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Seasonal Cycles, Business Cycles, and the Comovement of Inventory Investment and Output

The importance of inventory investment in the business cycle is well known. Its role in the seasonal cycle is less well known. We examine the variation of inventory investment and its comovement with output over the seasonal and business cycles. We measure the deterministic and stochastic seasonal components of monthly disaggregated inventory data and find seasonality contributes about 75 percent of the total variance, similar to the proportion found in GDP. We find that inventory investment and output exhibit high correlation, with similar magnitudes, at seasonal and business cycle frequencies. These findings are consistent with the idea that seasonal cycles and business cycles are propagated through similar mechanisms and suggest that inventory investment may play as important a role in the seasonal cycle as it does in the business cycle.

INVENTORY INVESTMENT PLAYS A MAJOR ROLE in the evolution of the business cycle. Indeed, Blinder and Maccini (1991) estimate that declines in inventory investment account for 87 percent of the decline in GNP during postwar recessions.[1] Less often discussed is inventory's seasonal variation. The seasonality of inventory investment in the manufacturing sector, however, is readily apparent in Figure 1.

Recent research shows that the bulk of the variation in most macroeconomic quantity series is seasonal (Barsky and Miron 1989). This research also shows that, in many respects, comovements of macroeconomic variables over the *business* cycle are mirrored in comovements over the *seasonal* cycle. The similarity in comovements suggests similar mechanisms may drive both seasonal and business cycles.[2] If so, information contained in seasonal cycles provides additional facts that can be used to build or test macro models (Beaulieu, Mackie-Mason, and Miron 1992; Chatterjee and Ravikumar 1992; Braun and Evans 1995; Cecchetti and Kashyap 1995; Cecchetti, Kashyap, and Wilcox, 1997).

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1. Inventories have strong predictive power for output fluctuations. Regean and Sheehan (1985) find about one-half of the total thirty-six-month ahead forecast error variance of industrial production is accounted for by inventory investment innovations. The role of inventories in the business cycle is frequently used to motivate studies on firm behavior (Maccini and Rossana 1984).

2. For a recent review, see Miron (1994).

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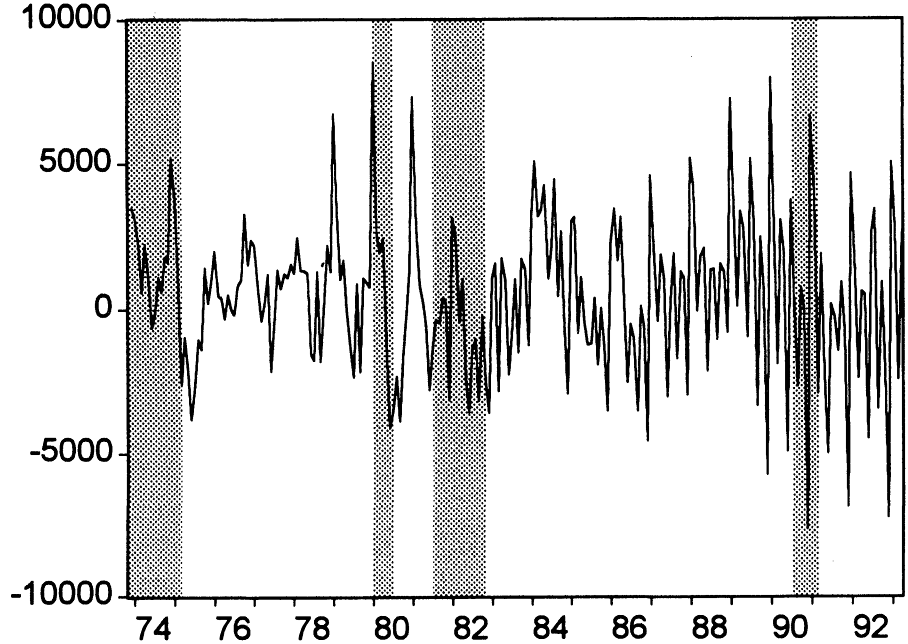

FIG. 1. Manufacturing Inventory Investment 1973.11–1993.04, Millions of 1987 dollars

A key feature of business cycle dynamics, however, has not yet been explored in the seasonal cycle literature. Given the close comovement of inventory investment and output over the business cycle, if seasonal cycles and business cycles are indeed propagated by similar mechanisms, they should be highly correlated over the seasonal cycle as well. But to our knowledge no research has yet examined the relationship between inventory investment and output over the seasonal cycle.

This paper makes two contributions to help fill this gap in the literature. First, we measure the seasonality of monthly manufacturing inventory investment, disaggregated to the two-digit level and by stage of processing. We use frequency domain techniques to decompose the variance of inventory investment into its long-run, business cycle, short-run, and seasonal frequency components. Second, we examine the dynamic relationship between inventory investment and output over the seasonal cycle. Sargent (1987, p. 282) states, "the business cycle is the phenomenon of a number of important economic aggregates . . . being characterized by high pairwise coherences at the low business cycle frequencies . . ." We extend this definition of business cycles to seasonal cycles and estimate the coherence of inventory investment and the change in output. This technique enables us to examine the dynamic relationship between inventory investment and ouptut at all frequencies simultaneously.[3] As a result,

3. Baxter and King (1995) and King and Watson (1996) discuss the advantages of using spectral analysis in macroeconomics.

we can examine whether the comovements between inventory investment and output over the business cycle also exist over the seasonal cycle.

We find that seasonal variation accounts for 75 percent of the total variation of inventory investment, suggesting a much greater role for seasonality in inventory investment than previously reported. For example, Barsky and Miron (1989) use quarterly data from the National Income and Product Accounts (NIPA) and report that seasonality accounts for only 38 percent of inventory investment's variance, among the least seasonal of the components of GNP.

There are two main reasons we find a greater role for seasonality in inventory investment. First, we estimate the share of the variation contributed by both deterministic and stochastic seasonality and find both are important. Second, since NIPA inventory data are quarterly, they understate the actual proportion of seasonal variation. We find that seasonal frequency components undetectable with quarterly data contribute substantially to overall seasonal variation (about 30–50 percent of the total). By accounting for stochastic seasonality and using monthly data our estimates of seasonality in inventory investment are almost double those previously reported.[4]

When we examine the comovements of inventory investment and output, we find the squared coherence (the frequency domain analog of a correlation coefficient) is statistically significant and almost always large at all seasonal frequencies (0.67 on average). Furthermore, the magnitude of these correlations are similar to those at business cycle frequencies (0.74 on average). These results are robust across sectors, industries, and stages of processing.

Overall, our results are consistent with the idea that seasonal cycles and business cycles might be propagated through similar mechanisms. We find that inventory investment may be approximately as seasonal as the other quantity components of GNP, especially output (Barsky and Miron 1989). This finding, however, does not rule out the possibility that the seasonal variation of the other components of GDP might also be enhanced if they were measured monthly. Moreover, we show the close comovement of inventory investment and output at business cycle frequencies also exists over the seasonal cycle, suggesting inventories may be as important for the seasonal cycle in output as they are for the business cycle.

The paper is organized as follows: Section 1 describes the data. Section 2 discusses methodology. The empirical results are contained in sections 3 and 4. Section 5 concludes.

1. DATA

We use inventory data obtained from the Bureau of Economic Analysis (BEA). The data set contains real, seasonally adjusted monthly inventory stock series for manufacturing firms, disaggregated to the two-digit SIC level and by stage of processing. We examine the period 1973.11–1993.04.

4. See Carpenter, Fazzari, and Petersen (1994) for a discussion of the importance of using high-frequency data to study inventory investment at the firm level.

We use the Bureau of the Census' M3 tape to construct seasonal factors and reintroduce seasonal variation into the BEA data (Reagan and Sheehan 1985; West 1986; Miron and Zeldes 1988). This tape contains nominal inventory data, both seasonally adjusted and unadjusted, by stage of processing, at the two-digit SIC level.[5] We calculate seasonal factors as the ratio of the unadjusted to adjusted stocks. The product of these factors and the real seasonally adjusted series yields the real unadjusted series.[6] We construct the inventory investment series by differencing the stock. Output is the sum of shipments and the change in finished goods inventories. We follow West (1983) to place inventories and shipments in comparable units.

2. METHODOLOGY

To decompose the variance of inventory investment into its frequency components we estimate the spectral density function, $f(\omega_j)$, where $\omega_j = j\pi/m$, $j = 0, 1, 2, \ldots, m$, and m is the number of ordinates.[7] We divide the frequency interval into bands, defining the interval $0.065 \leq \omega \leq 0.174$ (36–96 month cycles) as the business cycle frequency band. Lower frequencies ($\omega < 0.065$) correspond to the long run, and higher frequencies ($\omega > 0.174$) to the short run.[8]

We follow the frequency domain literature to specify seasonal frequency components and their bands within the short-run frequency interval.[9] We assume inventory investment is a stochastic process with stochastic, but stationary, seasonality.[10] We specify the exact seasonal frequencies as $\omega_s k$, where $\omega_s = 2\pi/12$ for monthly data, and $k = 1, 2, \ldots 6$. These frequencies correspond to cycles of 12, 6, 4, 3, 2.4, and 2 months. Seasonal frequency *bands* are the exact seasonal frequencies with their neighborhoods,

$$\omega_s(\delta) = \{\omega \text{ in } (\omega_s k - \delta, \omega_s k + \delta), k = 1, 2, \ldots, 5, (\omega_s 6 - \delta, \pi)\}, \text{ where } \delta = \pi/24$$

5. Reagan and Sheehan (1985) report that calendar effects for the inventory data we use are negligible.

6. This procedure implicitly assumes the seasonality of the inventory price deflators is small (Reagan and Sheehan 1985; Miron and Zeldes 1988). As a rough check of this assumption, we examined the seasonal patterns of the intermediate materials price indices for the manufacturing, durable, and nondurable sectors. Seasonal variation accounts for less than 6 percent of the total variance of these series. Miron and Zeldes (1988) report similar findings.

7. The spectrum of the series y_t is defined as $f_y(\omega) = (1/2\pi)\sum_{-\infty}^{\infty}\gamma(\tau)e^{-i\tau\omega}$, $-\pi \leq \omega \leq \pi$, where ω is the frequency measured in cycles per period (in radians), and $\gamma(\tau)$ is the autocovariance function. But $\gamma(\tau) = \int_{-\pi}^{\pi} f_y(\omega)e^{i\tau\omega}d\omega$ which, after setting $\tau = 0$, implies that $\gamma(0) = \sigma_y^2 = \int_{-\pi}^{\pi} f_y(\omega)d\omega$, that is, the integral of the spectrum equals the total variance of the series. (The covariance between spectral estimates at different frequencies is zero.) We set $m = 2\sqrt{n}$, where $n = 234$.

8. Similar frequency bands are used by Levy (1994) and Levy and Chen (1994).

9. Hylleberg (1992, p. 4) describes seasonality as "the systematic, although not necessarily regular, intra-year movement caused by the changes of the weather, the calendar, and timing of decisions, directly or indirectly through the production and consumption decisions made by the agents of the economy."

10. We assume the data-generating process can be written as $\phi(B)x_t = \varepsilon_t$, where ε_t is an i.i.d. disturbance and all roots of $\phi(B) = 0$ lie outside the unit circle, but where some are complex pairs with seasonal periodicities. Hylleberg et al. (1990) show the spectrum of such a process is given by $f(\omega) = \sigma^2/|\phi(e^{i\omega})|^2$, which will have peaks at some or all seasonal frequencies (Barsky and Miron 1989; Bryan and Cecchetti 1995).

(Sims 1974). Seasonal frequency bands consist of all frequencies within δ of the exact seasonal frequencies.

The point estimates of the spectrum at the exact seasonal frequencies measure the deterministic seasonal component of a time series (that is, when $\delta = 0$) and their sum is equivalent to the proportion of the variation explained by monthly seasonal dummies. Positive values of δ capture the stochastic (but stationary) component of the seasonal variation (Granger 1978).

There are important differences between the deterministic and stochastic components of seasonality (Granger 1978; Hylleberg et al. 1990). Deterministic seasonality is nonstochastic, does not vary from year to year, and is perfectly predictable. Stochastic seasonality, in contrast, is not perfectly predictable. However, if the seasonal process is stationary, past observations can be useful for prediction.[11]

To examine the comovement of inventory investment and the change in output over the seasonal and business cycles, we estimate their squared coherence. Squared coherence is similar to a correlation coefficient—the higher the coherence at frequency ω, the more closely the two series are related at that frequency.

3. SEASONAL CYCLES AND BUSINESS CYCLES IN INVENTORY INVESTMENT

A concrete advantage of spectral analysis is that it enables us to identify the variation contributed by different frequency components to the series' total variance. The influence of these components is readily apparent in Figures 2a, 2b, and 2c, which display estimated spectral densities for total inventory investment for total manufacturing, and for the durable and nondurable sectors, respectively. The graphs provide a detailed view of the distribution of spectral mass across the frequency bands. We show two-standard deviation confidence intervals as dotted lines. The horizontal axis shows the frequency measured in radians from 0 to π and the $2\pi/\omega$ scale underneath it indicates corresponding periodicity in months.

Figures 2a, 2b, and 2c exhibit several distinct features. First, a large portion of the variance is concentrated within the seasonal frequency bands. Second, while the business cycle variation ($0.065 \leq \omega \leq 0.174$) is statistically significant, it is small relative to short-run variation ($\omega > 0.174$). More importantly, the figures show each of the seasonal frequency components contributes to overall seasonal variation. The large amount of mass contained within the neighborhood of the exact seasonal frequencies indicates the importance of stochastic seasonality.[12]

Table 1 summarizes the estimated spectral density functions for total inventories and each stage of processing in the nondurable and durable sectors, total manufacturing, and eight key individual industries.[13] Each column shows the variance accounted

11. Many seasonal adjustment procedures assume stochastic seasonality (Abraham and Ledolter 1983). Seasonality will be stochastic if it varies with the stage of the business cycle (Canova and Ghysels 1994; Cecchetti, Kashyap, and Wilcox, 1997).

12. Random data measurement errors should spread variation uniformly throughout the short run. Therefore, they are unlikely to drive our results.

13. We present estimates for fabricated metals, industrial machinery, electronics, transportation, food,

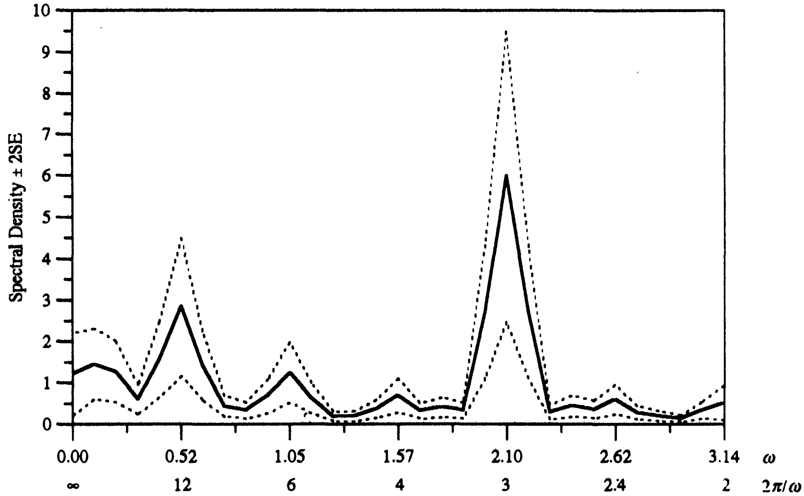

FIG. 2a. Spectrum of Manufacturing Inventory Investment: All Manufacturing Industries

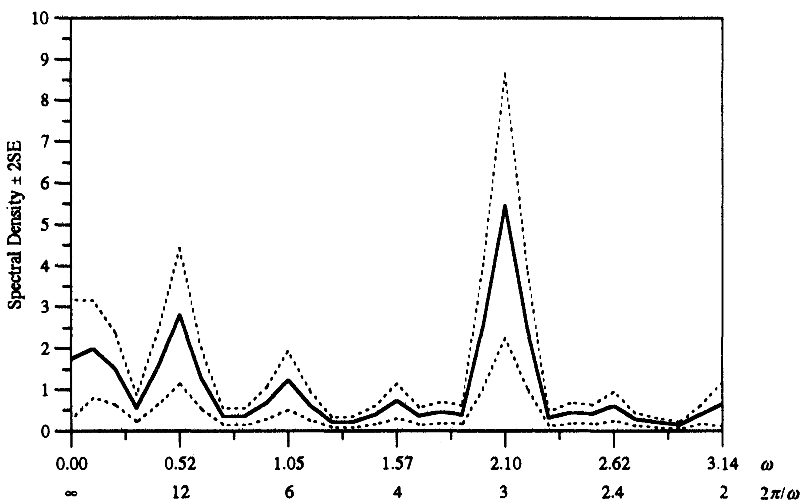

FIG. 2b. Spectrum of Manufacturing Inventory Investment: Durable Goods Industries

for by a different frequency component: long-run (LR), business cycle (BC), short-run (SR), seasonal (SEAS), and deterministic seasonal (DET. SEAS).

Our results can be summarized succinctly. The total variation of inventory investment is dominated by short-run cycles. Moreover, the bulk of the short-run variation

printing, chemicals, and petroleum. These industries are large in terms of the inventories they hold, and have the largest weights in the industrial production index.

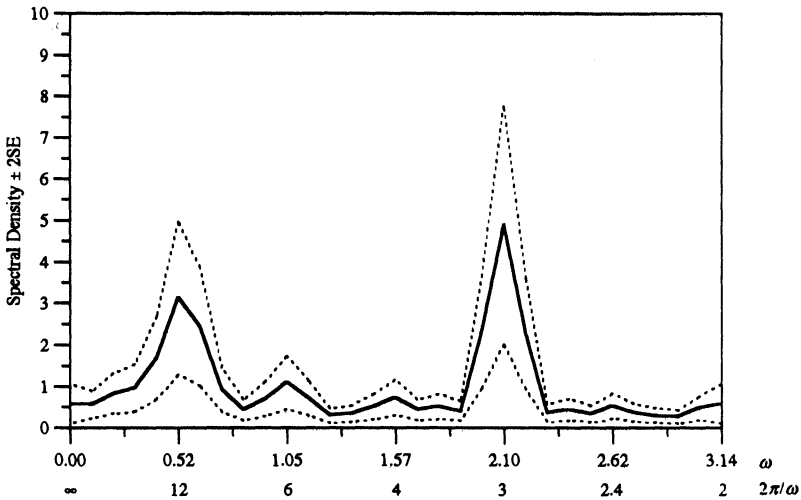

FIG. 2c. Spectrum of Manufacturing Inventory Investment: Nondurable Goods Industries

derives from seasonal fluctuations, and a substantial proportion of the seasonal variation is accounted for by the stochastic component. In contrast, variation at business cycle frequencies is extremely small.[14] These facts are true whether one looks at inventory investment by stage of processing or at total inventory investment, and is true for all industries and sectors.

3.1 Short-run Cycles and Business Cycles

Table 1 expresses the variance in each frequency band as a percentage of total variance. For the total manufacturing sector, less than 5 percent of the variation of total inventory investment can be accounted for by the business cycle component. For nondurable industries, this proportion is less than 2 percent. Although there is a larger business cycle component in the durable goods sector, it is still only 6.4 percent of the total variance.

In contrast, over 90 percent of the total variation of inventory investment in the manufacturing sector is accounted for by short-run variation. The *minimum* contribution of the short-run variation of total inventory investment to its total variance is approximately 88 percent in the durables sector. The results are similar for each of the four individual durable industries. In the nondurables sector (as well as in the four individual nondurable industries) short-run variation accounts for over 95 percent of the total.

Examining inventory investment disaggregated by stage of fabrication shows that about 90 percent or more of the series' variance, for all stages of processing in each in-

14. The long-run component accounts for only about 6 percent of the variation of inventory investment.

TABLE 1

PROPORTION OF INVENTORY INVESTMENT'S TOTAL VARIATION EXPLAINED BY EACH FREQUENCY COMPONENT

	Total Inventories					Raw Materials					Work in Process					Finished Goods				
	LR	BC	SR	SEAS	DET. SEAS	LR	BC	SR	SEAS	DET. SEAS	LR	BC	SR	SEAS	DET. SEAS	LR	BC	SR	SEAS	DET. SEAS
Nondurables																				
Food	0.013	0.008	0.980	0.850	0.775	0.015	0.015	0.970	0.767	0.559	0.012	0.013	0.975	0.754	0.346	0.010	0.005	0.985	0.852	0.750
Printing & Publishing	0.016	0.010	0.974	0.804	0.591	0.022	0.029	0.949	0.693	0.305	0.007	0.007	0.986	0.722	0.372	0.014	0.006	0.980	0.779	0.480
Chemicals	0.021	0.023	0.955	0.743	0.390	0.023	0.030	0.946	0.683	0.199	0.008	0.009	0.984	0.744	0.257	0.015	0.015	0.970	0.744	0.394
Petroleum	0.018	0.025	0.957	0.622	0.165	0.016	0.018	0.966	0.598	0.071	0.019	0.021	0.961	0.642	0.087	0.009	0.014	0.977	0.723	0.147
Durables																				
Fabricated Metal	0.039	0.039	0.922	0.686	0.391	0.029	0.040	0.932	0.597	0.185	0.019	0.016	0.965	0.695	0.271	0.013	0.011	0.975	0.772	0.473
Industrial Mach.	0.057	0.071	0.871	0.691	0.410	0.065	0.081	0.854	0.567	0.149	0.041	0.049	0.910	0.676	0.378	0.015	0.016	0.969	0.746	0.299
Electronic Equip.	0.048	0.059	0.893	0.554	0.128	0.063	0.083	0.854	0.574	0.212	0.039	0.046	0.916	0.535	0.072	0.022	0.028	0.951	0.716	0.454
Transportation	0.060	0.052	0.888	0.676	0.429	0.019	0.018	0.963	0.682	0.142	0.065	0.057	0.877	0.621	0.324	0.004	0.008	0.987	0.727	0.380
Totals																				
Nondurables	0.019	0.018	0.963	0.763	0.373	0.012	0.011	0.977	0.790	0.539	0.011	0.010	0.980	0.793	0.474	0.014	0.015	0.972	0.766	0.387
Durables	0.056	0.064	0.881	0.718	0.481	0.065	0.085	0.850	0.557	0.209	0.059	0.058	0.884	0.713	0.498	0.013	0.013	0.974	0.830	0.636
Manufacturing	0.039	0.047	0.913	0.756	0.493	0.042	0.055	0.903	0.657	0.353	0.047	0.047	0.906	0.748	0.553	0.011	0.013	0.975	0.827	0.577

Estimates of long-run (LR), business cycle (BC), and short-run (SR) frequency components presented as proportions of total variance. Seasonal variance (SEAS) is a subset of the short run, and is also expressed as a proportion of total variance. Estimates of deterministic seasonality (DET. SEAS) constructed by regressing the inventory investment series on seasonal dummies. Long-run (LR), business cycle (BC), and short-run (SR) variation may not sum to one due to rounding.

dustry and sector is contained in the short-run frequency band. These findings indicate that while inventory investment plays an important propagating role in the business cycle, the largest share of its variation is determined by short-run frequency components.

3.2 Seasonal Cycles

The SEAS column in Table 1 reports the combined contribution of the deterministic and stochastic seasonal frequency components to total series variation. Our estimates indicate these seasonal factors account for approximately three-quarters of the variation of total manufacturing sector inventory investment. Examining the results by stage of processing, it appears that seasonality plays a slightly more important role in finished goods.

The seasonal frequency components' contribution to the total variance is slightly higher for nondurables, where seasonal variation accounts for 76 percent of total variance. For durables, seasonal variation accounts for 72 percent of the total. For the four durable sector industries we present, seasonal variation accounts for roughly two-thirds of total variation. For the individual nondurables industries, the seasonal variation accounts for three-quarters or more of total variation for each stage of processing, with the exception of the petroleum industry, where it accounts for 62 percent of the total.[15]

To assess the relative importance of stochastic and deterministic seasonality, we report estimates of the deterministic seasonal component in the DET. SEAS column of Table 1. The sum of the heights of the spectrum at the exact seasonal frequencies represents the deterministic seasonal component, which is equivalent to the R^2 of a regression of the inventory investment series on seasonal dummies. The DET. SEAS column contains those R^2 values. We emphasize that monthly dummies do not correspond to the twelve-month seasonal component of the spectrum. When dummy variables are used to measure seasonality, they include the influence of each frequency, giving all components equal weights. For example, a seasonal dummy will include the influence of the twelve-month cycle, as well as the six-month and quarterly cycles that terminate in that month. The advantage of spectral analysis is its ability to separate precisely these different seasonal components.

We find that the deterministic seasonal variation of inventory investment accounts for more than one-third of the total variance for nondurables and about one-half for durables.[16] The differences between the estimates of deterministic seasonal variation (DET. SEAS) and estimates of the total seasonal component (SEAS) is equivalent to the stochastic seasonal component, and we find that this component is often quite large. For the durables industries, stochastic seasonality is one-third the size of the deterministic and stochastic components combined. For the nondurables industries, stochastic seasonal variation is roughly half of the combined components.

Table 2 contains a breakdown of the proportion of total *seasonal* variation contained in each of the six seasonal frequency bands. Our results show that all seasonal

15. The results for the remaining twelve industries also indicate a high degree of seasonal variability.
16. The large interindustry variation shows the importance of using disaggregated data.

TABLE 2

PROPORTION OF INVENTORY INVESTMENT'S SEASONAL VARIATION EXPLAINED BY INDIVIDUAL SEASONAL COMPONENTS

	Total Inventories						Raw Materials					
Cycle length (months)	2.0	2.4	3.0	4.0	6.0	12.0	2.0	2.4	3.0	4.0	6.0	12.0
Nondurables												
Food	0.023	0.046	0.185	0.031	0.141	0.574	0.055	0.070	0.168	0.138	0.154	0.415
Printing	0.048	0.059	0.088	0.076	0.200	0.529	0.126	0.142	0.079	0.106	0.258	0.289
Chemicals	0.029	0.055	0.178	0.136	0.116	0.486	0.104	0.175	0.190	0.134	0.144	0.252
Petroleum	0.128	0.127	0.204	0.104	0.131	0.306	0.089	0.161	0.224	0.220	0.110	0.196
Durables												
Fabricated Metal	0.088	0.101	0.111	0.094	0.102	0.504	0.124	0.143	0.172	0.115	0.265	0.180
Industrial Mach.	0.044	0.053	0.539	0.051	0.084	0.230	0.136	0.178	0.309	0.132	0.129	0.117
Electronic Equip.	0.094	0.126	0.182	0.130	0.172	0.296	0.070	0.137	0.225	0.147	0.116	0.305
Transportation	0.079	0.118	0.390	0.107	0.239	0.067	0.088	0.184	0.268	0.208	0.136	0.116
Totals												
Nondurables	0.046	0.053	0.408	0.073	0.108	0.312	0.078	0.110	0.165	0.100	0.086	0.462
Durables	0.046	0.057	0.469	0.066	0.112	0.250	0.083	0.132	0.191	0.134	0.264	0.197
Manufacturing	0.037	0.053	0.490	0.059	0.110	0.250	0.088	0.122	0.183	0.113	0.188	0.305

	Work in Process						Finished Goods					
Cycle length (months)	2.0	2.4	3.0	4.0	6.0	12.0	2.0	2.4	3.0	4.0	6.0	12.0
Nondurables												
Food	0.039	0.116	0.225	0.144	0.169	0.307	0.022	0.042	0.167	0.052	0.191	0.525
Printing	0.088	0.091	0.245	0.148	0.301	0.128	0.100	0.068	0.110	0.066	0.042	0.615
Chemicals	0.147	0.137	0.287	0.134	0.152	0.143	0.071	0.059	0.137	0.167	0.168	0.397
Petroleum	0.162	0.129	0.216	0.150	0.191	0.151	0.156	0.139	0.176	0.160	0.089	0.280
Durables												
Fabricated Metal	0.098	0.123	0.209	0.122	0.221	0.226	0.143	0.115	0.100	0.098	0.098	0.446
Industrial Mach.	0.150	0.107	0.301	0.098	0.227	0.117	0.094	0.103	0.527	0.069	0.060	0.147
Electronic Equip.	0.112	0.137	0.184	0.141	0.201	0.224	0.042	0.087	0.157	0.131	0.154	0.429
Transportation	0.120	0.116	0.275	0.162	0.236	0.092	0.110	0.176	0.420	0.124	0.090	0.080
Totals												
Nondurables	0.077	0.083	0.424	0.100	0.219	0.097	0.030	0.097	0.446	0.142	0.119	0.166
Durables	0.108	0.075	0.377	0.099	0.211	0.131	0.023	0.043	0.339	0.066	0.046	0.485
Manufacturing	0.101	0.065	0.396	0.093	0.221	0.123	0.021	0.063	0.455	0.094	0.071	0.296

frequency components contribute to seasonal fluctuations of inventory investment. For the nondurable, durable, and total manufacturing sectors, the twelve-month and three-month seasonal components contribute the largest proportion of seasonal variation to the data (with the exception of work in process inventories, where the influence of the six-month cycle exceeds that of the twelve-month).

The three-month component alone contributes from more than 40 to nearly 50 percent of the total seasonal variation in total inventories for each sector aggregate. These results show that seasonal variation undetectable with quarterly data is a quantitatively important source of seasonality.[17] The twelve-month band contains between one-fourth and one-third of the total seasonal variation. These two seasonal frequency bands tend to contribute the largest proportion of the seasonal variation for raw materials and finished goods inventories. The six-month seasonal frequency component contributes a large proportion of seasonal variation for raw materials and work in process inventories.

Overall, our results indicate that while deterministic seasonality is important, stochastic seasonal variation is also a first-order source of variation in the data. Accounting for both types of seasonality and using monthly data doubles the role for seasonality in inventory investment relative to the quarterly NIPA data used by Barsky and Miron (1989, Table 1), who found that seasonality accounted for only 38 percent of inventory investment's total variance.

4. INVENTORY INVESTMENT-OUTPUT COMOVEMENTS

In the empirical macroeconomics literature business cycles are defined as the common comovement of macroeconomic aggregates and output as captured by high pairwise coherence at business cycle frequencies (Sargent 1987). We extend this definition to the seasonal cycle by defining it as a high pairwise coherence of macroeconomic variables and output at *seasonal* frequencies.[18] By estimating the squared coherence of inventory investment and the change in output over the entire frequency band $0 \leq \omega \leq \pi$, we can examine the comovement of these variables over both the seasonal cycle and the business cycle.

We present the estimated coherences for the aggregate manufacturing industry and for the durable and nondurable sectors in Figures 3a, 3b, and 3c, respectively. The vertical axis represents the squared coherence. The horizontal dotted lines represent the 95 percent critical value for testing the null of zero coherence.

We find three main results. First, seasonal coherences are statistically significant over the seasonal cycle. Second, these coherences are generally large. Lastly, the magnitude of the coherences are similar in both the seasonal and business cycle frequency bands.

17. Beaulieu and Miron (1989, p. 6) also suggest that the use of quarterly data may mask interesting features of seasonal patterns that are observable in monthly data.

18. This notion of the seasonal cycle is also used by Barsky and Miron (1989).

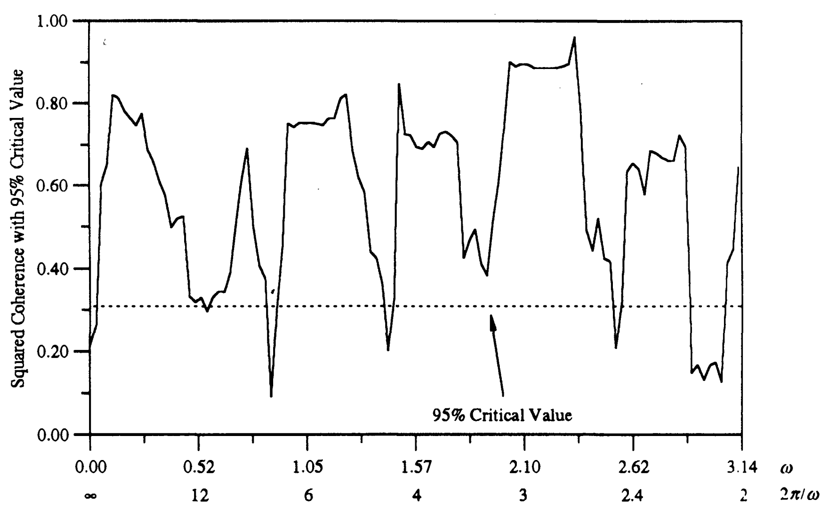

FIG. 3a. Coherence of Inventory Investment and Change in Output: All Manufacturing Industries

4.1 Seasonal Comovements

The most striking feature in each panel of Figure 3 is the high coherence of inventory investment and the change in output over the seasonal cycle. Virtually all coherences are statistically significant at the exact seasonal frequencies and their neighborhoods. Furthermore, these seasonal coherences are large, indicating a close relationship between inventory investment and output over the seasonal cycle.

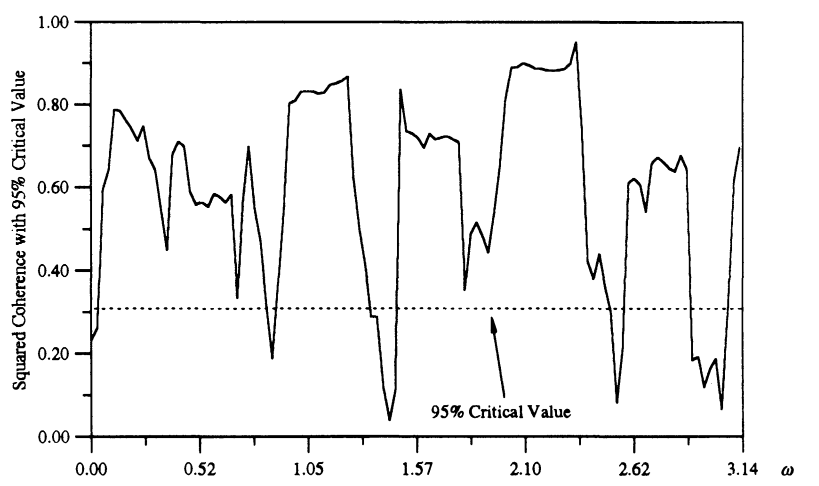

FIG. 3b. Coherence of Inventory Investment and Change in Output: Durable Goods Industries

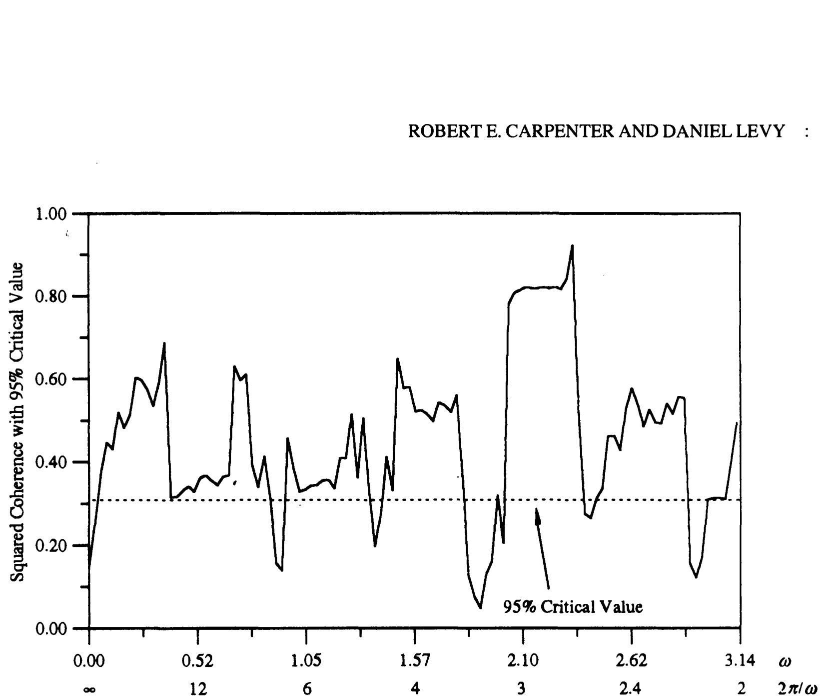

FIG. 3c. Coherence of Inventory Investment and Change in Output: Nondurable Goods Industries

For total manufacturing (Figure 3a) the point estimates of the squared coherence at the exact seasonal frequencies corresponding to 2-, 2.4- 3-, 4-, 6-, and 12-month cycles are 0.64, 0.65, 0.89, 0.72, 0.75, and 0.33, respectively, with an average of 0.67. The coherences at the frequency bands corresponding to the three- and six-month cycles are particularly large, averaging 0.89 and 0.76.

For durables, Figure 3b, the point estimates of the coherence at the exact seasonal frequencies are 0.69, 0.62, 0.90, 0.73, 0.83, and 0.58, with an average of 0.73. As in the case of the total manufacturing industries, the comovement is particularly close at the frequency bands corresponding to the three- and six-month cycles, where the coherence averages 0.90 and 0.83.

For nondurables, Figure 3c, we find somewhat smaller seasonal coherences. However, they still indicate close comovements over the seasonal cycle. The point estimates of coherence at the exact seasonal frequencies are 0.49, 0.57, 0.82, 0.52, 0.33, and 0.36, with an average of 0.52.

4.2 Comovement over the Seasonal Cycle and Business Cycle

An other important feature of Figures 3a, 3b, and 3c is the high coherence of inventory investment and output at business cycle frequencies, averaging 0.74 for the aggregate manufacturing industry. For a narrower portion of the band, corresponding to a 3.5–4.5-year cycle, the coherence is even higher, averaging 0.82. These estimates are consistent with the well-documented fact that inventories and output move together over the business cycle. The durables sector shows a comovement of inventory investment and output that is somewhat more pronounced than nondurables. For durables the business cycle squared coherence averages 0.77, and for nondurables, 0.47.

Perhaps the most striking feature is the similarity in the magnitudes of the seasonal and cyclical coherences. Specifically, the average squared coherence at the seasonal and business cycle frequency bands are 0.74 and 0.67 for aggregate manufacturing, 0.77 and 0.73 for durables, and 0.47 and 0.52 for nondurables, respectively. All twenty individual manufacturing industries exhibit similar patterns of comovements.

The general pattern which emerges from these results suggests the comovements of inventory investment and output over the seasonal cycle are statistically significant and strong. In addition, the seasonal comovements of inventory investment and output are very similar in magnitude to their comovements over the business cycle. These findings are consistent with the idea that similar mechanisms drive both seasonal cycles and business cycles. More importantly, our results suggest that inventory investment may play as important a role in the fluctuations of output over the seasonal cycle as it does over the business cycle.

5. CONCLUSION

This study makes two principal contributions. First, we show that approximately 90 percent of the total variance of inventory investment is short run. Seasonal fluctuations are the dominant feature of the short run, accounting for approximately three-quarters of short-run variation. Stochastic seasonality is an important component of these seasonal fluctuations, accounting for between one-third and one-half of total seasonal variance. Second, we show a close *seasonal* comovement of inventory investment and output that is remarkably similar to their well-known comovement over the business cycle. The average squared coherence between inventory investment and the change in output for the aggregate manufacturing sector is large and statistically significant over both the seasonal cycle (0.67) and the business cycle (0.74). These facts are robust across all manufacturing sectors, industries, and stages of processing and reinforce arguments that seasonal cycles and business cycles are propagated through similar mechanisms.[19]

Macroeconomists of all persuasions stress the central role of inventories in the business cycle. For example, Barro (1993, p. 220) states that "as a first approximation, explaining recessions amounts to explaining the sharp contractions in the investment components." Of the investment series he studies, inventories account for the largest proportion of the decline in investment during recessions. Blinder states that "inventory behavior can explain, indeed must explain, a lot of the business cycle" (Klamer 1983, p. 157). Our results suggest their statements may be true for the seasonal cycle as well.

19. We performed a number of additional tests to examine the robustness of our results. We estimated the spectrum of inventory investment scaled by seasonally adjusted manufacturing sector output and seasonally adjusted own industry output to see whether changes in the size of the economy affected the results. We examined an alternative definition of output, defined as shipments plus work in process and finished goods inventories. We repeated our analysis for the period 1959.01–1973.11 and the period 1959.01–1993.04. We examined each of the twenty individual manufacturing industries. Lastly, we used different lag windows to smooth the estimated periodograms (Bartlett's, Tukey's, and Parzen's). In each case, our results are very similar to those we report. An appendix of these additional results is available from the authors.

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