NOTES

TRENDS, RANDOM WALKS AND PERSISTENCE: AN EMPIRICAL STUDY OF DISAGGREGATED U.S. INDUSTRIAL PRODUCTION

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Abstract—Unit-root and variance-ratio tests are used to examine the trend properties and degree of persistence of industrial production in U.S. industries and comparable aggregates during the post World War II period. The evidence from unit-root tests suggests that less than one-half of these industries have output which may be characterized as a random walk. The variance-ratio test results generally support this conclusion. Consistent with standard economic theory, fluctuations in durable-goods industries are less persistent than in nondurable goods industries. Finally, tests find relatively greater persistence in the aggregate industrial production data.

I. Introduction

Economists have become increasingly interested in the trend properties of macroeconomic time-series variables (see, for example, Nelson and Plosser (1982), Campbell and Mankiw (1987, 1989)). The main issue is whether these variables, such as GNP or industrial production, contain a unit root or a deterministic linear time trend. The difference has important implications for both economic theory and econometric estimation.

When a time-series variable contains a deterministic linear time trend, the variable can be characterized as a trend stationary process. Fluctuations around trend for a trend stationary process are considered to be mostly temporary. Until recently, this was a fairly standard belief in the business-cycle literature (see, for example, Blanchard (1981)). This approach was first challenged by Nelson and Plosser (1982). Nelson and Plosser were unable to reject the hypothesis that most U.S. macroeconomic variables contain a unit root. In other words, these variables appear to follow a random walk and can be characterized as a differenced stationary process. The principal implication of a differenced stationary process is that at least part of the change in these variables is permanent. This suggests that when the variable is shocked, it never completely returns to its trend. In this setting, emphasis is generally placed on taste and technology shocks (real factors) rather than monetary shocks as the source of these permanent fluctuations.[1] In the unit root case, the distinction between long-term economic growth and the short-term business cycle becomes blurred (see Beveridge and Nelson (1981) for a discussion).

This paper extends the analysis of the trend properties and degree of persistence in time-series data to disaggregated or individual industrial production indices in the United States during the post World War II period. Disaggregated industrial production may provide us with a different picture of output trend properties and persistence. For example, how comparable are the trend properties across U.S. industries? Durable goods industries are generally considered to be highly cyclical (Black (1982)). As a result, durables should tend to be trend stationary and show less persistence compared to nondurable goods industries. In addition, the literature investigating the trend properties of economic time-series variables has focused almost entirely on variables such as GNP or aggregate industrial production. Since this paper investigates the trend properties of disaggregated and comparable aggregate industrial production indices, it will be possible to compare evidence using standard econometric measures of persistence at different levels of aggregation.

Augmented Dickey-Fuller and variance-ratio tests are used to investigate the trend properties and degree of persistence in individual and aggregate industrial production indices. We find that in only eight of the twenty-two industries investigated does the industrial production index appear to follow a random walk. All durable goods industries appear to be trend stationary. Furthermore, aggregate industrial production measures show greater persistence than disaggregated industrial production indices. This last result is consistent with the idea that aggregating nonstationary and stationary processes results in a nonstationary aggregate process (see Granger (1988)).

Received for publication June 19, 1989. Revision accepted for publication February 6, 1991.

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I would like to thank Lee Ohanian, Shirley Svorny, and two anonymous referees for very helpful comments. The author is responsible for any remaining errors. This research was supported in part by CSUN and the CSUN School of Business Administration and Economics.

[1] West (1988) however, shows that in an overlapping wage contract model, near random-walk behavior in output is possible even when all shocks are purely monetary.

TABLE 1.—TEST STATISTICS FOR THE TREND PROPERTIES

Series	D-F(Q)	D-F(ΔQ)	Quadratic Trend	Drift
Total	−2.96	−6.88[a]	−0.71	3.09[a]
Durables	−3.61[b]	...	−0.53	...
Nondurables	−2.20	−7.51[a]	−0.44	4.14[a]
Mining	−2.85	−8.21[a]	−1.18	1.35
Utilities	0.20	−10.05[a]	−6.35[a]	5.68[a]
(Mining)				
Metal	−3.47[b]	...	−0.66	...
Oil and Gas	−1.10	−7.51[a]	−2.24[b]	1.68[c]
Minerals	−2.70	−7.42[a]	−1.18	2.07[b]
Coal	−4.03[a]	...	0.82	...
(Electrical Utilities)	0.20	−10.36[a]	−5.64[a]	6.81[a]
(Nondurables)				
Paper	−3.64[b]	...	−0.44	...
Printing	−2.59	−5.92[a]	0.59	4.12[a]
Textiles	−3.41[c]	...	−0.03	...
Apparel	−3.99[a]	...	−0.34	...
Chemicals	−1.57	−7.44[a]	1.56	4.24[a]
Petroleum	−0.89	−10.37[a]	−2.69[a]	3.74[a]
Rubber	−3.16[c]	...	−0.44	...
Foods	−3.74[b]	...	0.73	...
Tobacco	−1.13	−11.84[a]	−1.57	1.84[c]
Leather	−0.93	−8.37[a]	−1.84[c]	−1.21
(Durables)				
Clay, Glass, Stone	−3.83[b]	...	−0.52	...
Lumber	−4.20[a]	...	0.21	...
Furniture	−4.55[a]	...	0.19	...
Primary Metals	−3.38[c]	...	−0.52	...
Electrical	−4.37[a]	...	−0.47	...
Nonelectrical	−4.83[a]	...	−0.44	...
Transportation	−3.28[c]	...	−0.85	...

Notes: Critical values for the Dickey-Fuller Tests are −3.98, −3.42 and −3.13 for significance levels of 1% ([a]), 5% ([b]) and 10% ([c]), respectively. Critical values of the quadratic trend and drift tests are 2.58, 1.96 and 1.65 for significance levels of 1% ([a]), 5% ([b]), and 10% ([c]), respectively. The sample period is 1/47–3/87.

The paper is organized in the following manner. Section II reports a series of econometric tests and results which describe the trend properties of individual and comparable aggregate industrial production indices in the United States. Section III discusses the implications of this evidence for business-cycle models. The paper ends with a brief conclusion.

II. Testing for Stochastic and Deterministic Trends

A. Unit Root, Trend and Drift Tests and Results

This section is divided into two parts. The first part (A) contains the results of tests for unit roots, drifts and trends in monthly industrial production data for 22 U.S. industries and five aggregate indices for the period January 1947 to March 1987. The data are seasonally adjusted at the source. All of the data are taken from *Citibase Citicorp Economic Database*. The second part (B) estimates a variance ratio similar to the one suggested by Cochrane (1988) to determine the size of the random walk component in these data.

The first null hypothesis tested is that the log level of industrial production for each industry contains a single unit root, versus the alternative hypothesis that the variable follows a deterministic linear time trend. If we fail to reject the null hypothesis of a unit root, then we can conclude that at least part of the fluctuations in industry output are permanent. An augmented Dickey-Fuller (ADF) test is conducted and is represented by regression (1) (see Fuller (1976)).

$$Q(t,i) = \alpha + \beta TIME + \gamma Q(t-1,i) + \sum_{j=1}^{6} \phi(j)\,\Delta Q(t-j,i) + e(t,i). \quad (1)$$

$Q(t,i)$ represents the log of the industrial production index for industry i in period t and $\Delta Q(t-j,i) = Q(t-j,i) - Q(t-j-1,i)$. We fail to reject the null hypothesis that industry i's industrial production index follows a random walk when $\hat{\gamma}$ does not differ significantly from one. The critical values for this test are found in Fuller (1976). For industries where we fail to reject the null hypothesis of a unit root, the ADF test is repeated on industrial production growth rates. This second test is conducted to determine if a second unit root is present. It should be pointed out, however, that the power of the unit root test is low in near unit root cases for finite samples. The results from these two tests are reported in columns one and two of table 1.

The ADF test results on log levels reported in column one (denoted $D - F(Q)$) reject the null hypothesis of a unit root at standard significance levels in 14 of the 22 industrial industries. This includes all durable goods, metal, coal, paper, textiles, apparel, rubber and food industries. For these industries, industrial production can be characterized as a trend stationary process. We fail to reject the null hypothesis of a unit root in the remaining eight industries. This includes oil and gas, minerals, electrical utilities, printing, chemicals, petroleum, tobacco and leather industries. For these industries, industrial production can be characterized as a differenced stationary process.[2] Finally, column two gives the results of tests for a second unit root by performing the ADF test on data measured in the first differences (denoted $D - F(\Delta Q)$). In every case, this hypothesis is rejected at the 1% level.

There is a possible weakness in the durable goods results. Mankiw (1982) has shown, using a rational expectations version of the permanent income hypothesis, that the consumption of durable goods should follow an ARMA (1, 1) process rather than an AR(1).[3] In equilibrium, when consumption equals production, production should have an ARMA (1, 1) stochastic representation.[4] The possible presence of a moving-average term in durable goods industrial production has implications for the results of the unit-root tests reported above. Schwert (1987) provides evidence that standard Dickey-Fuller tests may tend to reject the null hypothesis of a unit root more often when the variable follows an ARMA rather than AR stochastic process. Schwert's results suggest that the consistent rejection of the null hypothesis of a unit root for durable goods may be due to the presence of a large moving-average component in the variable. However,the lower estimated variance ratios presented in the next section tend to support the proposition that durable goods production is a trend stationary process and shows less persistence.

[2] The ADF test results change very little when the lag length was set at nine and twelve.

[3] The principal reason lies in the fact that most durable goods are not depreciated in one period. Deviations away from an AR(1) representation may also be due to consumer search or adjustment costs.

[4] I am ignoring the production smoothing role of durable goods inventories.

Additional tests are conducted for the presence of a quadratic trend and drift. The results of these tests are reported in columns three and four of table 1. In order to test for a quadratic time trend, we estimate regression (2) and conduct a t-test on the time trend. For those industries which have a unit root, tests for drift are accomplished by dropping the time trend in regression (2) and conducting a t-test on the constant (see Stock and Watson (1989)).

$$\Delta Q(t,i) = \alpha + \beta TIME + \sum_{j=1}^{6} \phi(j)\, \Delta Q(t-j,i) + e(t,i) \quad (2)$$

Four out of 22 industries show evidence of a quadratic trend. The previous analysis indicated that the level of output in each of these industries follows a random walk. This implies that, in addition to the random movement in levels, the growth rates in the oil and gas, electrical utilities, petroleum and leather industries have significant linear trends.[5] Oil and gas, minerals, electrical utilities, printing, chemicals, petroleum and tobacco industries have significant drift terms. The level of production in these industries follows a random walk with drift.

The first five rows of table 1 provide a similar set of test results for aggregated industrial production indices. Total, non-durable goods, and utilities industrial production indices follow random walks with drift. Mining industrial production is a random walk. Only durable goods industrial production can be represented as stationary around a linear time trend. This last result is consistent with the previous industry level analysis which showed each individual durable goods industry appears to be trend stationary.

The ADF test fails to reject the null hypothesis of a unit root using aggregate industrial production but rejects a unit root in fourteen of twenty-two industry level industrial production cases. The non-stationary aggregate industrial production index is made up of a stationary component (durables) and some non-stationary components (nondurables, mining and electrical utilities). This is consistent with the theoretical results reported in Granger (1988) that aggregating a non-stationary process with a stationary one results in a non-stationary aggregate process.

B. *Variance-Ratio Tests and Results*

In this part of the paper, a variance-ratio statistic is estimated with the same industrial production indices used in the ADF tests reported in section A. Since any

[5] Tests for a break in trend between 1973 and 1974 were also conducted. The first oil price shock and a shift to flexible exchange rates occurred at that time. The results suggest that no significant break occurred at that time.

time-series variable can be decomposed into a temporary and permanent component, the purpose of estimating a variance ratio is to estimate the size of the random walk or permanent component in individual industrial production (see Cochrane (1988), Campbell and Mankiw (1987, 1989)). Cochrane (1988) has proposed the following variance-ratio estimate of the random-walk component:

$$VR(i,k) = \frac{\mathrm{Var}[Q(t+k,i) - Q(t,i)]}{k\,\mathrm{Var}[Q(t+1,i) - Q(t,i)]}. \tag{3}$$

This estimate compares the variance of the k difference of industrial production from industry i to k times the variance of the first difference of industrial production for the same industry.

The variance ratio has the following interpretation. When industrial production in a particular industry follows a pure random walk, the variance of industrial production increases proportionally with k (k is the difference horizon). Therefore the variance of $Q(t+k,i) - Q(t,i)$ will equal k times the variance of $Q(t+1,i) - Q(t,i)$. The variance ratio equals one for the pure random walk case. When industrial production in a particular industry is a pure trend stationary process, the variance of $Q(t+k,i) - Q(t,i)$ approaches two times the variance of $Q(t,i)$. Therefore, as k approaches infinity, the variance ratio approaches zero. However, the variance-ratio estimate is not strictly bounded by zero and one. Variance ratios less than one imply that some negative serial correlation is present, while a variance ratio greater than one implies more positive serial correlation (see Campbell and Mankiw (1987)). By computing a variance ratio, we have a measure of persistence in the movement of an industry's production.

Cochrane shows the variance ratio (equation (3)) can be estimated using equation (4).

$$\widehat{VR}(i,k) = 1 + 2\sum_{j=1}^{k-1} \frac{k-j}{k}\hat{\rho}(j,i) \tag{4}$$

where $\hat{\rho}(j,i)$ equals the j^{th} order autocorrelation coefficient of industrial production for industry i. A problem with this estimator is that there is no objective rule for determining the size of k. k needs to be large in order to capture long-term mean reversion in industrial production (i.e., negative $\hat{\rho}(j,i)$'s). However, with finite samples, choosing a large value of k reduces power. Lo and MacKinlay (1989) have conducted Monte Carlo simulations to determine the impact of varying k on the power of the variance-ratio test. Lo and MacKinlay find that power is preserved, compared to standard unit-root tests, when k is less than one-half of the sample size. In this paper, I compute variance ratios with k's ranging from 24 to 120 months. One hundred twenty months is approximately one-fourth of the sample size. I also examine a Bartlett standard error for each value of k.[6] The results are reported in table 2.

TABLE 2.—VARIANCE RATIO STATISTICS

Series	$k = 24$	$k = 48$	$k = 96$	$k = 120$
Total	1.44	0.89	1.50	1.19
Durables (r)	1.28	0.73	1.07	0.80
Nondurables	1.07	0.47	1.16	0.93
Mining	0.54	0.67	0.57	0.55
Utilities	1.22	2.11	2.64	2.67
(Mining)				
Metal (r)	0.25	0.08	0.07	0.11
Oil and Gas	1.66	2.40	1.90	1.82
Minerals	0.22	0.17	0.31	0.25
Coal (r)	0.01	0.03	0.03	0.03
(Electrical Utilities)	0.60	1.27	1.60	1.62
(Nondurables)				
Paper (r)	0.35	0.27	0.50	0.37
Printing	1.20	0.83	0.98	0.86
Textiles (r)	0.51	0.53	0.77	0.60
Apparel (r)	0.37	0.03	0.22	0.17
Chemicals	1.16	1.24	1.93	1.83
Petroleum	0.53	0.58	0.66	0.62
Rubber (r)	0.29	0.07	0.40	0.33
Foods (r)	0.00	−0.02	0.09	0.07
Tobacco	−0.03	−0.01	0.06	0.05
Leather	0.45	0.47	0.58	0.57
(Durables)				
Clay, Glass, Stone (r)	0.65	−0.06	0.37	0.28
Lumber (r)	0.68	0.17	0.37	0.33
Furniture (r)	0.90	0.06	0.61	0.42
Primary Metals (r)	0.11	0.13	0.27	0.23
Electrical (r)	0.52	0.29	0.34	0.26
Nonelectrical (r)	1.37	0.61	1.30	0.88
Transportation (r)	0.90	0.06	0.61	0.42

Notes: (r) indicates industries where the null hypothesis of a unit root was rejected using an augmented Dickey-Fuller test reported in table 1. Bartlett standard errors are estimated using $(4k/3T)^{1/2}$ where k is the difference horizon and T is the sample size (see Cochrane (1988)). The Bartlett standard errors equal 0.257 ($k = 24$), 0.364 ($k = 48$), 0.515 ($k = 96$) and 0.576 ($k = 120$).

The estimated variance ratio varies considerably between the different industries. This implies the size of the random walk or permanent component of fluctuations in individual industry production differs from one industry to the next. In the discussion that follows, emphasis is placed on the difference between nondurable and durable goods industries. Also, the computed variance ratio can differ greatly as the value of k changes. In order to conserve space, the discussion of results focuses on a value of k equal to 120. A k value of 120 is chosen in an attempt to have a reliable measure of persistence while maintaining power.

For nondurable goods when k equals 120, the estimated variance ratio ranges across industries from a

[6] Cochrane (1988) reports that estimates of Bartlett standard errors tended to be smaller than standard errors estimated using Monte Carlo methods.

low of 0.05 to a high of 1.83. Most of the variance ratios, however, are between zero and one. Five out of ten of the estimated variance ratio's for nondurable goods are more than one standard error below one. These industries are paper, apparel, rubber, foods and tobacco. For comparison, the ADF tests rejected unit roots for paper, rubber and foods. The other five variance ratios exceed one-half, suggesting that more than 50% of the observed output fluctuations in those nondurable goods industries is permanent. These industries are printing, textiles, chemical, petroleum and leather. The ADF tests rejected a unit root for textiles. We can conclude there is a fairly high degree of persistence in many nondurable goods' output fluctuations.

For durable goods industries when k equals 120, the estimated variance ratio ranges across industries from a low of 0.23 to a high of 0.88. The range is considerably smaller for durable goods industries than for nondurable goods industries. Six out of seven of the estimated variance ratios for durable goods are more than one standard error below one. These industries are clay, glass and stone, lumber, furniture, primary metals, electrical and transportation. All but nonelectrical equipment have variance ratios less than one-half suggesting more than 50% of the observed fluctuations in durable goods output is temporary. Recall that ADF tests rejected unit roots for all durable goods industries. Compared to nondurable goods, there appears to be a lower degree of persistence in durable goods output fluctuations.

III. Interpretation and Discussion of the Results

The results from the previous section indicate that individual industrial production indices have heterogeneous trend properties. Also, the trend properties of the majority of the industries differ from that of aggregate industrial production, which appears to follow a random walk with drift. These results have a number of general implications for business-cycle analysis.

First, all durable goods industrial production indices appear to be trend stationary. This is consistent with standard economic theory which suggests that durable goods production has a strong cyclical component (see Black (1982)). When there is a reduction in the demand for durable goods services, output declines significantly as the stock depreciates over time. However, durable goods output gradually adjusts back to its trend rate of growth.

Second, there is a growing literature examining the impact of unanticipated money supply changes on individual industry output (see Gauger (1988) and Kretzmer (1989)). In rational expectation models, unanticipated money supply shocks have temporary direct effects on individual industry output. The statistical inferences from similar types of studies using aggregate data have been shown to be highly sensitive to the method of trend removal (see, for example, Krol and Ohanian (1990)). The results reported above suggest that the appropriate detrending method may differ depending on the particular industry under investigation. The Gauger (1988) and Kretzmer (1989) papers do not take into account the different trend properties of individual industrial production.

Third, there is increasing interest among economists in the sectorial shifts hypothesis developed by Lilien (1982) for explaining aggregate unemployment. The sectorial shifts model suggests that observed aggregate unemployment is generated when specific shocks to industry supply or demand reduce employment in a particular sector. Since labor cannot move quickly and costlessly to new jobs in other sectors, aggregate unemployment rises. The results from this paper confirm the heterogeneous nature of the trend properties of industry output. Individual industries do appear to have heterogeneous industry-specific shocks which could contribute to aggregate unemployment along the lines of the sectorial shifts hypothesis. In addition, the degree of persistence differs between industries, particularly when comparing durable and nondurable goods industries. For industries which experience mostly temporary shocks, labor reallocation to other sectors seems less likely. When industry shocks are more permanent, labor reallocation between sectors seems more likely (see Davis (1987)).

IV. Summary and Conclusions

This paper investigates the trend properties of industrial production in twenty-two U.S. industries and five comparable aggregate indices for the period January 1947 to March 1987. By using disaggregated industrial production indices in addition to aggregate data, a different picture of output trend properties emerges. We fail to reject the null hypothesis of a unit root in eight of these industries. Industrial production in oil and gas, minerals, electrical utilities, printing, chemicals, petroleum, tobacco and leather industries appear to behave like random walks, similar to aggregate industrial production. The remaining fourteen industries, which include all durable goods industries, appear to be trend stationary. The trend stationary or cyclical nature of durable goods production provides evidence consistent with standard economic theory concerning durable goods production. In general, the results suggest that the trend properties of industrial production vary considerably across U.S. industries.

To determine the size of the permanent or random walk component of individual industry production, a variance ratio was estimated. The results show a lower variance ratio for durable goods industries than nondurable goods industries. Lower variance ratios imply less persistence in output fluctuations, or in other words, a smaller random walk component. Generally, the degree of persistence in output fluctuations differs between industries.

Finally, the more aggregated the production measures, the greater the degree of persistence implied by both unit-root and variance-ratio tests.

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THE EMERGING U.S. CURRENT ACCOUNT DEFICIT IN THE 1980s: A COINTEGRATION ANALYSIS

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Abstract—This paper seeks to understand the recent history of U.S. external imbalances by identifying the "long-run tendency" of the U.S. current account balance and investigating its behavior. The procedure that is adopted is to estimate cointegrating regressions between U.S. exports and imports of goods and services. Estimates from cointegrating regressions between several measures of U.S. exports and imports show that up to about the end of 1983 the U.S. current account tended toward zero. Since that time, there has been an apparent structural shift resulting in a long-run tendency for a deficit in excess of $100 billion per year.

Received for publication November 3, 1989. Revision accepted for publication January 7, 1991.

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Earlier versions of this paper were presented at the 1989 meetings of the Applied Econometrics Association and the International Trade and Finance Association and before seminars at the University of Pittsburgh and the Board of Governors of the Federal Reserve. Dave DeJong deserves considerable mention for many important suggestions and much advice. Asatoshi Maeshiro and Stanko Racic made several helpful comments. Craig Hakkio graciously supplied software needed to conduct several tests. I also would like to acknowledge the many insightful comments of several anonymous referees. Their input helped substantially to improve both the content and exposition of the paper. The usual proviso applies.

LINKED CITATIONS

Trends, Random Walks and Persistence: An Empirical Study of Disaggregated U.S. Industrial Production
Robert Krol
The Review of Economics and Statistics, Vol. 74, No. 1. (Feb., 1992), pp. 154-159.
Stable URL:
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[Footnotes]

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Permanent and Transitory Components in Macroeconomic Fluctuations
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