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INVENTORY FLUCTUATIONS IN THE UNITED STATES SINCE 1929

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ABSTRACT

It has been known for a long time that inventory fluctuations are of great importance in business cycles. But inventory fluctuations are fundamentally a short-period phenomenon. 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, durable manufacturing, and nondurable manufacturing. To our knowledge, these are the first such series ever made available. (The data are available on request.) Second, we apply to the prewar data certain statistical procedures and models that are in common use with postwar data. In this way, we can address the central issue of the paper: Has inventory behavior 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. But the relevant stylized facts and regressing are displayed below, and each reader can make up his or her own mind.

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INVENTORY FLUCTUATIONS IN THE UNITED STATES SINCE 1929

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I. INTRODUCTION

Inventory fluctuations are of great importance in business cycles. Indeed, to a surprisingly large extent, business cycles <u>are</u> 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's 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, durable manufacturing, and nondurable manufacturing. To our knowledge, these are the first such series ever made available. We offer these data in the data appendix to this volume in the hope that others will find them useful. Second, we apply to the prewar data certain statistical 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, the degree of similarity was surprising to us. 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 II documents the dominant role of inventories in recessions. Here the facts are fairly well known. Section III investigates some less well-known aspects of the variances of production, sales, and inventory investment which one of us (Blinder (1981, 1984)) has recently emphasized using postwar data. In Section IV, stock-adjustment models similar to those popularized by Lovell (1961) are fit to data covering 1929-1983 and subperiods. At least qualitatively, the results are rather similar in the prewar and postwar periods. Section V is a brief conclusion.

II. INVENTORIES IN RECESSIONS

In a previous paper (Blinder (1981)), one of us documented the dominant role of inventory swings in cyclical contractions. The data presented there are repeated and extended in Table 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 "mini-recession" 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 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.

TABLE 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 a percentage of change in real GNP	Change in inventory investment as a percentage of GNP gap at trough[b]
A. Postwar recessions (peak and trough)[c]				
1948:4-1949:4	-7.1	-13.0	183	71
1953:2-1954:2	-20.2	-9.2	46	90
1957:3-1958:1	-23.0	-10.5	46	41
1960:1-1960:4	-8.6	-18.0	209	68
1969:3-1970:4	-7.3	-12.3	168	60
1973:4-1975:1	-60.7	-38.0	63	52
1980:1-1980:2	-35.0	-1.6	5	3
1981:3-1982:4	-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]

TABLE 1 (continued)

1953-1954	-7.5	-3.7	49	71
1957-1958	-2.9	-3.3	114	14
1969-1970	-2.0	-7.3	365	365
1973-1975	-22.7	-23.9	105	37
1979-1980	-4.4	-11.7	266	23
1981-1982	-28.4	-17.9	63	13

Source: Postwar data are from the national income and product accounts; interwar data are adapted from Moses Abramovitz, Inventories and Business Cycles (National Bureau of Economic Research, 1950), table 84, pp. 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.

(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 durable 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 durable and nondurable 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, however, 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 (1981).

III. 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.

A. 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:

$$(3.1) \quad Y_t = X_t + \Delta N_t$$

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

$$(3.2) \quad var(y) = var(x) + var(\Delta n) + 2cov(x,\Delta n),$$

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

Estimates of the elements of (3.2) 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 farther, or to be more precise, a serious data problem must be confronted. The period from 1929 to 1946 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 (3.2), 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 (3.1) on a constant, time, and time squared -- omitting the years 1930-1939 and 1941-1946 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 (3.1) does not add up in the detrended data, and so (3.2) does not hold exactly. This discrepancy never amounted to much in previous work on postwar data by Blinder (1981, 1984). But, in this application, the lefthand side of (3.2) turned out to be 16% smaller than the righthand 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 C.)

Table 2 shows the elements of equation (3.2), plus some related statistics, for the whole period and for several subperiods. Several dramatic differences between the 1947-1983 and 1929-1946 periods 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

TABLE 2

DECOMPOSITION OF THE VARIANCE OF REAL GNP

(annual data, in billions of 1972 dollars)

Period	(1) var(y)	(2) var(x)	(3) var(Δn)	(4) 2cov(x,Δn) (corr(x,Δn))	(5) var(y)/var(x)	(6) var(Δn)/var(x)
1929-1983	3123.7	2821.7	41.8	260.2 (.38)	1.11	.015
1947-1983	1746.3	1327.1	48.7	370.5 (.73)	1.32	.037
1929-1946	5992.9	5935.3	29.5	28.0 (.03)	1.01	.005
1929-1941	1355.1	1109.6	28.0	217.6 (.62)	1.22	.025

earlier period (column 1), and the variance of detrended final sales is less than one-fourth as large (column 2). In contrast, the postwar variance of inventory investment is actually larger than its value in the earlier period (column 3). Thus the remarkably more stable postwar economy did not have more stable inventory behavior. In consequence, inventory fluctuations played a much more important role in the postwar economy than it had previously (column 6).

Since the covariance between inventory investment and final sales rises tremendously after the war (column 4, top number of each row), x and Δn are much more positively correlated in the postwar period (column 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 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 1929-1941 period to the 1947-1983 period, 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 columns 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 (1981, 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 which 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 which 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 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 (1981, 1984) did not originate in the postwar period.

B. The Manufacturing Sector

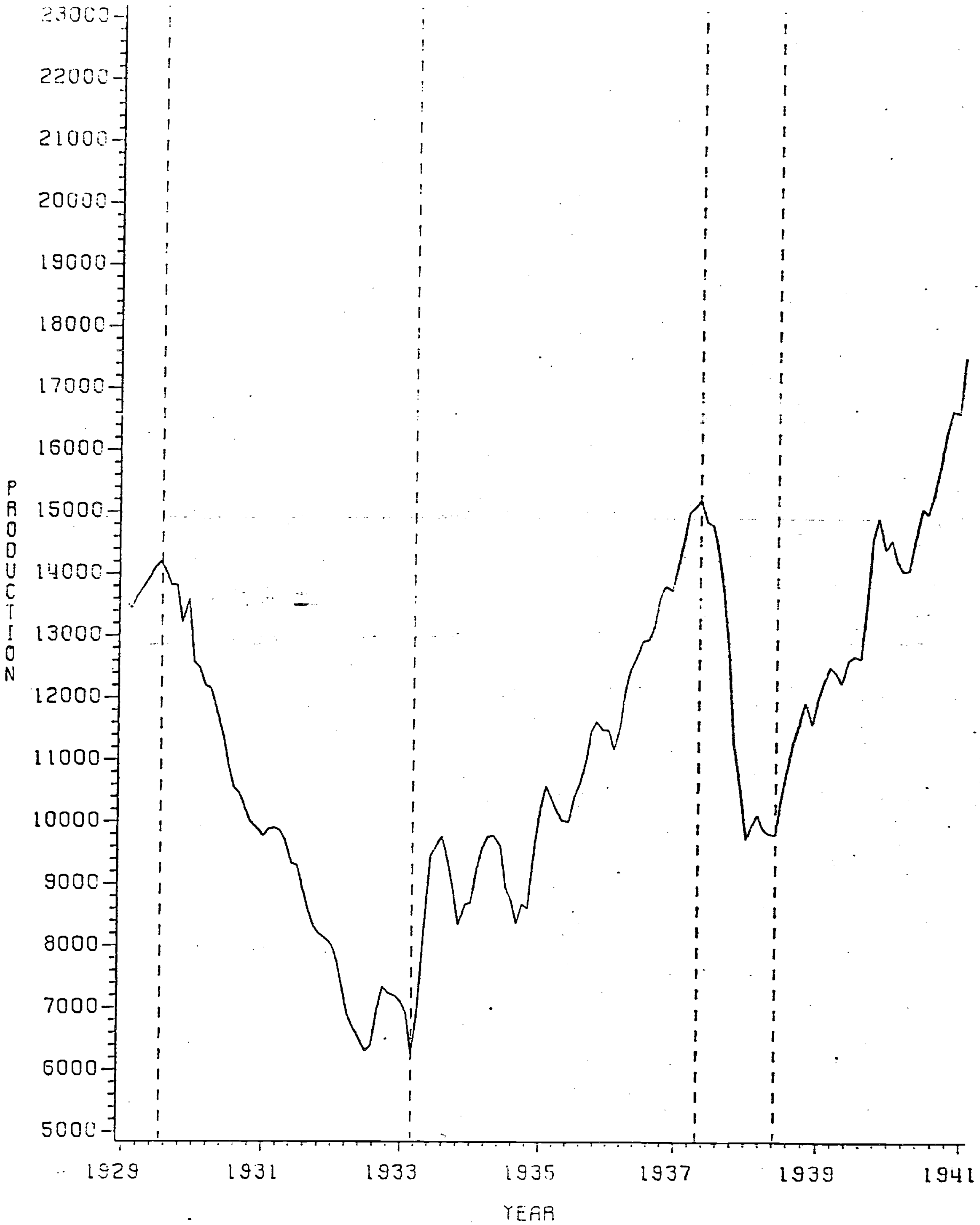
Manufacturing output is the most volatile component of GNP, so it is worth seeing how a variance decomposition like (3.2) looks using monthly data for manufacturing. Before looking at the results, we should say something about how the prewar data on manufacturing output, shipments, and inventories were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

In this context, it is important to note that when the identity (3.1) 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] Unfortunately, the data available to us did not distinguish among finished goods, works in progress, and raw materials, but rather 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 (3.1), 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 A.) From these, X was created by using (3.1). 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 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 (3.1). (Details are in Appendix B, and the data are in the data appendix.) Thus our series on Y_t is actually the

FIGURE 1
TOTAL MANUFACTURING PRODUCTION



VERTICAL LINES ARE TURNING POINTS

"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 (3.1) excludes them, our measured series for manufacturing are related to the conceptually "true" series by:

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

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,Δn) depending on how strongly X and ΔM covary.[7] The output series (Y) is constructed independently, and hence is not affected by this particular measurement problem. Some evidence presented in Appendix A 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 Figure 1.) For manufacturing we have no "natural output" series, analogous to Gordon's natural GNP, on which to fall back. 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 1929-1941 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 funny 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 1929-1941 period as "above trend" and half as "below trend." Neither procedure is particularly appealing. Fortunately, as Appendix C shows, while the choice of detrending procedure affects the estimated variances very much, 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 (1959-1982) 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 BEA has revised the data since 1966, but not before -- is unimportant in practice.)

Finally, we are ready to look at the results. The top panel of Table 3 shows that the prewar data share with the postwar manufacturing inventory and sales data the two outstanding characteristics emphasized above:

(a) 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]

(b) 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.

One noticeable difference between the two periods is the relatively greater role of inventory variability in the (stabler) postwar period. The variance of inventory investment is only

TABLE 3

ANALYSIS OF THE VARIANCE OF MANUFACTURING OUTPUT

(monthly data)

Period	(1) var(y)/var(x)	(2) corr(x,Δn)	(3) var(Δn)/var(x)
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. Durable 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. Nondurable 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

about 1% of the variance of shipments in the prewar period, but rises to 6% in the postwar period. This finding in the monthly manufacturing data echoes what we saw earlier in the annual economy-wide data for 1929-1946, but not for 1929-1941.

The third line in each panel of Table 3 requires some explanation. Our postwar data have been corrected (by us, not by the BEA) to account for the facts that (a) one 1972 dollar of finished goods in inventory represents more physical units than one 1972 dollar of shipments, and similarly (b) 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 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 Table 3. In general, they suggest that the data errors are not of enormous import.

C. Durable and Nondurable Manufacturing

Data problems are a little different in the durable and nondurable 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 than those that were present in the data for manufacturing as a whole.

Results from decomposing the variance of output in durable and nondurable manufacturing are presented in panels B and C of Table 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 to be quite robust. Like the postwar data, the prewar data are characterized by (1) a ratio of var(y)/var(x) that exceeds unity, (2) a positive cov($x,\Delta n$), and (3) 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.

IV. 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:

$$(4.1)\quad N_{t+1} - N_t = b(N^*_{t+1} - N_t) - c(X_t - {}_{t-1}X^e_t) + e_t,$$

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:

$$(4.2)\quad N^*_{t+1} = A + a\,{}_{t-1}X^e_{t+1}.$$

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 (4.1) and (4.2) 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 (4.2) 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.

A. 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 (4.2) into (4.1) 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 (4.1).

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 (4.1) and (4.2), 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 (a) the disturbance e_t in (4.1) is AR(1), and (b) final sales are generated by an autonomous AR(2) time series process around a quadratic time trend:

$$(4.3)\quad X_t = a_0 + a_1 t + a_2 t^2 + pX_{t-1} + qX_{t-2} + u_t;$$

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 1929-1983 period below:

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

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

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

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

$$R^2 = .996 \qquad DW = 1.86$$

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 either for the war or the Depression, the tracking performance was quite 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 1929-1946 and 1947-1983 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 4 reports the results for the whole period and for the two subperiods.[16]

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 1929-1945, the estimates differ only moderately from those for the whole sample and postwar subperiod. The main difference is that the estimated speed of adjustment (32% per year) is much faster in the 1929-1945 period than in the 1947-1983 period (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 1929-1945 and 1947-1983 estimates of the stock-adjustment are qualitatively similar.

TABLE 4

Estimates of Stock Adjustment Model: Whole Economy

Parameter	1929-1983	1929-1945	1947-1983
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^2 [a]	.34, .996	.71, .98	.66, .996
rho [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_e^2	30.3	8.51	16.2
σ_u^2	645.1	328.0	383.8

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

[b] For the inventory investment equation

NOTE: The model is:

$$(4.1)\quad N_{t+1} - N_t = b(N^*_{t+1} - N_t) - c(X_t - {}_{t-1}X^e) + e_t$$

$$(4.2)\quad N^*_{t+1} = A + a_{t-1}X^e$$

$$(4.3)\quad X_t = \text{const.} + pX_{t-1} + qX_{t-2} + u_t$$

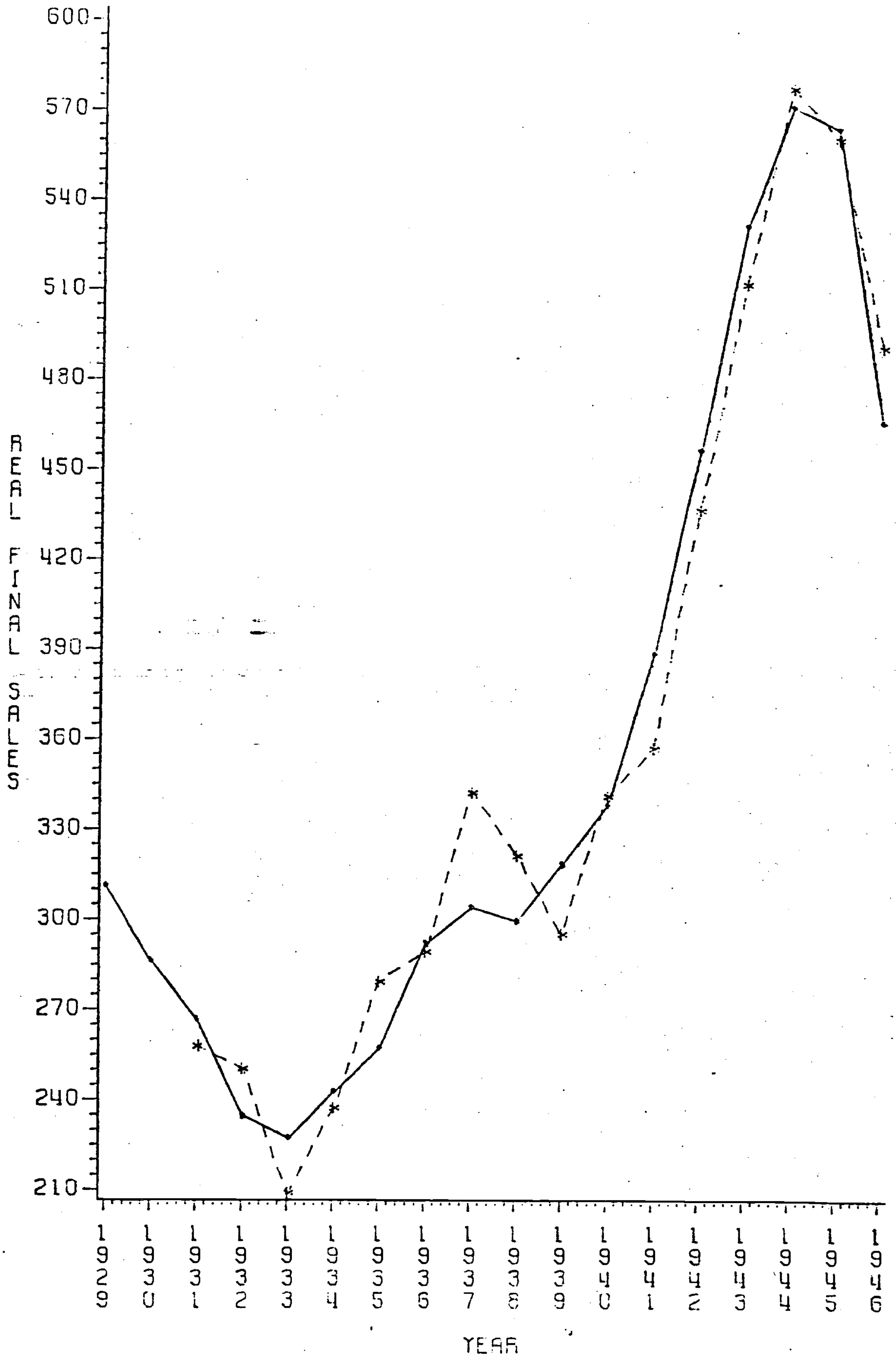
Finally, and not surprisingly, the estimated AR(2) processes for final sales are quite different in the two subperiods. (Remember: No special allowances were made for the Great Depression or World War II.) Figure 2 shows how the simple AR(2) model of final sales copes with the Great Depression and World 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.

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 the 1947-1983 period as in the 1929-1945 period. By this simple measure, then, business cycle <u>impulses</u> originating in the inventory sector have been almost twice as important since the war ended.

B. Stock-Adjustment Estimates for Manufacturing

The same stock-adjustment model can be estimated for the manufacturing sector, and for the durable and nondurable subsectors. In doing this with monthly data, we modelled 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

FIGURE 2
STOCK ADJUSTMENT MODEL FOR WHOLE ECONOMY
ESTIMATION PERIOD 1929 TO 1946
ACTUAL (.) AND PREDICTED (*) FINAL SALES



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 fall 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 5 (for all manufacturing), Table 6 (for durables), and Table 7 (for nondurables). In each table, there are two

TABLE 5

Estimates of Augmented Stock-Adjustment Model: Manufacturing

Parameter	Pre-War	Post-War Good Data	Post-War 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	683.8	-68.4	-18.8
(sum of lag coefficient)	(3.7)	(2.7)	(10.0
expected capital gains	-4.9	.16	.44
(sum of lag coefficient)	(4.1)	(0.5)	(1.6)
real wages	1.9	-.012	-.004
(sum of lag coefficients)	(1.2)	(1.4)	(0.7)
variance of residuals[a]	0.11, .298	.133, .769	.088, .770
R^{2a}	.86, .96	.297, .995	.49, .995
DW[a]	1.73, 1.74	2.06, 1.98	2.08,1.95
rho[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 correlation correction was made to the inventory investment equation.

equations for the postwar period: the first uses the "correct" data, while the second deliberately makes the two data errors mentioned previously.

There are both differences and similarities between the pre- 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 economy-wide 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 1959-1983 than it was in 1929-1941.

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 period than in the postwar period -- just as we found with economy-wide 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 economy-wide results, the proxy for unexpected sales gets the correct (positive) sign in all equations, and is even significantly positive in several cases. However, all of 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 (a) more rapid (but still slow) adjustment, (b) a correctly-signed, but small effect of unanticipated sales on inventory investment, and (c) 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 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 to be quite similar, even if they fail to accord with the theory.

TABLE 6

Estimates of Augmented Stock-Adjustment Model: Durable Manufacturing

Parameter	Pre-War	Post-War Good Data	Post-War 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 coefficient)	18.2	-30.1	7.8
	(0.4)	(1.5)	(0.5)
expected capital gains (sum of lag coefficient)	-.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^{2a}	.68, .97	.35, .991	.53, .991
DW[a]	1.96, 1.98	2.04, 1.97	2.09, 1.92
rho[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.

TABLE 7

Estimates of Augmented Stock-Adjustment Model: Nondurable Manufacturing

Parameter	Pre-War	Post-War Good Data	Post-War Bad Data
a (inventory accelerator)	0.61 (2.1)	1.83 (0.9)	1.58 (4.9)
b (adjustment speed)	.14 (3.1)	.01 (0.5)	.03 (1.7)
c (unexpected sales)	.05 (1.3)	.07 (1.8)	.07 (2.2)
nominal interest rate (sum of lag coefficient)	57.2 (2.3)	-13.4 (1.5)	-7.0 (0.9)
expected capital gains (sum of lag coefficient)	.50 (2.2)	-.15 (1.1)	-.17 (1.2)
real wages (sum of lag coefficients)	.65 (1.8)	-.003 (1.0)	-.002 (0.9)
variance of residuals[a]	.0032, .021	.031, .095	.022, .095
R^{2}[a]	.54, .88	.08, .996	.23,.996
DW[a]	1.93, 1.86	1.99, 1.97	1.95, 1.98
rho[b]	.43 (4.0)	.09 (1.4)	.24 (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.

V. 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 U.S. 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.

While the variability of the other 99% or so of GNP fell drastically between the 1929-1946 period and the 1947-1983 period most of this can be attributed to the wartime gyrations of final sales. The variability of inventory investment actually increased after the war. Furthermore, while inventory investment and final sales are essentially uncorrelated over 1929-1946 and strongly positively correlated over 1947-1983, most of this difference is also attributable to the war years. In fact, if the periods 1929-1941 and 1947-1983 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: 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.

FOOTNOTES

* A previous draft of this paper was presented at the National Bureau of Economic Research Conference on Business Cycles in Puerto Rico, March 22-25, 1984.

** We thank Ben Bernanke and Bruce Lehmann for alerting us to useful sources of historical data, Robert Gordon for providing his data on "natural" GNP, and Owen Irvine, Michael Lovell, Louis Maccini, Carl Walsh, Kenneth West, our discussants, and several conference participants for helpful coments on earlier drafts. Research support from the National Science Foundation and the Social Science Research Council is gratefully acknowledged.

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 of time, 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.

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 which, 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.

5. This is actually what is done with the postwar data as well. The BEA provides data on inventories and shipments, from which we create production data to satisfy (3.1).

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,Δn) might actually both be biased down by the

measurement error. But we cannot be sure.

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.

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

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

11. Maccini and Rossana (1984) appears to be a prominent exception. But we believe their rapid adjustment speeds to be artifacts of their estimation technique. Blinder (1984), using essentially the same data as Maccini and Rosanna, 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) or Blinder (1982) show that the model can be derived by maximizing discounted profits subject to quadratic revenue and cost functions

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 1929-1945, not 1929-1946. At first we included 1946, but 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 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.

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

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

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).

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.

REFERENCES

Abramovitz, Moses, 1950, Inventories and Business Cycles, National Bureau of Economic Research.

Blinder, Alan S., 1981, "Retail Inventory Behavior and Business Fluctuations," Brookings Papers on Economic Activity, 2, pp. 443-505.

Blinder, Alan S., 1982, "Inventories and Sticky Prices," American Economic Review, 72 (June), pp. 334-348.

Blinder, Alan S., 1984, "Can the Production Smoothing Model of Inventory Behavior be Saved?", National Bureau of Economic Research Working Paper No. 1257, January.

Alan S. Blinder and Douglas Holtz-Eakin, 1983, "Constant Dollar Manufacturers' Inventories: A Note," Princeton University (September), mimeo.

Conference Board Economic Record, various issues.

Gordon, Robert J., 1984, Macroeconomics, Third Edition (Boston: Little Brown).

Holt, Charles C., Franco Modigliani, John Muth, and Herbert A. Simon, 1960, Planning Production, Inventories and Work Force (Englewood Cliffs: Prentice Hall).

Lovell, Michael C., 1961, "Manufacturers' Inventories, Sales Expectations, and the Acceleration Principle," Econometrica, 29 (July), pp. 293-314.

Maccini, Louis J. and Robert J. Rossana, 1983, "Joint Production, Quasi-Fixed Factors or Production and Investment in Finished Goods Inventories" (June), mimeo (forthcoming in The Journal of Money, Credit, and Banking, 1984).

McCallum, Bennett T., "Rational Expectations and the Natural Rate Hypothesis: Some Consistent Estimates," Econometrica, January 1976, pp. 43-52.

McCallum, Bennett T., "Topics Concerning the Formulation, Estimation, and Use of Macroeconometric Models with Rational Expectations," Proceedings of the Business and Economics Statistics Section, American Statistical Association, 1979, pp. 65-72.

Sargent, Thomas J., "Estimation of Dynamic Labor Demand Schedules under Rational Expectations," Journal of Political Economy, December 1978, pp. 1009-1044.

West, Kenneth D., 1983, "A Note on the Econometric Use of Constant Dollar Inventory Series," Economic Letters, pp. 337-341.

APPENDIX A: 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 U.S. economy monthly from 1929 to 1942. We constructed these data using a variety of sources; the details are presented in this appendix.

I. Production

The primary source is the monthly Federal Reserve Board index of industrial production (1957-1959 = 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 3 annual outputs divided by 36) 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).

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[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.

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.

II. 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 December 26, 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 the result of the fact that 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 which account for only about 1/8 of inventory and shipment values, and it deliberately excludes data covering "food products, tobacco, liquors and petroleum, and certain lumber products." (CBER, p. 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 December 31 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, the fact that inventories are often valued at cost implies that this procedure will not exactly mimic movements in physical quantities of inventories.

III. 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.

IV. Price Index

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

V. 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 manufacturer's 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.

VI. 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 which computes benchmarks for the production and inventory indices 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 it is 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

VII. 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.

(a) 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 indices 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:

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

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

$$\mathrm{Cov}(x^1,\Delta\hat{N}) = \mathrm{Cov}(x,\Delta N) + \mathrm{Cov}(x,\Delta M) - \mathrm{Cov}(\Delta M,\Delta F+\Delta W) - \sigma^2_{\Delta M},$$

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

$$\sigma^2_{x^1} > \sigma^2_x \text{ i.f.f. } 2\rho < \sigma_{\Delta M}/\sigma_x$$

and:

$$\mathrm{Cov}(x^1,\Delta\hat{N}) > \mathrm{Cov}(x,\Delta N) \text{ i.f.f. } \mathrm{Cov}(x,\Delta M) > \sigma^2_{\Delta M} + \mathrm{Cov}(\Delta M,\Delta F+\Delta W).$$

Neither of these conditions are 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 upwards.

(b) 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:

$$\sigma^2_{x^2} = \sigma^2_x \, [1 - \frac{\Delta M_B}{\Delta X_B}]^2$$

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

$$\mathrm{Cov}(x^2,\Delta\hat{N}) = (1 - \frac{\Delta M_B}{\Delta X_B})\{\mathrm{Cov}(X,\Delta N) + \sigma^2_x(\frac{\Delta M_B}{X_B})\}$$

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

APPENDIX B: Construction of Data for the Durables and Non-Durables 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 A. Hence, our data for durable and nondurable manufacturing in the paper do not add up to our data for all manufacturing.

I. Inventories

Indices of the value of end-of-month inventories, seasonally adjusted, are available from the CBER for both durables and non-durables. These indices are not ideal. (See the discussion in Appendix B.) The indices were converted into a series on the nominal value (in millions of dollars) of inventories by benchmarking the indices in December 1937 using information in the 1937 Census of Manufactures.[1] (In particular, volume 2, page 121.) The nominal value of inventories in the durable and non-durable 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

[1]1937 was chosen because this Census was used by CBER to weight its indices.

subject to the same problems as the basic total manufacturing series.

Durable Goods Industries	Non-Durable Goods Industries
Forest Products	Food
Stone, Clay, Glass	Textiles
Iron and Steel	Paper
Non-ferrous 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 B.

II. Shipments

The CBER data provide indices 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 non-durables.

III. 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.

IV. A Check on Data Construction

Ideally, the sum of the data on, say production, for durable manufacturing and non-durable 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 a) total manufacturing as derived above and b) the sum of durable and non-durable manufacturing as derived for this paper.

	Total Manufacturing	Sum of Durable plus Non-Durable	Ratio
Production	13216.3	4669.7	.392
Shipments	12858.7	4646.8	.392
Inventory	13405.8	9275.7	.713

However, while 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 C: Detrending Procedures

I. Whole Economy

A) 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 1929-1983 (excluding 1932 and 1933). While the ratio is quite stable over time, these latter two years are obvious outliers, and were removed for that reason. In practice it makes little difference; our computed is .994, while 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 C.1.)

B) Alternative (Statistical) Trend

Here we simply fit the trend model

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

to each of GNP, final sales, and inventories, dropping the years 1930-1939 and 1941-1946 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 C.1.

II) Total Manfufacturing

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 1929-1941.

The variance decompositions for each type of detrending is shown in Table C.1.

TABLE C.1

	σ_y^2	σ_x^2	$\sigma_{\Delta N}^2$	Cov $(x,\Delta N)$	σ_y^2/σ_x^2	σ_x^2/σ_N^2	Corr. $(x,\Delta N)$
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

<u>Note</u>: In billions of 1929 dollars for manufacturing and billions of 1972 dollars for total economy.