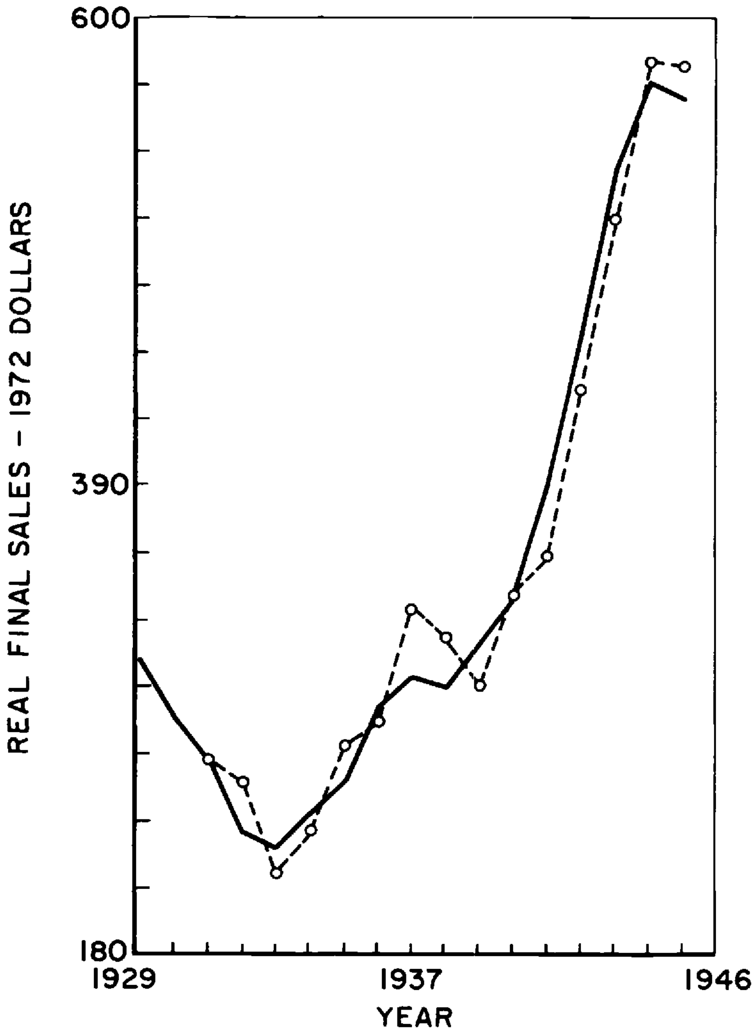

Fig. 3.2 Stock adjustment model, 1929–45. Actual, solid line; predicted, broken line.

One interesting observation can be added here. Notice that the variance of the disturbance term in the inventory equation—σ_e^2—is estimated to be almost twice as large in 1947–83 as in 1929–45. By this simple measure, then, business cycle *impulses* originating in the inventory sector have been almost twice as important since the war ended.

3.4.2 Stock Adjustment Estimates for Manufacturing

The same stock adjustment model can be estimated for the manufacturing sector and for the durables and nondurables subsectors. In doing this with monthly data, we modeled shipments as an AR(12) process around a quadratic time trend, rather than an AR(2). We do not bother reporting the many AR coefficients, but simply confine ourselves to three remarks. First, the coefficients in the prewar and postwar periods are not as different as might be expected. Second, the cross-equation restrictions implied by rational expectations were again imposed in all equations, with little effect on the estimates. Third, the autoregression fits the data on shipments so well that there is no point displaying its performance graphically. Even in the tumultuous prewar period, the R^2 of the autoregressions never falls below .92.

We are more interested in the stock adjustment equations. In estimating these equations on monthly manufacturing data, we added three new variables to the specification:

1. The nominal interest rate. Interest rates play an obvious role in all theoretical inventory models but rarely "work" empirically in postwar regressions. We thought it worth finding out if they do any better in prewar regressions. The theoretically predicted sign is negative.

2. Expected capital gains, as generated by an autoregression. This variable allows the two components of the real interest rate to enter separately rather than constraining the coefficients to be equal and opposite.

3. The real product wage, which serves as an empirical proxy for "cost shocks." The theoretically predicted sign is negative.

Each of these variables was entered in distributed lag form.[17] The estimates, with asymptotic t-ratios in parentheses, are shown in table 3.5 (for all manufacturing), table 3.6 (for durables), and table 3.7 (for nondurables). In each table there are two equations for the postwar period: the first uses the "correct" data, while the second deliberately makes the two data errors mentioned previously.

17. These were all quadratic Almon lags running from t to $t - 11$ with no endpoint constraints.

Table 3.5 Estimates of Augmented Stock Adjustment Model: Manufacturing

Parameter	Prewar	Postwar Good Data	Postwar Bad Data
a (inventory accelerator)	.50	3.06	1.85
	(5.8)	(2.5)	(6.7)
b (adjustment speed)	.43	.01	.02
	(8.2)	(1.1)	(3.6)
c (unexpected sales)	.11	.02	.03
	(4.0)	(1.8)	(1.3)
Nominal interest rate (sum of lag coefficients)	683.8	−68.4	−18.8
	(3.7)	(2.7)	(10.0)
Expected capital gains (sum of lag coefficients)	−4.9	.16	.44
	(4.1)	(0.5)	(1.6)
Real wages (sum of lag coefficients)	1.9	−.012	−.004
	(1.2)	(1.4)	(0.7)
Variance of residuals[a]	0.11, .298	.133, .769	.088, .770
R^2[a]	.86, .96	.297, .995	.49, .995
DW[a]	1.73, 1.74	2.06, 1.98	2.08, 1.95
ρ[b]	.85	.08	.23
	(22.0)	(1.2)	(3.7)

[a]The first number pertains to the inventory investment equation, the second to the sales equation.

[b]A first-order serial corrrelation correction was made to the inventory investment equation.

There are both differences and similarities between the prewar and postwar estimates. And where notable differences emerge, the fact that the postwar estimates with the deliberate data errors are close to the postwar estimates with the "correct" data suggests that the differences are genuine, not artifacts of the data. As in the economywide data, we once again find an indication that business cycle impulses originating in the inventory sector have been larger since the war. In each case, the variance of the residual in the inventory investment equation is larger in 1959–83 than it was in 1929–41.

It is probably best to deal with the individual coefficients variable by variable.

Adjustment speeds: With one exception (all manufacturing in the prewar period), monthly adjustment speeds are very low.[18] Interestingly, there is a clear tendency to find faster adjustment in the prewar

18. Notice that, in conformity with note 11, the one equation with rapid adjustment also has high estimated serial correlation in the disturbance term.

Table 3.6 Estimates of Augmented Stock Adjustment Model: Durables Manufacturing

Parameter	Prewar	Postwar Good Data	Postwar Bad Data
a (inventory accelerator)	2.19	3.38	2.33
	(3.3)	(3.5)	(9.0)
b (adjustment speed)	.06	.02	.04
	(2.8)	(2.8)	(6.0)
c (unexpected sales)	.07	.01	.01
	(2.0)	(0.4)	(0.5)
Nominal interest rate (sum of lag coefficients)	18.2	−30.1	7.8
	(0.4)	(1.5)	(0.5)
Expected capital gains (sum of lag coefficients)	−.08	−.10	.33
	(0.4)	(0.5)	(1.9)
Real wages (sum of lag coefficients)	−.15	−.11	−.003
	(0.7)	(1.2)	(0.5)
Variance of residuals[a]	.0022, .0134	.101, .449	.059, .451
R^2[a]	.68, .97	.35, .991	.53, .991
DW[a]	1.96, 1.98	2.04, 1.97	2.09, 1.92
ρ[b]	.34	.07	.12
	(3.7)	(1.1)	(2.0)

[a]The first number pertains to the inventory investment equation, the second to the sales equation.

[b]A first-order serial correlation correction was made to the inventory investment equation.

period than in the postwar period—just as we found with economywide annual data.

Inventory accelerator: In all manufacturing and in nondurables, the marginal inventory/sales ratio is much lower in the prewar period. In durables, this tendency is obscured by the data problems in the prewar period.

Unexpected sales: Unlike the economywide results, the proxy for unexpected sales gets the correct (positive) sign in all equations and is even significantly positive in several cases. However, all the coefficients are small in magnitude. So the basic finding of a weak buffer stock motive is maintained.

In sum, as compared with the postwar period, the inventory adjustment mechanism in the prewar period in manufacturing seems to have been characterized by more rapid (but still slow) adjustment, a correctly signed but small effect of unanticipated sales on inventory investment,

Table 3.7 Estimates of Augmented Stock Adjustment Model: Nondurables Manufacturing

		Postwar	
Parameter	Prewar	Good Data	Bad Data
a (inventory accelerator)	0.61	1.83	1.58
	(2.1)	(0.9)	(4.9)
b (adjustment speed)	.14	.01	.03
	(3.1)	(0.5)	(1.7)
c (unexpected sales)	.05	.07	.07
	(1.3)	(1.8)	(2.2)
Nominal interest rate	57.2	−13.4	−7.0
(sum of lag coefficients)	(2.3)	(1.5)	(0.9)
Expected capital gains	.50	−.15	−.17
(sum of lag coefficients)	(2.2)	(1.1)	(1.2)
Real wages	.65	−.003	−.002
(sum of lag coefficents)	(1.8)	(1.0)	(0.9)
Variance of residuals[a]	.0032, .021	.031, .095	.022, .095
$\bar{R}^2$[a]	.54, .88	.08, .996	.23, .996
DW[a]	1.93, 1.86	1.99, 1.97	1.95, 1.98
ρ[b]	.43	.09	.24
	(4.0)	(1.4)	(3.8)

[a]The first number pertains to the inventory investment equation, the second to the sales equation.

[b]A first-order serial correlation correction was made to the inventory investment equation.

and a lower marginal inventory/sales ratio (and hence a weaker inventory accelerator).

Interest rates: The nominal interest rate variable gets the correct sign in all three postwar regressions (using good data).[19] But it is significant only in total manufacturing, not in either subsector—which raises suspicions about aggregation. Furthermore, the expected capital gains term is correctly signed in only one of the three postwar regressions, and the signs of the two interest rate variables are systematically wrong in the prewar regressions. In general, the interest rate variables

19. To interpret the magnitudes of the coefficients, it is necessary to know the units of measurement. In the prewar regressions, inventories and sales are in billions of 1929 dollars at monthly rates; in the postwar regressions, inventories and sales are in billions of 1972 dollars at monthly rates. In both cases the interest rate variables are monthly rates in decimal form (that is, .01 means roughly a 12% annual rate of interest).

do not perform well—which echoes the findings of most investigators of this issue.

Wage rates: Real wages get the wrong sign in two of the three prewar regressions. They get the correct sign in the postwar regressions but are far from significant.[20]

In general, then, neither the prewar nor the postwar data embrace the stock adjustment model—a matter not improved by the addition of some basic cost variables suggested by economic theory. Again, however, we find the prewar and postwar estimates quite similar, even if they fail to accord with the theory.

3.5 Summary and Conclusions

Inventory investment is the most volatile component of GNP. It plays a major role in business cycles, especially around turning points and during cyclical downswings, and is strongly procyclical. These facts are all well established for the postwar United States economy. And everything we know from prewar data—including annual national income data and monthly data on the manufacturing sector—suggests that the same stylized facts held in the prewar period as well.

Although the variability of the other 99% or so of GNP fell drastically between 1929–46 and 1947–83, most of this can be attributed to the wartime gyrations of final sales. The variability of inventory investment actually increased after the war. Furthermore, though inventory investment and final sales are essentially uncorrelated over 1929–46 and strongly positively correlated over 1947–83, most of this difference is also attributable to the war years. In fact, if the periods 1929–41 and 1947–83 are compared, the basic stylized facts about inventories and final sales for the whole economy look quite similar.

These stylized facts, for both the whole economy and the manufacturing sector in both the prewar and postwar periods, appear to contain bad news for the dominant empirical model of inventory behavior—the production smoothing/buffer stock model. In particular, while the fact that production is more variable than sales does not literally contradict the model, it certainly does move production smoothing off center stage. And the fact that sales and inventory change covary positively rather than negatively casts serious doubt on the empirical importance of the buffer stock motive.

Besides this circumstantial evidence, conventional stock adjustment equations do not perform at all well when estimated econometrically:

20. In the postwar regressions, real wages are an index number (1972 = 100); in the prewar regressions, real wages are in real 1929 dollars per hour. Hence the coefficients are not comparable across periods.

speeds of adjustment turn out to be implausibly low, the effect of "unanticipated" sales is rarely important and sometimes incorrectly signed, and such cost variables as interest rates and wages often (but not always) get the wrong sign. These annoying features of the inventory data are by now well known in postwar data. This paper shows that they more or less characterize the prewar data as well and that estimated stock adjustment models for inventory investment in the prewar period look moderately similar to their postwar counterparts.

The emphasis of this paper, therefore, unlike many of the others at this conference, is on continuity rather than on change. While other aspects of the business cycle were undergoing a virtual transformation, changes in the nature of inventory behavior were surprisingly small.

Appendix 3.1
Construction of Total Manufacturing Data

This study employs new data on production, shipments, and inventory holdings in constant dollars for the manufacturing sector of the United States economy monthly from 1929 to 1942. We constructed these data using a variety of sources; the details are presented in this appendix.

1. Production

The primary source is the monthly Federal Reserve Board (FRB) index of industrial production (1957–59 = 100) obtained from the Mitchell data base.[1] This index number was converted into a (seasonally adjusted) series on real output measured in 1929 dollars in the following steps:

1. From the *Economic Report of the President*, real GNP originating in manufacturing was obtained for the years 1957, 1958, 1959.
2. The average monthly output (the sum of the three annual outputs divided by thirty-six) was converted from 1972 to 1929 dollars using the implicit price deflator for total goods. In addition, the units were changed from billions to millions of dollars to be conformable with shipments and inventory data (see below).
3. A monthly real output series was created by using this benchmark and the monthly percentage changes from the FRB index.
4. The real output series was seasonally adjusted using the Census Bureau's X-11 program.

1. A computerized data base containing most of the time series used by Mitchell, available from the Inter-University Consortium for Political and Social Research.

2. Inventories

Two basic data sources are available. From the Mitchell data base, and ultimately from Abramovitz (1950), annual observations on the value of inventory holdings at the end of December of each year are available from 1929 to 1942. To create a monthly time series we used a monthly, seasonally adjusted index of the value of inventory holdings of the end of each month from the *Conference Board Economic Record* of 26 December 1940 (henceforth, *CBER*). Several observations are in order.

First, the inventory data from both sources include finished goods, works in progress, *and* raw materials. The inclusion of the latter presents a problem when the inventory data are used in the production-shipments-inventory investment identity:

$$Y_t = X_t + (N_{t+1} - N_t).$$

Here the conceptually appropriate inventory concept is the sum of finished goods and works in progress. Since the identity is used extensively, the inclusion of materials stocks in inventories is strictly incorrect, certainly unfortunate, but unavoidable. An effort will be made below to judge the importance of this on all critical calculations.

Second, the series created by deflating the nominal value of inventories by an (index of) output prices does not accurately reflect physical quantities. This is because inventory values are book values, which depend on the type of accounting (LIFO vs. FIFO), composition of inventory, and whether the inventories are valued at cost or market value. Typically, they are entered at the lower of the two choices. These problems are not restricted to interwar data but also are important in postwar inventory analysis (see West 1983 and Blinder and Holtz-Eakin 1983).

Finally, the *CBER* index is not a comprehensive index of manufacturing inventories. It is based on industries that account for only about one-eighth of inventory and shipment values, and it deliberately excludes data covering "food products, tobacco, liquors and petroleum, and certain lumber products" (*CBER*, 2).

The data used in this paper were derived in the following steps:

1. Consider the two series N_1 and N_2. N_1 is created by benchmarking the *CBER* index to the beginning-of-year inventory values given by Abramovitz (actually the 31 December value from the previous year), and N_2 is created by using the end-of-year values. The nominal, monthly series we use is a linear combination of N_1 and N_2 given by:

$$N_t = a_k N_{1t} + (1 - a_k) N_{2t},$$

where the weight in month k is a decreasing function of the distance from the start of the year. Specifically, the weight (a_k) for January is 1, February 10/11, March 9/11, and so forth until a_k for December is equal to 0.

2. This series was converted to a real inventory series using the index (1929 = 100) of manufacturing prices described above. As noted above, that inventories are often valued at cost implies that this procedure will not exactly mimic movements in physical quantities of inventories.

3. Shipments

Real monthly shipments (in millions of 1929 dollars) were created using the identity

$$X_t = Y_t - (N_{t+1} - N_t),$$

and a corresponding nominal output series was created by multiplying the real series by the price index described below. As mentioned above, the inclusion of raw materials in the inventory stocks induces an error into the constructed shipments series. If X_t is the "true" shipments and $\hat{X}_t$ our estimate:

$$X_t - \hat{X}_t = M_{t+1} - M_t,$$

where M_t is the raw material inventory at the start of month t.

4. Price Index

The data from Mitchell contain a Bureau of Labor Statistics index of manufacturers' prices (1926 = 100). The price index was first converted to a 1929 = 100 base and then seasonally adjusted using the Census X-11 program.

5. A Check on Data Construction

There is one possible check on the accuracy of the data construction used above. The *CBER* data include a monthly, seasonally adjusted index of the value of manufacturers' shipments. Since our method of deriving shipments understates true shipments by the amount of raw material inventory investment (see above), it is of interest to see how well it resembles the movements in the direct measure of shipments given by the *CBER* index. In *levels*, the two measures are in close accord; the simple correlation between them is .989. However, the correlation between *percentage changes* in the *CBER* index and percentage changes in the constructed shipments series is less satisfactory—.511.

Because of this, we investigated alternative methods of constructing the data series.

6. Alternative Construction of Manufacturing Data

The alternative methods of data construction all involve measuring two of three variables—production, shipments, and inventories—and then using the identity linking them to impute the third. Earlier, we described a method that computes benchmarks for the production and inventory indexes and then constructs shipments as the residual. Below, we present the results of three variants of the following procedure: find benchmarks for shipments and production, and construct inventory investment using the identity. There is a catch. We are unable to locate a source containing estimates of the level of manufacturing shipments in the interwar period to use in converting the *CBER* index number into real 1929 dollars. Instead, we use various years from our basic series, above, as benchmarks to the *CBER* shipments index and then compute inventories accordingly. By doing this we include in the benchmark shipments the amount of raw materials inventory disinvestment during the benchmark month. However, the remaining monthly movements in raw materials inventory will be included in the inventory series via the identity. Ideally, the behavior of our basic series and the alternative will be quite similar. In practice they are not similar, and the behavior of the alternative is highly dependent upon the benchmark month chosen. We computed three variants of this alternative method:

	Benchmark Month
Variant I	February 1929
Variant II	January 1932
Variant III	December 1942

The relationships among the basic series and our three variants are summarized by the simple correlations:

	Shipments			
	Basic	*Variant 1*	*Variant 2*	*Variant 3*
Basic	1.0	—	—	—
Variant 1	.981	1.0	—	—
Variant 2	.981	1.0	1.0	—
Variant 3	.981	1.0	1.0	1.0

	Inventories			
	Basic	*Variant 1*	*Variant 2*	*Variant 3*
Basic	1.0	—	—	—
Variant 1	.457	1.0	—	—
Variant 2	−.207	−.402	1.0	—
Variant 3	.382	.864	.114	1.0

	Inventory Investment			
	Basic	*Variant 1*	*Variant 2*	*Variant 3*
Basic	1.0	—	—	—
Variant 1	−.030	1.0	—	—
Variant 2	−.180	.897	1.0	—
Variant 3	−.150	.936	.995	1.0

7. Effect of Construction Method on Variance Decomposition

The variance decomposition is the workhorse summary measure in this paper. We wish to determine the size and direction of the bias induced into the variance measures by the alternative methods of constructing the data.

Method 1

This is the method used to derive our "basic" series. First production and inventory data are derived, and then shipments are computed using the identity. *Assuming* that the indexes accurately reflect physical production and the value of inventory *and* that we may deflate using our price index (both are probably wrong):

$$X_t^1 = X_t - \Delta M_t,$$

where ΔM_t is raw materials inventory *investment* in month t, X^1 is the constructed series, and X is actual shipments. Accordingly:

$$\sigma_{x^1}^2 = \sigma_x^2 + \sigma_{\Delta M}^2 - 2\rho\sigma_x\,\sigma_{\Delta M}\,.$$

We know that $\rho > 0$ in postwar data. Similarly, we can show:

$$\operatorname{cov}(x^1,\hat{\Delta N}) = \operatorname{cov}(x,\Delta N) + \operatorname{cov}(x,\Delta M) - \operatorname{cov}(\Delta M,\Delta F+\Delta W) - \sigma_{\Delta M}^2\,,$$

where ΔF is finished goods inventory investment and ΔW is investment in inventories of work in process. Thus:

$$\sigma_{x^1}^2 > \sigma_x^2 \text{ iff } 2\rho < \sigma_{\Delta M}/\sigma_x\,,$$

and

$$\operatorname{cov}(x^1,\hat{\Delta N}) > \operatorname{cov}(x,\Delta N) \text{ iff } \operatorname{cov}(x,\Delta M) > \sigma_{\Delta M}^2 + \operatorname{cov}(\Delta M,\Delta F + \Delta W).$$

Neither of these conditions is satisfied in the postwar data. Thus it seems likely that the variance of shipments is *biased down* and the covariance of shipments with inventory investment is *biased upward.*

Method 2

In this method we use the production series derived above and benchmark the *CBER* index of the value of shipments using a shipments value from our basic series. Assuming the same things as above, this method implies:

$$X_t^2 = X_t - X_t\,(\Delta M_B/X_B),$$

where X^2 is the constructed shipments series, ΔM_B is the investment in raw materials inventory in the base year, and X_B is shipments in the base period. Clearly, the behavior of this series is highly dependent upon the base period chosen. In particular

$$\sigma_{x^2}^2 = \sigma_x^2 \left[1 - \frac{\Delta M_B}{\Delta X_B}\right]^2,$$

which is biased either up or down depending upon the (unobserved) movement of raw materials inventory in the base period. Similarly:

$$\mathrm{cov}(x^2,\Delta\hat{N}) = \left(1 - \frac{\Delta M_B}{\Delta X_B}\right)\left\{\mathrm{cov}(X,\Delta N) + \sigma_x^2\left(\frac{\Delta M_B}{X_B}\right)\right\}.$$

Again the direction of the bias in the constructed series is unclear.

Appendix 3.2
Construction of Data for the Durables and Nondurables Sectors

This appendix describes the construction of data on manufacturers' production, shipments, inventory, and prices for durable and nondurable goods. It is worth emphasizing at the outset that different basic data series and different benchmarks were used to construct these data then were used to construct the data for all manufacturing described in appendix 3.1. Hence our data for durables and nondurables manufacturing in the paper do not add up to our data for all manufacturing.

1. Inventories

Indexes of the value of end-of-month inventories, seasonally adjusted, are available from the *CBER* for both durables and nondurables. These indexes are not ideal. (See the discussion in appendix 3.1.) The indexes were converted into a series on the nominal value (in millions of dollars) of inventories by benchmarking the indexes in December 1937, using information in the *1937 Census of Manufactures*[1] (in particular, 2:121). The nominal value of inventories in the durables and

1. 1937 was chosen because this census was used by *CBER* to weight its indexes.

nondurables sectors was computed as the sum of the end-of-year inventories in the appropriate (see below) industries from the census. Note that this includes raw materials and hence is subject to the same problems as the basic total manufacturing series.

Durable Goods Industries	*Nondurable Goods Industries*
Forest products	Food
Stone, clay, glass	Textiles
Iron and steel	Paper
Nonferrous metals	Printing and publishing
Machinery	Chemicals
Transportation equipment	Petroleum and coal
Miscellaneous	Rubber products
	Leather products

This division was chosen so as to conform as closely as possible with the categorization used by the BEA on postwar data.

The nominal series were converted to real (1929) dollars using a (common) price index for total manufacturing. This index was described in appendix 3.1.

2. Shipments

The *CBER* data provide indexes of the value of shipments, monthly and seasonally adjusted, for both types of goods. A direct benchmark to convert this index number into dollars was not available. Instead, the 1937 Census of Manufactures was employed to derive an average value of shipments in 1937, which was equated with the average value of the index in 1937. To do so, it was necessary to assume that the identity

$$y_t = x_t + (n_{t+1} - n_t)$$

held in value terms for 1937. That is, the value of shipments for 1937 was estimated by:

value of shipments = value of production − value of end of year inventory + value of beginning of year inventory,

where data for the value of production and value of inventory are taken from the census.

Then the value of shipments series constructed in this manner was deflated using the total manufacturing price index, resulting in a series on real shipments for both durables and nondurables.

3. Production

Real production was computed using the shipments-inventory-production identity. A nominal series was computed by multiplying the real series by the total manufacturing price index.

4. A Check on Data Construction

Ideally, the sum of the data on, say, production for durables manufacturing and nondurables manufacturing should exactly match the data for total manufacturing. Because of the methods employed here, however, this is far from true. Below are mean values (in millions of 1929 dollars) of shipments, inventories, and production for both total manufacturing as derived above and the sum of durables and nondurables manufacturing as derived above and the sum of durables and nondurables manufacturing as derived for this paper.

	Total Manufacturing	*Sum of Durables plus Nondurables*	*Ratio*
Production	13,216.3	4,669.7	.392
Shipments	12,858.7	4,646.8	.392
Inventory	13,405.8	9,275.7	.713

However, though the levels differ substantially, the movements in the two measures of manufacturing behavior are closely related. Below are correlations between the two:

Production	.983
Shipments	.979
Inventory	.932

Thus, while estimates of the behavior of levels of manufacturing shipments, production, and inventory will vary depending upon which method is chosen, the overall response to business cycle conditions will likely be similar.

Appendix 3.3
Detrending Procedures

1. Whole Economy

Method Used in Text

We take Gordon's natural GNP series as the starting point, extending it to 1983 by assuming (as he did for 1981–82) a 3% natural growth rate. We then compute "natural final sales" as

$$X^T = \theta y^T,$$

where y^T is natural GNP and θ is the mean ratio of final sales to GNP over the period 1929–83 (excluding 1932 and 1933). Although the ratio is quite stable over time, these two years are obvious outliers and were removed for that reason. In practice it makes little difference; our computed θ is .994, and including 1932 and 1933 changes this only to .996.

The process is completed by computing natural inventory investment via the identity $y^T = x^T + \Delta N^T$. Using deviations from this series gives the variance decomposition in the text (reproduced in the top row of table 3.A.1.)

Alternative (Statistical) Trend

Here we simply fit the trend model

$$\log(z_t) = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + \epsilon_t$$

to each of GNP, final sales, and inventories, dropping the years 1930–39 and 1941–46 as aberrant. For reasons described in the text, this procedure is not entirely satisfactory. Nevertheless, the variance decomposition derived by detrending in this manner is shown for comparison in the second row of table 3.A.1.

2. Total Manufacturing

The method used in the text was method A, log-linear interpolation between 1929 and 1941. We also experimented with method B, log-linear interpolation using 1929 and 1940, and method C, log-linear trend line fitted to all months in 1929–41.

Table 3.A.1

	σ_y^2	σ_x^2	$\sigma_{\Delta N}^2$	Cov (x, ΔN)	σ_y^2/σ_x^2	$\sigma_x^2/\sigma_{\Delta N}^2$	Corr (x, ΔN)
Total economy (ECONOMIC)	1309.9	1210.4	20.9	43.2	1.082	57.9	.271
Total economy (STATISTICAL)	951.4	965.6	23.9	70.5	.985	40.4	.464
Manufacturing (Method A)	7.39	6.85	.084	.270	1.079	81.8	.250
Manufacturing (Method B)	10.35	9.73	.084	.371	1.063	116.1	.318
Manufacturing (Method C)	7.29	6.77	.084	.276	1.076	80.8	.259

Note: In billions of 1929 dollars for manufacturing and billions of 1972 dollars for total economy.

The variance decomposition for each type of detrending is shown in table 3.A.1.

Comment Moses Abramovitz

Blinder and Holtz-Eakin have given us a stimulating and useful paper. Besides developing new data, their survey confirms the existence of certain broad similarities in inventory behavior between prewar and postwar years. At the same time, their data and findings raise questions about both the observed relations between output and inventory investment and the adequacy of our working model of inventory behavior. My remarks are intended mainly to supplement the authors' argument and to suggest directions for future work.

The Variances of Production and Sales

Early in the paper, the authors make a calculation decomposing the variance of GNP in the years 1929–83 into the variances of final sales and inventory accumulation and the covariance of the two. They find that the variance of GNP is larger than that of final sales and, of course, that the covariance of inventory investment and final sales is positive. They point out that their finding "appears to contain bad news for the dominant empirical model of inventory behavior—the production smoothing/buffer stock model."

As the authors suggest, this finding is a generalization of what is already implicit in a familiar observation—that for the interwar years inventory investment rose and fell in perfect, synchronous conformity with business cycles, at least annually. But the authors' result has several virtues. It extends the finding to postwar years; it bases it on an analysis of monthly data; and it derives it from an analysis of data in all units of the entire period and not merely an analysis of cyclical troughs and peaks.

I think there is some interest in pointing out that the results represent a notable bit of continuity in business cycles work connected with the NBER. A finding with similar implications (but, of course, derived from much less satisfactory data) was made by Simon Kuznets in his second publication—his first in English. This was his Columbia University doctoral dissertation, prepared under Wesley Mitchell's supervision. It was published as *Cyclical Fluctuations: Retail and Wholesale Trade* in 1926, fifty-eight years ago. Here Kuznets found that retail

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sales, wholesale sales, and production in manufacturing moved together during business fluctuations, but the amplitude of wholesale sales was wider than that of retail sales and the amplitude of manufacturing production was wider than that of wholesale sales. By comparing sales and production of similar products at the three stages, Kuznets satisfied himself that the amplitude difference was due only in part to the presence of capital formation items that were produced at the manufacturers' level but that did not move through wholesale and retail trade channels.

Kuznets's explanation of the magnification of cyclical amplitude as one progresses from the consumer to the manufacturer was inventory investment. His model was derived from J. M. Clark's acceleration principle as published three years earlier in *The Economics of Overhead Costs*. Kuznets's adaptation of Clark to the inventory case, however, is exactly the stock adjustment model on which contemporary students rely. Purchases at any level are the sum of expected sales—assumed, by way of illustration, to be equal to last period's sales—plus desired inventory investment. Desired investment has two parts. One is a multiple of the change in expected sales, a multiple that reflects the desired inventory/sales ratio. The second is the amount needed to reverse last period's unintended investment. And unintended investment is the difference between actual sales last period and expected sales.

In developing his argument, Kuznets is fully conscious of the feedback from desired inventory investment to income and retail sales. Only the absence of a definite consumption function prevents him from taking the subject as far as Metzler and Nurkse eventually did in their well-known papers. In certain other respects, however, he went further than these writers, and further than most contemporary treatments go today. I want to return to that somewhat later.

Next—I go on to the question Blinder and Holtz-Eakin's paper poses: Why indeed do inventories serve to destabilize production rather than to stabilize it, as the micro theory of inventories would have it? A minor part of the answer lies in the technical lock between output and goods that are truly in the process of production or in the process of transportation. I believe that a major part of the answer, however, is connected with the fact that by far the greatest part of total stocks consists of inventories of firms who are the purchasers, not the producers, of the goods. They have an interest in supporting their own production or marketing activities, not in stabilizing their suppliers' operations. Since supporting their own activities—given their uncertainty about the delivery of supplies and about their own customers' requirements—usually means carrying larger, not smaller, stocks of purchased materials when the volume of sales or production is high, an expansion of sales is passed back to suppliers in earlier stages with magnified force.

Needless to say, that is no more than a partial answer. It assumes there are good reasons, still to be spelled out quantitatively, that explain why manufacturers' stocks of goods *for sale* do not move inversely with sufficient force and weight to protect their production fully from fluctuations in their sales or that explain why suppliers do not when business falls off, offer price concessions big enough to induce customers to build up rather than liquidate stocks. I do not have a tested answer, but I imagine many of us share the same hunch. Plant capacity is expensive to hold idle, but it has the virtue of flexibility. It permits a manufacturer to adapt the specifications of the goods he makes to the varied and changing technical requirements of customers or to the styles that may rule when the goods are finally to be sold. In that respect, excess plant capacity reduces risk. Inventories, on the other hand, carry the heavy risks associated with predetermining the characteristics of goods, whether in technical matters like chemical composition, speed, hardness, specialized function, and so on, or in matters of color, style, and fashion. And that is why it is only for inventories of durable staples made to stock that one finds the inverse behavior implied by the buffer stock model.

This judgment again is dependent on a set of institutional arrangements that makes fixed capital an overhead cost but permits most labor to remain a variable cost. If labor became more largely an overhead cost than it now is in this country, one might see changes in the kinds of goods produced and used that would make business safer for countercyclical inventory policy. It might be useful to see whether such changes have been taking place in Western Europe now that those countries have made it harder to lay off workers.

Comparisons between the Interwar and Postwar Periods

The Blinder/Holtz-Eakin variance analysis generally confirms earlier ideas that inventory investment fluctuations are positively associated with those of output and final sales.[1] Inventory investment has mostly acted to magnify the cyclical impact of sales movements on output rather than to cushion them. Nevertheless, the results of the variance analyses do present some features that call for comment.

In their analysis of the whole economy (annual data: 1929–41 vs. 1947–83), our authors find that the covariance between inventory investment and final sales and the correlation between these variables rise between the prewar and postwar periods. This finding is generally

1. In saying this, I disregard findings for periods including the World War II years when extreme pressures of demand on capacity constrained inventory accumulation in the face of rapidly rising output and even required some inventory liquidation.

consistent with the familiar notion that inventories have been more tightly controlled since the war and more sensitively adjusted to movements of sales. On the other hand, when they turn to an analysis of activity in manufacturing (monthly data 1929–41 vs. 1959–82), they find that the correlation coefficients between inventory investment and final sales, besides being much lower in both periods than they are for the whole economy, appear to decline between the prewar and postwar periods. The decline is small for total manufacturing, substantial for durables manufacturing (table 3.3).

Why these differences? Is it a difference between manufacturing and trade? A vagary of the methods of data estimation our authors had to resort to in order to build up their data for manufacturing? Or is it a quirk of monthly data? It does seem likely that the adjustment of inventories to sales would be quite rough from month to month and more nearly parallel over somewhat longer intervals. Experiments with quarterly and annual data would be revealing.

For both the whole economy and manufacturing, the ratio of the variance of inventory investment to the variance of final sales rises considerably between the prewar and postwar periods. For the whole economy, the increase is about 50% (1929–41 vs. 1947–83). For manufacturing the percentage increase in the ratio is about eight times as great.[2] The same questions arise.

What should we make of these numbers? Although Blinder and Holtz-Eakin point to an apparent increase in the variance of inventory investment, they conclude: "if we exclude the war years, a clear picture of continuity in the stylized facts emerges between prewar and postwar periods." They seem to refer mainly to the ratios between the variances of GNP and final sales and to the covariances (or correlations) between inventory investment and final sales. Their interpretation may be right. It is unfortunate, however, that data problems required them to confine their analyses to a prewar period running from 1929 to 1941 (or including the war years, to 1946). In that period, fluctuations of output and final sales were, of course, dominated by great contractions and expansions in fixed investment and consumer purchases. By contrast, postwar business cycles can be more nearly characterized as inventory cycles. On that account, it seems important to compare the postwar years with the predepression period, say 1919–29, when consumption and fixed investment were also more stable.

I have not followed our authors in making a variance analysis, and I confine my attention to comparisons between the postwar period and

2. The increase is concentrated in durables. For nondurables, the ratio rises by only 31%.

the 1920s in just one respect: the contributions of changes in inventory investment to the changes of GNP between cyclical peaks and troughs. There are two matters to consider:

1. Although the share of inventory investment in the postwar GNP *contractions* was larger than in 1919–29, as our authors say, its share in postwar GNP *expansions* was smaller. The average share in the four expansions of the 1920s was 43%. The average share in seven postwar expansions was under 10%.

2. Inventory investment and GNP reached cyclical troughs together (in annual data) both before the war and after. In expansions, however, there was a change. Inventory investment turned synchronously with GNP before the war.[3] After the war, however, there were repeated long and significant leads of inventory investment compared with GNP, which I shall describe presently.

We can make a first, somewhat superficial approach to the change in the inventory investment share of GNP fluctuations by considering the differences between the durations of prewar and postwar expansions. We expect the inventory investment share of GNP change to vary inversely with the duration of the cyclical phase. The underlying reason is that the change in the volume of inventory investment between expansion and contraction (or vice versa) will be strongly influenced by the interphase difference in the growth rate of GNP or final sales. But the change in GNP itself during a contraction or expansion will depend on both the average growth rate and the duration of the phase. On that account, we expect the inventory investment share to be larger in contractions than in expansions. It is a notable fact, however, that from the 1920s to the postwar period, contractions became shorter and expansions longer.[4] And these changes are consistent with the larger postwar inventory investment contribution to GNP contractions and its smaller postwar contribution to expansions.

The reduced postwar share of inventory investment in expansions, however, reflects more than the longer durations of those phases. In the postwar period, inventory investment often reached its peak level

3. That is not literally true. Total inventory investment reached a peak in 1925. The reference peak was 1926. The lead, however, was due entirely to stocks on the farms. Nonfarm inventory investment peaked in the reference peak year without exception.

4. The figures for the average durations of reference contractions and expansions run as follows:

	Durations (in months)			
	1919–29		*1948–82*	
Contractions	(3)	16.0	(8)	10.0
Expansions	(4)	19.5	(7)	45.9

Figures in parentheses are the number of phases.
Computed from the NBER Quarterly Reference Cycle Chronology.

long before GNP and declined a great deal before the reference cycle peak.[5] Measured between GNP turns, therefore, the contribution of inventory investment change to GNP change is reduced.

These are, in a sense, preliminary considerations. To push the matter further, we should ask why the durations of expansions and contractions changed the way they did and why inventory investment, which reached its peaks, as well as its troughs, more or less synchronously with GNP before the war, has tended to exhibit a long lead at cycle peaks in the postwar period. There are a number of possibilities, which may share responsibility for the outcome.

An obvious consideration is autonomous spending. Subject as it is to a rising trend, such spending tends to stretch out expansions even in the face of a decline of inventory investment, a decline that is itself induced by retardation in the rate of increase of final sales. Inventory investment then tends to turn ahead of total spending. Just the opposite happens in contractions. The general contraction is cut short by the rising trend of autonomous expenditures. The GNP trough is therefore brought closer to the low point in the rate of decline of output and thus to the trough of inventory investment. Autonomous spending was probably more important after the war than before. The increased importance of government outlays is the most obvious matter, but its effect may have been supported by larger elements of fixed capital formation sustained by confident anticipations of long-term growth and so rendered less responsive to short and mild contractions of current output.

Next there are lessons we can take from Ragnar Nurkse (1954). Both the inventory investment share in output changes and the duration of cyclical phases are under the combined influence of the marginal propensity to save and the trend of autonomous spending. Suppose we follow Nurkse and divide total spending into autonomous spending, inventory investment, and other income-induced spending. Then it emerges that if autonomous spending were a constant, the inventory investment share in GNP growth or decline would equal the marginal propensity to save, if that were constant. And that points to a reason the inventory investment share tends to be smaller in expansions than in contractions—the standard finding. The reason is that the Duesenberry/Modigliani ratchet effect makes the marginal propensity to save lower and the multiplier higher in the latter portions of expansions than it is in contractions (or during the initial recovery segment of expan-

5. Inventory investment turned down before GNP at five out of eight postwar turning points (annual data). There was one lead of three years, two leads of two years, and two of one year. On the average, inventory investment in the GNP peak years was only 61% as large as it was at its own specific cycle peaks. (Cf. Stanback 1962, who had already stressed this point in his early postwar study.)

sions). If we now allow for autonomous spending that follows a rising trend, than the difference between the inventory investment shares in expansions and contractions is made all the larger.[6]

Our main concern, however, lies in the prewar/postwar change of marginal spending propensities in contractions and expansions separately. For representative contractions in each period (I set aside the Great Depression), I suggest that the postwar marginal propensity to save out of GNP was probably higher than before the war. I am thinking about the postwar built-in stabilizers. If that is right, it would help explain the larger postwar contribution of inventory investment during contractions. It would also help explain the shorter duration of contractions. If the feedback from inventory investment to spending is weaker, it permits faster liquidation of unwanted stocks and therefore an earlier reversal of orders and production.

The situation for expansions is less clear. Built-in stabilizers act in expansions as well as contractions. On the other hand, the long and vigorous postwar expansions may have worked to lift people's expectations and so to have strengthened the responses of spending to income change as growth continued. If that is right, then by analogy with my contraction argument, we have a consideration that helps to explain both the reduced contribution of inventory investment to the postwar expansions of GNP and the longer duration of such expansions. And all these considerations, speculative as some of them may be, are strengthened if, as seems likely, the rising trend of autonomous spending was more pronounced after the war than before.

Finally, there is a question about the proper lag structure in a model of inventory investment. It bears on the observed postwar leads of inventory investment before the upper turning points of GNP. We know

6. Nurkse employs a simple Keynesian model. Adapting and simplifying his notation, we may write the value of realized inventory investment (ΔN) at the peaks and troughs of GNP (or indeed in any period) as follows:

$$\Delta N_p = (1 - c)\, Y_p - Z_p$$
$$\Delta N_t = (1 - c)\, Y_t - Z_t,$$

where c is the marginal propensity to spend, Z is autonomous spending, and p and t are indexes for peaks and troughs. Subtracting values for troughs from those for following peaks and expressing the change in ΔN as a ratio to the change in Y gives us (for expansions):

$$\frac{\Delta N_p - N_t}{Y_p - Y_t} = (1 - c) - \frac{Z_p - Z_t}{Y_p - Y_t}.$$

If autonomous spending is constant, the last term disappears. The inventory investment share equals the marginal propensity to save. And (remembering to subtract peaks from following troughs) the same is true for contractions. Allowing for a rising trend in Z makes the inventory investment share smaller than $(1 - c)$ in expansions and larger than $(1 - c)$ in contractions.

that in stock adjustment models the existence and importance of unintended inventory investment arise from the presumption that the lag of planned output behind final sales is longer than the lag of final sales behind income. And Metzler and Nurkse have taught us that given a relatively long output lag, it is the rise of unintended investment as the growth rate of sales declines that keeps total realized investment increasing after planned investment begins to fall. In a pure inventory cycle, this ensures that inventory investment and GNP reach cyclical turns together. But if the output lag is short relative to the expenditure lag, unintended investment disappears. On the other hand, as Nurkse shows, output continues to increase after planned investment turns down because of the lag of expenditures—and therefore of output to meet sales—behind income produced (1954, 219–20). Realized inventory investment then tends to lead turns of output.

Nurkse (1954) and others—for example, Ackley (1951) and Metzler (1947)—have argued persuasively that the output lag is longer than the expenditure lag. There *is* unintended investment. What we do not know—at least I do not know—is whether there has been a change in the relative size of these lags that might make unintended investment less important and might enter, together with other factors, into an explanation for the current long leads of inventory investment ahead of the postwar peaks of GNP.

These comments suggest several considerations likely to be useful in the continuing work on inventory investment and business cycles:

1. The possible importance of changes in the composition of inventory holdings in explaining changes in the behavior of the aggregate. The differences, noted above, between durables and nondurables manufacturing in the relations of inventory investment and final sales are suggestive. So are the differences between inventory investment in manufacturing and in the whole economy (tables 3.2 and 3.3).

2. The need to distinguish between contractions and expansions—because of interphase differences in the marginal propensity to spend; because of the differential impact of autonomous expenditure; and because inventory responses to income change may be different in expansions and contractions.

3. The need to consider the comparative durations of output and expenditure lags because of what these mean for unintended investment and for the roles of inventory investment and other spending near turning points. Here again there may be differences between expansions and contractions.

The Stock Adjustment Model

I turn now to Blinder and Holtz-Eakin's attempt to compare the prewar and postwar behavior of inventory investment in terms of the stock adjustment model familiar in comtemporary studies. Their estimates of the coefficients of the model appear to replicate the unsatisfactory outcome of earlier work and to show that the defects characteristic of work with postwar data also emerge in estimates based on their own new prewar data. I cannot add anything substantive to their findings, but I think it useful to raise a question that bears on the structure of a satisfactory model. I can do little more than indicate the nature of the problem.

The standard stock adjustment models are usually, perhaps uniformly, evaluated empirically on the presumption that the coefficients on the various elements of inventory change are cyclically stable. There are three coefficients to consider:

The desired ratio of inventories to expected sales.

The rate at which firms try to reduce the difference between desired and actual stocks.

The relation between unintended investment and firms' misjudgment of sales.

Each of these relations, however, is influenced by supply conditions—by what is usually called "vendor performance" and "expected vendor performance." Such performance varies with the state of business, and one only has to look at each month's report of the survey of purchasing agents to see the interest such agents take in the changing state of vendor performance. When capacity utilization rises, delivery periods begin to lengthen and to become less assured. Firms then want to hold larger stocks to support an expected volume of sales. When supply conditions become still tighter, there are more vigorous efforts to meet their higher stock objectives and to correct inventory deficiencies. Orders are placed further ahead and in larger volume than would be required to meet objectives if firms were confident that everything ordered would be actually delivered or accepted. In spite of magnified orders, firms may be disappointed by deliveries. The unintended investment equation changes. Unintended investment is no longer correctly portrayed as the difference between actual and expected sales. There must be an allowance for a difference between deliveries and orders.

It is in this respect that Kuznets's early book went further than Metzler did and perhaps further than many contemporary studies go. He tried to take account, at least in a verbal treatment, of the effect of changing supply conditions. And as we all know, Ruth Mack seized on the same idea and developed it both theoretically and empirically in her 1956 study *Consumption and Business Cycles*. And then Mack and Victor Zarnowitz carried it still further (Mack and Zarnowitz 1958; Zarnowitz 1961). Perhaps I am raising issues here that adequate tests already show are of little significance. I suspect, however, that we shall have to return to the themes and problems of these earlier NBER studies if we are to get a good understanding of the changing role of inventories in business cycles.

Comment Bennett T. McCallum

Introduction

In its original conference version, the paper by Blinder and Holtz-Eakin filled me with enthusiasm, for what a discussant likes most in a paper is something of significance with which he can wholeheartedly disagree. Now the most objectionable portion of the paper—a genuine, full-fledged Keynesian multiplier model of the business cycle[1]—has been deleted, taking with it a substantial part of my discussion. In addition, other arguments have been modified and the language has been adjusted in several ways. Nevertheless, there are a few items remaining that call for qualification or partial disagreement. In all cases, it should be said, my objections are directed not at the explicit conclusions of section 3.5, but at statements and suggestions that are scattered through the body of the paper. My remarks presume, furthermore, that the basic rationale for the study is the possibility of shedding light on macroeconomic fluctuations, not the analysis of inventory behavior per se.

There is little possibility for disagreement in sections 3.1 and 3.2, which include (respectively) a short introduction and a tabulation showing that the peak-to-trough declines in inventory investment are nearly as large as those for GNP itself in both postwar and prewar business cycles. But I would like to emphasize the restrictive nature of the authors' statement that "there is really no hope of understanding the dynamics of recessions without analyzing inventory behavior." It is indeed likely that good models of inventory fluctuations are needed to account for the details of month-to-month or quarter-to-quarter movements in aggregate output. But such models may nevertheless be unnecessary for understanding business cycles in the sense of knowing

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1. The inclusion of this model provided a contribution, in a sense, by serving as a reminder of what hard-core Keynesian macroeconomics was actually like. The model implied, for example, that real GNP could be controlled (subject to random errors) by manipulation of real government purchases, with a steady state multiplier of 4.5.

what are the sources of the initiating shocks and why—in the case of monetary shocks—they have (apparently) major effects on real aggregates. Nor is it clear that such knowledge is crucial to learning whether the nature of recessions is such that activist demand management would be socially beneficial.

Variance Decompositions and Prevailing Theory

In section 3.3, the first of those that constitute the heart of the paper, Blinder and Holtz-Eakin present a large quantity of data concerning the variability of production, sales, and inventory changes. The discussion begins with the identity

$$y_t = x_t + \Delta n_t, \tag{1}$$

where y_t is production and x_t the quantity of sales during period t, with n_t denoting the inventory stock at the end of period t and $\Delta n_t = n_t - n_{t-1}$. The variance of production is then decomposed as

$$\text{var}(y) = \text{var}(x) + \text{var}(\Delta n) + 2\text{cov}(x,\Delta n) \tag{2}$$

where var(.) and cov(.,.) denote variance and covariance magnitudes for the indicated series. Throughout, this decomposition is applied to *detrended* versions of the basic variables. Since one of the subperiods examined is 1929–46, the authors have some difficulty in deciding how to detrend. Accordingly, they experiment with different methods and report only figures that are reasonably insensitive to the method utilized. This strategy is commendable, but the discussion would be improved by some explicit recognition of the reason detrending is desired. Apparently their reason has only to do with the concept of "fluctuations" they have in mind rather than a desire to obtain series that could be viewed as resulting from covariance stationary stochastic processes.[2]

In their table 3.2, Blinder and Holtz-Eakin report sample variances pertaining to the decomposition (2) using annual GNP data. For postwar, prewar, and combined sample periods they find that var(y) exceeds var(x) and that cov(x,Δn) is nonnegative. These inequalities also hold, they show in table 3.3, if one uses monthly rather than annual data for total manufacturing and its two main subdivisions (i.e., durable and nondurable products). This finding reinforces similar ones previously reported by Blinder (1981a, 1984) for various postwar data sets and suggests that $\text{var}(y) > \text{var}(x)$ and $\text{cov}(x,\Delta n) \geqslant 0$ should be regarded as empirical regularities that a satisfactory theory must accommodate. This demonstration is quite useful, as is their construction and reporting of monthly series for y, x, and n during the prewar period.

2. There seems to be, in other words, no concern for issues of the type discussed by Plosser and Schwert 1978.

The authors go on, however, to suggest that these two empirical regularities "seem to cast doubt on the major prevailing theory of inventory behavior." Elsewhere, Blinder has stated that "these facts add up to a stunning indictment of the production smoothing/buffer stock model" (1984, 4). Now, to evaluate these statements we have to specify what model or models they refer to. But there appears to be ample reason to say that "the prevailing theory" is well represented by the models utilized in Blinder (1981a) and Blinder and Fischer (1981)—which are essentially the same as those in Brennan (1959), Muth (1961), McCallum (1972), and many other papers. That Blinder himself shares this judgment is evidenced by section 3 of his 1984 paper, in which he considers the issue within precisely this framework.[3] Let us, then, consider whether this "standard prevailing" model is inconsistent with the findings $\text{var}(y) > \text{var}(x)$ and $\text{cov}(x,\Delta n) \geqslant 0$.

The model in question pertains to a monopolistic firm[4] that at t chooses sequences of x_t, y_t, and n_t values to maximize the objective function

$$E_t \sum_{j=0}^{\infty} (1 + r)^{-j} [R(x_{t+j}, v_{t+j}) - C(y_{t+j}, u_{t+j}) - B(n_{t+j-1})] \tag{3}$$

subject to the sequence of constraints

$$y_{t+j} + n_{t+j-1} - x_{t+j} - n_{t+j} = 0, \qquad j = 0,1,2, \ldots \tag{4}$$

Taking the disturbance processes $\{u_t\}$ and $\{v_t\}$ to be white noise and pretending that certainty-equivalence prevails, we obtain first-order conditions that for $j = 0$ we write as

$$R_1(x_t, v_t) - \lambda_t = 0 \tag{5}$$

$$-C_1(y_t, u_t) + \lambda_t = 0 \tag{6}$$

$$-B'(n_t) - (1 + r)\lambda_t + E_t\lambda_{t+1} = 0 \tag{7}$$

$$y_t + n_{t-1} - x_t - n_t = 0, \tag{8}$$

where λ_t is of course the relevant Lagrange multiplier.

3. It should be noted that a slightly (but crucially) more general framework—involving a more general specification of the firm's cost structure—was proposed in a managerial-economics context by Holt et al. 1960. The most satisfactory empirical studies I am familiar with, namely, those of Blanchard 1983 and Eichenbaum 1984, provide results that indicate these generalizations are important. That does not contradict the argument to be developed in the remainder of the present section, which is adapted from McCallum 1981.

4. Eichenbaum 1983 has shown that it is not necessary to give the firm monopoly power, as several analysts have claimed, but doing so simplifies the present discussion.

To render these expressions operational, let us suppose that the R, C, and B functions are quadratic. Then (5), (6), and (7) can be written as

$$(5') \quad a_1 + a_2x_t + v_t = \lambda_t \qquad a_2 < 0$$
$$(6') \quad c_1 + c_2y_t + u_t = \lambda_t \qquad c_2 > 0$$
$$(7') \quad b_1 + b_2n_t + (1 + r)\lambda_t = E_t\lambda_{t+1}. \qquad b_2 > 0$$

Reduced-form "solution" equations will then be of the form

$$(9) \quad y_t = \pi_{10} + \pi_{11}n_{t-1} + \pi_{12}u_t + \pi_{13}v_t$$

$$(10) \quad x_t = \pi_{20} + \pi_{21}n_{t-1} + \pi_{22}u_t + \pi_{23}v_t$$

$$(11) \quad n_t = \pi_{30} + \pi_{31}n_{t-1} + \pi_{32}u_t + \pi_{33}v_t$$

$$(12) \quad \lambda_t = \pi_{40} + \pi_{41}n_{t-1} + \pi_{42}u_t + \pi_{43}v_t,$$

and the π values can be found by the familiar undetermined coefficients procedure. The only complication involved is that there are two possible sets of solutions, these arising because π_{31} is found from a quadratic equation. The approach developed in McCallum (1983) can be used, however, to pick out the unique bubble-free solution.

To avoid entanglement in tedious algebraic expressions, let us consider a numerical example that will suffice to make the relevant point. In particular, suppose that $a_2 = -1.0$, $b_2 = 0.1$, $c_2 = 0.1$, and $r = 0.01$. Then simple calculations reveal that production, sales, and inventory stocks obey

$$(13) \quad \begin{aligned} y_t &= -.574n_{t-1} - 4.26u_t + .574v_t \\ x_t &= .057n_{t-1} - .574u_t + .943v_t \\ n_t &= .368n_{t-1} - 3.68u_t - .368v_t, \end{aligned}$$

where constant terms are ignored. Furthermore, let us suppose that the variances of u_t and v_t are equal in magnitude, and in particular that $\sigma_u^2 = \sigma_v^2 = 1.0$. Also, suppose that $E(u_tv_t) = 0$. Then it is easily found that

$$(14) \quad \mathrm{var}(y_t) = 23.7, \ \mathrm{var}(x_t) = 1.27, \ \mathrm{var}(n_t) = 15.8.$$

But these values demonstrate that the model at hand—the "prevailing" model—is consistent with much larger fluctuations in production than in sales. In addition, the example yields $\mathrm{cov}(x_t,\Delta n_t) = 1.72$ and thus also shows that the model under consideration does not imply a negative correlation between sales and inventory change. Thus the two empirical regularities stressed by Blinder and Holtz-Eakin may in some sense spell bad news for "buffer stock" or "production smoothing" *notions*, but they do not discredit the prevailing model in any fundamental way. That they appear to do so in the early parts of Blinder (1984) is because the analysis there proceeds under the assumption that supply-side shocks are nonexistent.[5]

We now ask if this conclusion continues to hold if one modifies the foregoing model in the ways that the Blanchard (1983) and Eichenbaum (1984) results suggest. The first of these is to add to the firm's objective function a term that reflects costs of *changing* production rates, namely, $0.5c_3(y_{t+j} - y_{t+j-1})^2$ with $c_3 > 0$. The second is to replace the inventory cost function implied by (7′), which is $b_0 + b_1 n_{t+j-1} + 0.5 b_2 n^2_{t+j-1}$, with one of the form $0.5\, b_3(n_{t+j-1} - n^*_{t+j-1})^2$, where the "desired" or "target" level n^*_{t+j-1} depends upon the rate of sales in period $t + j$, $n^*_{t+j-1} = \alpha x_{t+j}$.[6] With those two changes in specification, the relevant set of first-order optimality conditions for the firm becomes

$$(5'') \qquad a_1 + a_2 x_t + \alpha b_3(n_{t-1} - \alpha x_t) + v_t = \lambda_t$$

$$(6'') \qquad c_1 + c_2 y_t + c_3(y_t - y_{t-1}) + u_t = \lambda_t$$

$$(7'') \qquad b_3(n_t - \alpha E_t x_{t+1}) + (1 + r)\lambda_t = E_t \lambda_{t+1}$$

plus the constraint (8), which we for convenience also refer to as (8″).

$$(8'') \qquad y_t + n_{t-1} - x_t - n_t = 0.$$

But from these conditions we see that the previous system can be regarded as a special case of this one, the special case that obtains as c_3 and α approach zero. So at the present level of analysis the two empirical regularities do not suffice to contradict this model either.

The foregoing does not, it might be added, constitute a claim that either of the two models under discussion is in fact thoroughly satisfactory. But to discredit them apparently requires more evidence than is provided by the findings that $\text{var}(y) > \text{var}(x)$ and $\text{cov}(x,\Delta n) \geq 0$.

Estimates of Stock Adjustment Speeds

In their section 3.4, Blinder and Holtz-Eakin characterize some features of the relation between inventories and sales by reporting estimates of the "stock adjustment" model that has been prominent in

5. This is recognized in a later section of Blinder 1984, which also shows that nontransitory components in the demand disturbance v_t will tend to increase the ratio of $\text{var}(y)$ to $\text{var}(x)$.

6. There is a related possibility, namely, that $n^*_{t+j-1} = \alpha E_{t+j-1} x_{t+j}$. This specification leads to equations (6″) and (7″) below but implies that (5′) prevails instead of (5″). The difference between this specification and the one in the body of the paper appears to correspond to the difference between "precautionary" and "transaction" motives for holding inventories. Blanchard 1983, 378, uses the latter specification but offers a rationalization that seems more applicable to the former. That he—like Eichenbaum—avoids the "precautionary" specification may reflect recognition that it implies dynamic inconsistency on the part of the firm.

empirical work on inventory movements.[7] In my notation, this model focuses on the adjustment relation

$$(15) \qquad n_t - n_{t-1} = b(n_t^* - n_{t-1}) - c(x_t - {}_{t-1}x_t) + \eta_t,$$

where n_t^* is the stock of inventories "desired" at the end of t and where ${}_{t-1}x_t$ is the value of sales during t anticipated at the end of $t - 1$. An essential component of this model is, of course, the specification of n_t^*. The ones utilized by Blinder and Holtz-Eakin are variants of

$$(16) \qquad n_t^* = \alpha_0 + \alpha_1 \, {}_{t-1}x_{t+1}.$$

In addition, hypotheses concerning expectation formation and the generation of x_t are needed to complete the system. The authors assume that expectations are rational, that is, that ${}_{t-1}x_t = E_{t-1}x_t$, and that x_t is generated by a second-order autoregression process[8] that is exogenous to n_t:

$$(17) \qquad x_t = \emptyset_1 x_{t-1} + \emptyset_2 x_{t-2} + \zeta_t.$$

Prewar, postwar, and full-period estimates of this system are reported by Blinder and Holtz-Eakin based on annual aggregate data and monthly data for manufacturing and its two major subdivisions. In all cases the results conform to the usual finding[9] that the estimated adjustment speed, represented by b, is implausibly low. In several cases, furthermore, the estimated values of c are negative and thus inconsistent with the theoretical presumptions of the model.

One possible reaction to this "empirical regularity" is to claim that the stock adjustment model is without rigorous theoretical content and so the findings should be of little or no interest. In my opinion it would be wrong to take that line, for the reduced-form equation (11), obtained above from a coherent theory, can obviously be expressed in stock adjustment form, with $1 - b = \pi_{31}$ and with $n_t^* = \alpha_0 + \alpha_1 E_{t-1}x_{t+1} = \alpha_0 + \alpha_1[\pi_{20} + \pi_{21}(\pi_{30} + \pi_{31}n_{t-1})]$. Instead, attention should be directed toward understanding what it is that the estimates are saying in terms of the models described above.

My attempt to do this will proceed in terms of the Blanchard/Eichenbaum specification summarized above in equations (5″) to (8″). To simplify the exposition, suppose that c_2 and c_3 are small enough that we will not be misled if we approximate λ_t as $c_1 + u_t$. Putting that expression in (5″) and rearranging gives

7. The model is usually attributed to Lovell 1961. For a sizable number of references to other applications, see Feldstein and Auerbach 1976, 352–53.

8. In the cases using monthly data, the autoregression is of order 12.

9. This finding gained prominence from the study of Feldstein and Auerbach 1976. It had been noted earlier by Orr 1967 and by Carlson and Wehrs 1974.

(18) $$x_t = \emptyset^{-1}[c_1 - a_1 - \alpha b n_{t-1} + u_t - v_t],$$

where $\emptyset = a_2 - \alpha^2 b_3 < 0$, while doing the same for (7″) yields

(19) $$b_3 n_t - \alpha b_3 E_t x_{t+1} + (1 + r)(c_1 + u_t) = c_1 + E_t u_{t+1}.$$

But from (18) we can find $E_t x_{t+1}$; substitution in (19) then yields an equation that relates n_t to u_t, $E_t u_{t+1}$, and $E_t v_{t+1}$:

(20) $$(b_3 + \alpha^2 b_3^2 \emptyset^{-1}) n_t = (1 + \alpha b_3 \emptyset^{-1}) E_t u_{t+1} - \alpha b_3 \emptyset^{-1} E_t v_{t+1} - (1 + r) u_t + \text{const.}$$

Now suppose that u_t is not white noise but is instead first-order autoregressive:

(21) $$u_t = \rho u_{t-1} + e_t, \qquad e_t \text{ white noise.}$$

Then (20) can be put in the form

(22) $$n_t = \zeta_0 + \zeta_1 u_t,$$

where ζ_0 and ζ_1 are composite parameters involving $\alpha, b_3, \emptyset$, and ρ. In terms of the white noise disturbance e_t this can be written as

(23) $$n_t = \rho n_{t-1} + \zeta_0(1 - \rho) + \zeta_1 e_t.$$

But the coefficient on n_{t-1} in this equation corresponds to $1 - b$ in the stock adjustment expression (15). Consequently, if this model is a good approximation to reality, the estimates usually interpreted as adjustment-speed parameters will actually be estimates of $1 - \rho$. Thus the finding that these estimates are close to zero may simply be a finding that shocks to technology—supply shocks—are highly serially correlated; that the process generating these shocks is close to a random walk.[10] Thinking about the nature of technological progress, and other cost shocks, that seems to me a highly plausible interpretation.

Now most of the estimates reported by Blinder and Holtz-Eakin in their tables 3.4 to 3.7 utilize a Cochrane/Orcutt correction designed to take account of first-order autoregression disturbances, and the same is true for stock adjustment estimates reported in Blinder (1984, table 4) for various two-digit industries (monthly postwar data). For the most part these estimates continue to suggest that reaction speeds (b values) are very low even when the existence of autoregression disturbances is taken into account.

Interestingly, though, Blinder (1984, 34) mentions that:

> in several cases, two local minima of the sum of squared residuals function were found. In such cases, one of the minima always had

10. Blinder has himself pointed out this possibility in a nice discussion that is less complicated than mine, but also less theoretically explicit (1984, 33–34).

> high ρ and rapid adjustment while the other had low ρ and slow adjustment. . . . This point is important because the extremely high adjustment speeds recently found by Maccini and Rosanna (1984) result from an estimation technique that, I [i.e., Blinder] believe, settles on the local minimum with high ρ. The estimation method used here [i.e., Blinder 1984] typically shows that the low ρ solution is the global maximum.

What this discussion—together with the Maccini/Rosanna results—indicates is that the data can be "explained" either by slow adjustment speeds in combination with low ρ values *or* by fast adjustment speeds in combination with large ρ values.[11] Blinder's case for the first combination relies on the empirical finding that it fits the data slightly better than the second combination, and that the Maccini/Rosanna estimates are obtained by an inappropriate estimation technique.[12]

But reflection upon the nature of the estimation problem suggests that Blinder (1984) and the present authors are at least as guilty as Maccini and Rosanna of using inappropriate estimators. In particular, Blinder's procedure involves a serial correlation "correction" applied after inserting fitted values from an autoregression on x_t to "proxy" for rationally anticipated sales (Blinder 1984, 32). But that is precisely the sort of procedure that involves the "pitfall" described by Flood and Garber (1980),[13] so Blinder's and the present authors' estimators are inconsistent, and their sums of squared residuals are consequently unreliable indicators of which ρ, b combination provides a better fit to the data.[14]

Furthermore, the instrumental variable procedure used by Maccini and Rosanna (1984) bears some resemblance to the one developed in McCallum (1979, 67–68), which is designed to be consistent in situations with autoregression disturbances. In particular, the Maccini/Rosanna procedure first estimates by instrumental variables[15] an equation in which the residual is serially correlated, then uses the residuals from that equation to estimate the serial correlation parameter. I do not believe that their procedure is actually appropriate, for they treat as

11. See Blinder 1984, 33–34. Also note the first column of Blinder and Holtz-Eakin's table 3.5.

12. This claim is cited by Blinder and Holtz-Eakin, note 11.

13. The point is also discussed in McCallum 1979, 68.

14. This statement presumes that the econometrician possesses fewer data than the agents whose behavior is being modeled. In that situation, use of "full information" (i.e., simultaneous estimation) econometric techniques will not escape the problems discussed in McCallum 1979. With sales treated as exogenous, it seems clear that this situation obtains in both of the studies under discussion.

15. With the instruments created by regressions on lagged values of (supposedly) exogenous variables.

exogenous variables that the theory says are jointly dependent, but it does not seem less appropriate than Blinder's.[16]

In short, I would conjecture that the data are trying to tell us that, in a representation of the form

$$n_t - n_{t-1} = b[n_t^* - n_{t-1}] + (1 - \rho L)^{-1}e_t, \tag{24}$$

both b and ρ are very close to 1.0. Adjustment is essentially complete within each period, even when these refer to monthly observations.

To complete the discussion, something needs to be said about the tendency for estimates of c in expression (15) to be negative. A likely reason for this finding is that it is unreasonable—and inconsistent with the prevailing theory described above—to treat x_t (sales) as exogenous to n_t. The point is that if x_t is in fact jointly determined with n_t, then it will be almost impossible to *identify* the parameter attached to the "surprise" term $x_t - E_{t-1}x_t$. Several writers have made analogous arguments in the course of debates over the nature of aggregate supply behavior; for a more general but technically elementary treatment see McCallum (1979, 68).

Conclusion

In sum, there are several ways Blinder and Holtz-Eakin's paper makes a useful contribution. One of these, clearly, is by compiling and reporting monthly data on manufacturing sales, output, and inventories for the prewar period. Another is by cataloging some empirical regularities and providing prewar/postwar comparisons for several series. But the paper's main *analytical* suggestions seem to be that the empirical regularity var(y) > var(x) serves to discredit prevailing inventory theories[17] and that econometric evidence implies very slow adjustment speeds for stock adjustment models. For the reasons developed above, I think both these suggestions should be viewed with considerable skepticism.

Reply

Alan S. Blinder and Douglas Holtz-Eakin

The reader of Bennett McCallum's comment may be puzzled because most of the items at which McCallum directs his fire are neither said

16. My interpretation of these results is consistent with Eichenbaum's (1984) finding of strong serial correlation in his inventory cost disturbance $\psi(t)$. He also found two local minima (i.e., likelihood function maxima) with high and low values of the serial correlation parameter, but his maximum likelihood procedure settled on the former.

17. This suggestion has been substantially qualified in the published version.

nor done in the paper he is allegedly discussing. In part this is because the two of us took his criticisms of our original draft to heart and revised the paper substantially. Rather than being flattered by this, McCallum appears chagrined that we have deprived him of target practice. That is a shame, but we thought intellectual exchange was the purpose of a conference.

Nonetheless, at least two points need rebuttal. The primary disagreement is over the nature of the major prevailing inventory theory—the production smoothing/buffer stock model. McCallum seems to view it as a model in which it is quite plausible that cost shocks dominate, leading production to be more variable than sales. This is a strange interpretation of a model that was designed to highlight the way production is smoothed in the face of demand shocks. It is, after all, pretty clear that supply shocks tend to make supply more variable than demand, while demand shocks tend to make demand more variable than supply. As we noted in note 8, his choice of numerical values makes cost shocks dominate all the variances and covariances. While it is true (see the text p. 189 and notes 10 and 12) that the empirical findings (production is more variable than sales, slow adjustment speeds, etc.) do not literally lead one to reject the theory, they do suggest that there is a problem. (The major points in this debate were all anticipated in Blinder 1984, as evidenced by McCallum's numerous references to it.)

McCallum's interpretation of the estimated adjustment speed leaves something to be desired as well. To analyze this parameter using his model, he assumes that "c_2 and c_3 are small" (despite earlier claims that costs of changing production rates (c_3) are too important to be ignored). In doing so, he creates a linear cost structure in which there is no incentive for either production smoothing or partial adjustment. As evidence of this, notice that lagged inventories do not appear in his equation (22); they show up in his equation (23) only after quasi-differencing to eliminate serial correlation in the disturbance term.

Our final remark concerns the methods used to estimate the stock adjustment models. McCallum takes Blinder (1984) to task for not following econometric procedures recommended in McCallum (1979), even though McCallum (1979, 68) notes that these procedures are unlikely to work in an equation containing both x_t and x^e_t. The reader should realize that the full-information procedure used in the present paper jointly estimates expectations formation, serial correlation, and the parameters of the model. It avoids, therefore, the Flood/Garber problem resulting from the use of separately fitted residuals. Any problems that remain are shared by much of the empirical literature using rational expectations (for example Sargent 1978). Although McCallum *asserts* a preference for the "high ρ rapid adjustment" estimate, we have in fact examined the likelihood functions and found that the "low ρ slow adjustment" estimate achieves a higher value in most cases—sometimes by a narrow margin, to be sure, but sometimes by quite a large margin. We prefer to let the data, not our priors, decide the issue.

Discussion Summary

Some of the discussion was directed to the absence of an interest rate variable in the conference version of the paper, and these suggestions led the authors to include the interest rate in table 3.5 in the final version. Among those suggesting that the interest rate variable be tested were Michael Lovell and Benjamin Friedman. Stanley Fischer pointed out that the fact that interest rate effects had not been detected until recently was consistent with the limited variation of real interest rates in much of the postwar era, when as the Eckstein/Sinai paper describes, financial disturbances influenced the real economy via credit rationing, not interest rate variation. Recent fluctuations in real interest rates, however, may well have caused inventory fluctuations. Fischer was also concerned that the data used for the prewar period may have been subject to considerable, possibly nonrandom, measurement errors.

Alan Auerbach drew attention to the model's inability to distinguish empirically between serial correlation and the partial adjustment coefficient estimated. He felt that this "weak identifiability" was a serious drawback in interpreting the results. Robert Barro questioned how much of the variation in inventories was for goods in progress and how much was in final goods inventories, and Moses Abramovitz stated that for individual firms, almost all inventory variation was in final sales, whereas for industry as a whole the variation was in work in progress. Barro continued that table 3.1 overstated the role of inventories by tabulating changes in inventories with respect to GNP, not relative to normal inventories.

Alan Blinder agreed that it was difficult to distinguish serial correlation from partial adjustment and that this was a serious drawback to the stock adjustment model. But, he added, there are some industrial sectors in which such a distinction is possible. He also noted that for the whole economy, most of the variation in postwar inventories was in finished goods, not work in progress. In manufacturing, work in progress and finished goods are roughly of equal importance. Unfortunately, there are no data for the interwar period to distinguish among the types of inventories.

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