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Capacity utilization in the USA and inflation: testing for cointegration and Granger causality

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This paper investigates the long-run and short-run dynamics between capacity utilization and inflation in the USA by using cointegration and error-correction models. It employs monthly data from January 1984 to December 1994. Although each variable in level is found non-stationary by unit root tests, ADF tests and error-correction models fail to confirm any long-run association between capacity utilization and inflation. Despite a lack of cointegration, error-correction models have been utilized to identify Granger causality that has been found to run from total industrial capacity utilization to inflation.

I. INTRODUCTION

Historically, high industrial capacity utilization, on average, preceded inflation in the past. But recent evidence does not tend to support this hypothesis. The US economy is now near its full capacity, but inflationary pressure remains subdued at around 3-4% per year, presumably due to the successful soft landing of the economy. This has sparked a lively debate in recent years about the relevance of high capacity utilization to inflation. When the capacity utilization rate peaks to the 84–85% range, production bottlenecks start appearing and labour shortages tend to develop. Both cause price levels to rise. In order to control inflation capacity utilization should be below 85% (Citicorp, 1994; Davies, 1994; Epstein, 1994).

The hypothesis that high capacity utilization is inflationary is a variant of the traditional Keynesian theory. According to this theory, the non-linearity in aggregate supply implies that the relationship between price and output responds to demand shifts on the level of real output or the level of overall resource use in the economy. When capital and labour are underemployed, firms are willing to increase supply of output to meet excess demand without raising output prices because in such circumstances wages and rents are likely to remain unchanged. Once capacity utilization reaches 85% level, wages and rents will tend to rise. Firms will now be willing to meet additional demand by producing more only if they can charge higher prices to cover additional unit production costs. Once the economy nears full capacity, aggregate output will stay the same and price pressure will build up because of rising wages and rents in tighter labour and capital markets. But the price pressure can be neutralized in part by the use of new technology, rightsizing of the firm and productivity enhancement (Aiyagari, 1994; Kydland and Prescott, 1991; Harper and Myers, 1994; and Finn, 1995). The relationship between capacity utilization and inflation, is on average positive, as the theory asserts. But it appeared to be negative due to oil price shocks during 1973–74 and 1979.

Most of the previous studies examined the causal relationship between industrial or manufacturing capacity utilization and inflation. But this study investigates the causal relation of inflation to total industrial capacity utilization, total manufacturing capacity utilization, durables capacity utilization, and non-durables capacity utilization. It also uses cointegration and error-correction models for estimation purposes.

The primary purpose of this paper is to investigate the long-run and short-run dynamics between capacity utilization and inflation. To accomplish this objective, it applies cointegration and error-correction models because they are better suited to distinguish between short-run and long-run dynamics. The remainder of the paper proceeds as follows. Section II outlines the empirical methodology. Section III reports the results. Finally, Section IV summarizes the results and offers conclusions.

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II. EMPIRICAL METHODOLOGY

A relatively new statistical procedure using cointegration and error-correction models has been applied in this paper. It is outlined as follows:

$$x_t = \alpha_0 + \alpha_1 y_t + z_t \qquad (1)$$

where x_t = the dependent variable, y_t = the independent variable and z_t is the stochastic error term. x_t and y_t are cointegrated of order d (i.e. $I(d)$) if the time-series data on x_t and y_t have to be differenced d times to restore stationarity. For $d = 0$, x_t and y_t are stationary in levels and no differencing is necessary. Again, for $d = 1$, first differencing is needed to induce stationarity.

First, following Engle and Granger (1987) the time-series property of each variable is examined by unit root tests. For unit root tests, the following equations are considered:

$$x_t = \mu + \beta T + \alpha x_{t-1} + \sum_{i=1}^{k} c_i \Delta x_{t-i} \qquad (2)$$

$$y_t = \theta + \pi T + \psi y_{t-1} + \sum_{i=1}^{k} d_i \Delta y_{t-i} \qquad (3)$$

Each time series has non-zero mean and non-zero drift. That is why the estimation should include both a constant term and a trend term in each specification. The relevant null hypothesis is that $|\alpha| = 1$ or $|\psi| = 1$ against the corresponding alternative hypothesis that $|\alpha| < 1$ or $|\psi| < 1$. A failure to reject the null hypothesis would imply that each time series is non-stationary at the level and that stationarity can be induced by first differencing of the level data. Recently, DeJong *et al.* (1992) have presented evidence that unit root tests have low power in distinguishing between the null and the alternative hypotheses.

Next, to search further for cointegration, the following ADF regression that corresponds to Equation 1 is considered:

$$\Delta z_t = a z_{t-1} + \sum_{i=1}^{m} b_i \Delta z_{t-i} + q_t \qquad (4)$$

The ADF test is applied on $\hat{a}$ to accept or reject the null hypothesis of no cointegration. The null hypothesis is rejected if the calculated pseudo t-value (ADF statistic) associated with $\hat{a}$ is greater than its critical value, provided in Engle and Yoo (1987) at various levels of significance.

If x_t and y_t are cointegrated, there must exist an error-correction representation which may take the following form:

$$\Delta x_t = \beta_1 e_{t-1} + \sum_{i=1}^{k} \phi_i \Delta x_{t-i} + \sum_{j=1}^{k} \delta_j \Delta y_{t-j} + u_{1t} \qquad (5)$$

If α_1 can be obtained from Equation 1 so that z_t can be cointegrated individually, the remaining parameters in Equation 5 can easily be estimated. Then the usual t-test can be applied for short-run or/and long-run linkages between x_t and y_t.

In Equation 5, the series x_t and y_t are cointegrated when $\hat{\beta}_1$ is not zero. It captures the short-run influence of long-run dynamics. If $\hat{\beta}_1 \neq 0$, then y_t will lead x_t in the long run. If $\hat{\delta}_j$'s are not all zero, movements in y_t will lead those in x_t in the short run. If $\hat{\phi}_i$'s are not all zero, there are short-term linkages between x_t and y_t.

The error-correction model (ECM) was first introduced by Sargan (1964) and subsequently popularized by numerous papers (i.e. Davidson *et al.*, 1978; Hendry *et al.*, 1984). It has enjoyed a revival in popularity due to the recent work of Granger (1986,1988), and Engle and Granger (1987) on cointegration. Its importance in the cointegration literature derives from the fact that if two variables are cointegrated of order 1 and are cointegrated, they can be modelled as having been generated by an ECM. The error-correction models should produce better short-run forecasts and will certainly produce long-run forecasts that hold together in economically meaningful ways. Engle and Yoo (1987) also provide a theoretical derivation to support the superior forecasting ability of the error-correction models over unrestricted VAR models. Even in the absence of cointegration, the error-correction model can produce good forecasts, especially at the larger horizons (LeSage, 1990). Furthermore, it can be used to search for Granger causality despite the absence of long-run relationship between x_t and y_t. So, there are some valid reasons to apply the error-correction model in this study.

Monthly data have been used in this study beginning from January 1984 to December 1994. The data on total industrial capacity utilization (TIC), total manufacturing capacity utilization (TMC), durables capacity utilization (DUC), non-durables capacity utilization (NDC) and the consumer price index (CPI) have been collected from various issues of the *Economic Report of the President*.

III. RESULTS

In a preliminary step, the estimates of cointegration regressions are reported in Table 1. The numerical values of $\bar{R}^2$'s reveal that very little of US inflation is explained by individual components of total industrial capacity utilization. The DW-values are also extremely low, which indicates that each cointegration regression suffers from severe positive autocorrelation. However, the associated t-value of $\hat{\beta}_1$ for each regression is statistically significant, except for that involving inflation and total manufacturing capacity utilization.

Next, unit root tests are conducted to investigate whether each variable of our current interest in levels is non-stationary or not. The test results are reported in Table 2. This shows that the null hypothesis of unit root cannot be rejected for any of the afore-mentioned variables in levels (both without trend and with trend) at the 5% level of significance. It implies, in other words, that each level variable being considered in this paper is non-stationary at 95% confidence limit.

Table 1. *Estimates of cointegration regression* ($X_t = \beta_0 + \beta_1 Y_t + \varepsilon_t$)

Definition of X and Y	β_0	β_1	DW	Adj R^2
X = CPI Y = TIC	–64.136 (–1.092)	2.3209 (3.221)	0.097	0.0672
X = CPI Y = TMC	91.4329 (1.666)	0.4144 (0.613)	0.002	0.0029
X = CPI Y = DUC	17.9067 (0.453)	1.3477 (2.711)	0.017	0.0462
X = CPI Y = NDC	420.9510 (6.377)	–3.5344 (–4.483)	0.012	0.1272

Notes: TIC = total industrial capacity utilization, TMC = total manufacturing capacity utilization, DUC = durables capacity utilization, NDC = nondurables capacity utilization and CPI = consumer price index.

Table 2. *ADF test of unit root (1984:1–1994:12)*

Variable	ADF without trend	ADF with trend	Number of lags
TIC	–1.33708	–1.63453	4
TMC	–1.3879	–1.41237	4
DUC	–1.22006	–1.43499	4
NDC	–1.59496	–1.54344	4
CPI	0.5856	–1.950	4

Note: critical value at 5% level of significance is –3.410 (with trend) and –2.8600 (without trend).

Table 3. *Cointegration tests based on ADF procedures*

X_t	Y_t	ADF statistics	DW	Adj R^2
CPI	TIC	–1.232 (2)	2.004	0.0016
CPI	TMC	–1.443 (5)	1.974	0.066
CPI	DUC	–1.458 (4)	2.000	0.1498
CPI	NDC	–1.581	1.988	0.0331

Note: The critical values of ADF statistics as reported in Engle and Yoo (1987), for 100 observations are –3.17 and –2.91 at 5 and 10% levels of significance respectively.

Table 4. *Simple Granger causality tests*

Dependent	Constant	ΔX_{t-1}	ΔX_{t-2}	ΔX_{t-3}	ΔX_{t-4}	ΔY_{t-1}	ΔY_{t-2}	ΔY_{t-3}	ΔY_{t-4}
1 ΔX_t with change in TIC as independent variable	0.1137 (1.143)	–0.098 (–1.063)	0.0353 (0.384)	0.15912 (1.751)	0.0351 (0.384)	0.00308 (0.028)	–0.1861 (–1.718)	–0.1861 (–1.718)	–0.0457 (–0.416)
2 ΔX_t with change in TMC as independent variable	0.104486 (1.319)	–0.00651 (–0.075)	0.0792 (0.903)	0.218 (2.507)		0.5525 (0.557)	–0.0325 (–0.327)	–0.2374 (–2.389)	
3 ΔX_t with change in DUC as independent variable	0.1617 (0.780)	–0.04414 (–4.852)	–0.2016 (–2.062)	–0.0182 (–0.201)		–0.00453 (–0.176)	–0.01148 (–0.044)	–0.14446 (–0.557)	
4 ΔX_t with change in NDC as independent variable	0.0696 (1.258)	0.06133 (0.700)	0.01111 (0.127)			0.0468 (0.587)	–0.2115 (–2.644)		

Note: Direction of causality	F–test
1 TIC ⇒ CPI (short–run)	0.3710
2 TMC ⇏ CPI (short–run)	0.2734
3 DUC ⇏ CPI (short–run)	0.3695
4 NDC ⇏ CPI (short–run)	0.1286

The critical values of F distribution are 1.99, 2.45, and 3.48 for 10%, 5% and 1% levels of significance, respectively.
The critical values of t distribution are 1.645, 1.96, and 2.326 for 10%, 5%, and 1% levels of significance, respectively.

Given the inherent inability of unit root tests to distinguish between null and alternative hypotheses, the ADF tests are subsequently conducted as shown in Table 3. By comparing the ADF statistics for each regression with the critical values, as provided in Engle and Yoo (1987) for 100 observations, the null hypothesis of no cointegration cannot be rejected at the 5 and 10% levels of significance.

Given the low power of ADF tests and since short-run Granger causality can be tested from error-correction models despite a lack of cointegration (Bahmani-Oskooee and Payesteh, 1993), the error-correction models are estimated and the results are reported in Table 4.

Since no cointegration has been found based upon the ADF tests, the lagged error term has been excluded from each error-correction model in identifying the short-run Granger causality. Calculated t-values are reported in parentheses. Table 4 reveals that there is a short-run relation between the consumer price index and total industrial capacity utilization and that the Granger causality is from total industrial capacity to the consumer price index. The table shows further that there is no short-run

Granger causality from total manufacturing capacity utilization to the consumer price index, from durables capacity utilization to the consumer price index, or from non-durables capacity utilization to the consumer price index. It is to be noted that attempts were also made to repeat the entire exercise using the wholesale price index as the dependent variable. But this did not yield any better results, so they have not been reported here.

IV. SUMMARY AND CONCLUSIONS

Based upon unit root tests, each variable in level is found non-stationary at the 5% level of significance. But the ADF tests cannot confirm at 5 and 10% levels of significance that each pair of variables is cointegrated. For tracing short-run Granger causality, the error-correction models have been estimated excluding the lagged differenced error term. The results show that causality runs only from total industrial capacity utilization to consumer price index. The individual components of total industrial capacity utilization do not contribute to inflation to any notable extent.

The short-run relation between total industrial capacity utilization and inflation is on average positive. But there is no solid evidence to substantiate any long-run association between the two variables. Again, in terms of short-run Granger causality, total manufacturing capacity utilization or durables capacity utilization or non-durables capacity utilization has no significant bearing on overall inflation in the USA. This phenomenon can be explained by a combination of factors such as the introduction of new technologies, downsizing of companies, labour productivity enhancement, globalization of the economy, the Federal Reserve Bank's success in managing a soft landing of the economy, etc.

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