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Presence of Persistence in Industrial Production: The Case of India

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Abstract

This paper tests for the presence of persistence in Indian industrial production. Persistence implies the existence of a unit root in the series. We therefore employ the augmented Dickey Fuller test as well as the Phillips Perron test. We also use the Bayesian framework which is superior to the classical procedure. Our results generally support the existence of a unit root thus differing from findings of earlier studies. The existence of persistence in industrial output has important policy implications.

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1. INTRODUCTION

Persistence implies the continuation of a process. A shock distorts the normal functioning of an economy or of a system by destabilising its macroeconomic fundamentals. Shock persistence therefore invokes the question of stability of the relevant variables as well as of other correlated variables in the system. Since persistence implies a process, its continuity may be transitory, or a short-run phenomenon, i.e. weak persistence. If the process prolongs and the shock accumulates, the variable has a permanent component or that the shock has an enduring impact on the historical trajectory of the series. Theoretically, this reflects the feature of strong persistence.

The theory of persistence has witnessed a long evolution over two centuries and has its origins in the theory of business cycles. Classical economists believed that regular cycles did not exist and that any instability in the system could be explained by short-run price stickiness. Several recent studies (e.g. Nelson and Plosser, 1982; Prescott, 1986; Clark, 1987; Christiano and Eichenbaum, 1988), however, show that regular cycles indeed exist and that the instability in or the deviation from the system cannot always be explained by short-run price stickiness. The cycles, in fact, can leave a permanent impact on the historical trajectory of variables which thus exhibit strong persistence. Strong persistence in output is generally attributed to supply factors while weak persistence is believed to be demand driven.

Demand shocks or shocks to aggregate demand are caused mainly by changes in taxes, government expenditure, money supply, investment or consumption spending. On the other hand, supply shocks (which may be either domestic or foreign) can be a result of productivity or technology shocks (see e.g. Prescott, 1986; Blanchard and Quah, 1989; Durlauf, 1989) or natural disasters such as bad harvests etc. In this case most macroeconomic disturbances are non-monetary. Though demand shocks are generally believed to have short-run and medium-run effects on real output and supply shocks a long-run effect, contradictory views also exist regarding this distinction (see e.g. Sharma and Horvath, 1997). Despite these controversies, economists and policy makers usually associate a transitory component with the demand shock and model the series with a deterministic trend while the permanent component is associated with a supply shock and modelled as possessing a stochastic trend.

Since high persistence reflects the presence of a permanent component, the shock comes mainly from the supply component, e.g. technological stagnation, inefficient and inadequate investment, etc. Thus high persistence calls for a supply management policy. One may also infer that high persistence is in fact indicative of successful demand management policy. For example, Durlauf (1989) notes that high persistence in the post-war US GNP indicates that demand management policy was successful during this period. Hence strong persistence questions the appropriateness of countercyclical policy. When movements in output are largely permanent, the costs and benefits of policy actions are far different from when movements are transitory. The price of higher or lower output over the entire future path of the economy, must, therefore, be weighed in the policy calculus.

Thus it is evident that testing for the presence of a shock, or the presence of persistence aims at identifying the possible source of fluctuations of different macroeconomic aggregates. Earlier studies for India report conflicting findings on the presence of persistence. For example, Krishnan and Sen (1992) do not find evidence of persistence in industrial production. Patnaik (1981) and Ahluwalia (1985), on the other hand, support the existence of a unit root in industrial output. Clearly, given the contrasting policy implications, there is a critical need to retest the hypothesis of existence of persistence in output.

Section 2 summarises the findings of earlier studies and describes the data. Section 3 outlines the tests for the presence of persistence. Section 4 reports the empirical results and Section 5 discusses the main conclusions and implications of the results.

2. EVIDENCE ON PERSISTENCE IN INDUSTRIAL OUTPUT

In the Indian context few attempts have been made to test for the presence of persistence. These include studies by Krishnan et al. (1992), Upadhyay (1992) and Krishnan and Sen (1995). Covering the sample from January 1955 to December 1989, Krishnan et al. test for nonstationarity in four macro time series - M1, M3, CPI for industrial workers and the index of industrial production (IIP). Using the Dickey- Fuller and Said-Dickey tests, they find that while unit roots are present in M1, M3, and CPI, IIP is stationary. In a similar study, Upadhyay (1992) taking the sample from January 1982 to December 1991 complements the results of Krishnan et al. and reports that IIP in fact belongs to the trend stationary class, i.e., the series concerned is stationary with a deterministic trend. Krishnan and Sen (1995) in their recent paper conclude that the IIP series is stationary.

The evidence of stationarity in these studies indicates that movements in industrial output are mainly driven by aggregate demand factors and not so much by aggregate supply factors. From a macroeconomic policy perspective, the use of both fiscal and monetary policies to counteract aggregate demand disturbances so as to stabilise industrial production may, therefore, prove to be successful (Krishnan et al., 1992).

The present study covers the period January 1957 to March 1997. It encompasses the sample periods used by the earlier three studies. For sake of comparison, we conduct the tests for the periods corresponding to these studies as well. We also include two more sub-samples, one for the post-reform period, and the other an arbitrary period (mid sixties to late seventies) to test for the causes of industrial stagnation. We therefore examine the following periods:

(i) January 1957 to March 1997 (entire period);

(ii) January 1957 to December 1989 (Krishnan et al. and Krishnan and Sen's period of study with a minor difference - their starting period is January 1955);

(iii) January 1982 to December 1991 (Upadhyay's period of study);

(iv) June 1991 to March 1997 (the period of liberalisation or the post-reform period); and

(v) January 1965 to December 1977 (an arbitrary period to test for the causes of the industrial stagnation hypothesis).

The present study also incorporates the index of industrial production for manufacturing (hereafter, IIPM) along with the general industrial production index (hereafter, IIPG). The IIPM accounts for more than 78% of the IIPG on average. It is therefore highly probable that persistence in IIPG originates from the manufacturing sector (IIPM).

Both IIPG and IIPM are collected from various issues of the *Monthly Abstract of Statistics* and the *RBI Bulletin*. Due to shifts in the base period and the change in the definitions, the IIP series contains several breaks. To obtain a running series we have spliced the series.

An important limitation of the paper is that industrial production is not truly representative of total production. In fact, industrial production accounts for less than one fourth of total production and does not include a very major component, construction activity. Another limitation is that the index of industrial production is biased towards the large industrial units, so that the index may not capture the developments in the small sectors .

3. PRESENCE OF PERSISTENCE: TESTS

The presence of persistence is studied by testing for a unit root in the industrial production. Since the presence of a unit root implies the accumulation of random innovations when the trend is stochastic, it also implies that the innovations will have a permanent impact on the historical trajectory of the series. The augmented Dickey-Fuller (1979, 1981) and the Phillips-Perron (1988) tests are used to study the presence of persistence. Further, the presence of a unit root is also examined in the Bayesian framework.

3.1 Augmented Dickey-Fuller and Phillips-Perron Tests

For the augmented Dickey-Fuller test, three equations are considered.

$$\Delta IIP_t = \alpha_0 + \alpha_1 t + \gamma IIP_{t-1} + \sum_{i=1}^{p} \beta_i \Delta IIP_{t-j} + \varepsilon_t.$$

(1.1a)

$$\Delta IIP_t = \alpha_0 + \gamma IIP_{t-1} + \sum_{i=1}^{p} \beta_i \Delta IIP_{t-j} + \varepsilon_t. \qquad (1.1b)$$

$$\Delta IIP_t = \gamma IIP_{t-1} + \sum_{i=1}^{p} \beta_i \Delta IIP_{t-j} + \varepsilon_t \qquad (1.1c)$$

The first model includes both a drift term and a deterministic trend; the second excludes the deterministic trend; and the third does not contain an intercept or a trend term. In all three equations, the parameter of interest is γ. If γ=0, the IIP_t sequence has a unit root. The estimated t-statistic is compared with the appropriate critical value in the Dickey-Fuller tables to determine if the null hypothesis is valid. The critical values are denoted by τ_τ , τ_μ , and τ for equations (1a), (1b), and (1c) respectively.

Following Doldado, Jenkinson, and Sosvilla-Rivero (1990), a sequential procedure is used to test for the presence of a unit root when the form of the data-generating process is unknown. Such a procedure is necessary since including the intercept and trend term reduces the degrees of freedom and the power of the test implying that we may conclude that a unit root is present when, in fact, this is not true. Further, additional regressors increase the absolute value of the critical value making it harder to reject the null hypothesis. On the other hand, inappropriately omitting the deterministic terms can cause the power of the test to go to zero (Campbell and Perron, 1991).

The sequential procedure involves testing the most general model first (equation 1a). Since the power of the test is low, if we reject the null hypothesis, we stop at this stage and conclude that there is no unit root. If we do not reject the null hypothesis, we proceed to determine if the trend term is significant under the null of a unit root. If the trend is significant, we retest for the presence of a unit root using the standardized normal distribution. If the null of a unit root is not rejected, we conclude that the series contains a unit root. Otherwise, it does not. If the trend is not significant, we estimate equation (1b) and test for the presence of a unit root. If the null of a unit root is rejected, we conclude that there is no unit root and stop at this point. If the null is not rejected, we test for the significance of the drift term in the presence of a unit root. If the drift term is significant, we test for a unit root using the standardized normal distribution. If the drift is not significant, we estimate equation (1c) and test for a unit root.

The null hypothesis γ=0 in the most general model (equation 1a) is tested against the critical value τ_τ. The critical values for equations (1b) and (1c) are τ_μ and τ respectively. The critical value for the test for a time trend in the presence of a unit root in equation (1) is ϕ_3. Similarly, the critical value for the test for a drift in the presence of a unit root in equation (1b) is ϕ_1. The sequential procedure is used so that if the null of unit root is rejected for the most general model, we stop at this stage. If the null is not rejected, we look at smaller models (equations 1b and 1c).

We also conduct the Phillips-Perron (1988) nonparametric test for a unit root that is valid even if the disturbances are serially correlated and heterogeneous. The test statistics are based on the Dickey-Fuller regressions but are modified so that serial correlation and possible heteroscedasticity do not affect their asymptotic regressions. This is a nonparametric test since no parametric specification of the error process is required. The critical values for the Phillips-Perron statistics are precisely those given for the Dickey-Fuller tests.

In general, the Phillips-Perron test is preferred to the ADF test if the diagnostic statistics from the ADF regressions indicate autocorrelation or heteroscedasticity in the error terms. Phillips and Perron (1988) also show that when the disturbance term has a positive moving average component, the power of the ADF tests is low compared to the Phillips-Perron statistics so that the latter is preferred. If, however, a negative moving average component is present in the error term, the Phillips-Perron test tends to reject the null of a unit root and therefore the ADF tests are preferred.

3.2 Unit Roots in a Bayesian Framework

Since the influential paper of Sims (1988), the Bayesian technique to test for unit roots has drawn enormous attention among empirical researchers. Bayesians frequently criticise the classical hypothesis testing procedures, arguing that the relevant question should be: How probable is a hypothesis relative to other competing hypotheses? The classical econemetricians cannot give the probability that a hypothesis holds. What they can tell us is whether a hypothesis is rejected or not rejected (Koop, 1992).

When the testable hypothesis is the presence of a unit root, Bayesian methods are generally preferred to the traditional tests. This is because most traditional unit root tests have extremely low power, especially against trend stationary alternatives (DeJong, Nankervis, Savin, and Whiteman, 1988). Moreover, the presence of unit roots complicates statistical inference in the classical approach since the OLS estimators and their corresponding statistics have nonstandard asymptotic distributions in the presence of unit roots and standard distributions without unit roots. Sims (1988) argues that Bayesian inference regarding parameters of linear time series models conditional on a Gaussian distribution of the error terms is straightforward even when a unit root is present. The likelihood, and therefore the posterior p.d.f. for a flat prior is Gaussian in shape regardless of whether there are unit roots. Further, while the classical inference is sharply affected by the presence of a trend and drift term, the Bayesian flat prior theory is not (Sims, 1988).

In general, Bayesian methods take the data as given but assume that the true parameter is random. Classical methods, on the other hand, regard the true parameter of interest as unknown and fixed and examine the behaviour of the estimator in repeated samples. Bayesian inference depends on the given sample and the posterior distribution that varies with the product of the likelihood function and the prior distribution. The form of the likelihood function is based on the probability distribution that underlies the data. The prior distribution of the unknown parameter can be specified in various ways. When there is no a priori belief regarding the distribution of the parameter, a diffuse or noninformative prior is used such that the variance of the prior distribution increases without an upper bound.

Often, a uniform distribution is used to represent the ignorance over the parameter space. This is known as the flat prior. A flat prior does not change much over the region in which the likelihood is appreciable. An alternative, following Jeffreys (1961) is the ignorance prior that represents complete ignorance about the distribution of the parameter. The ignorance prior takes into account the information content of the sample variance of the regressor (Jeffreys, 1961). This information content grows as the number of observations increase and at a geometric rate when the autoregressive coefficient is greater than one.

For stationary time series, the results from Bayesian methods using diffuse priors generally conform with classical procedures (see e.g. Jeffreys, 1961; Lindley, 1965; Zellner, 1971). The results, however, differ in the case of nonstationary time series and depend on the choice of the noninformative prior (Sims, 1988). Phillips (1991) uses the Nelson and Plosser (1982) database to illustrate that the ignorance prior yields results that are consistent with classical methods, i.e. most U.S. economic time series are indeed nonstationary as reported by

Nelson and Plosser. The flat prior, on the other hand, produces results that deviate from these conclusions and is generally biased towards stationary models. Phillips also argues that the flat prior is indeed informative since in the equation $y_t = \rho y_{t-1} + \varepsilon_t$ the data have more information about ρ than say, about β in the regression model $y_t = \beta y_{t-1} + \varepsilon_t$. Phillips therefore supports the ignorance prior.

Kim and Maddala (1991) note that the relevant question is not one of the existence or nonexistence of a unit root but of using an appropriate prior for the autoregressive coefficient. On the basis of their Monte-Carlo study they conclude that the flat prior leads to a posterior mean and mode that are lower than the autoregressive coefficient, ρ when ρ is close to one. The ignorance prior, however, gives greater weight to higher values of ρ and produces a bias in the other direction. This upward bias is, in fact, more than the downward bias caused by the flat prior. Kim and Maddala conclude that the ignorance prior distorts the sample evidence as summarised in the likelihood function. Further, the ignorance prior yields a bimodal posterior distribution (proportional to the product of the prior and likelihood function) with the higher mode at $\rho > 1$ even when the true value of ρ is much less than one. Leamer (1991) also argues that Jeffreys' prior favours high values of ρ in the model $y_t = \rho y_{t-1} + \varepsilon_t$. Schotman and van Dijk (1991) show that this is not the case once a trend and intercept are included. Thus the results from using Jeffreys' prior are sensitive to the formulation of the model.

Sims and Uhlig (1991) illustrate that classical hypothesis testing based on the asymmetric nonstandard distribution of the OLS estimator gives higher weight to large values of ρ. They conclude that the Bayesian procedure using the symmetric posterior distribution of the true autoregressive parameter and a simple flat prior is a better starting place for inference. Koop and Steel (1991) argue that the ignorance prior discussed by Phillips (1991) puts more emphasis on the explosive roots than on the unit root. Sims (1991) echoes this view and notes that the Jeffreys prior depends strongly on the sample size and puts increasingly greater weight on explosive models as sample size increases.

In this study we use a flat prior in the posterior odds ratio test for a unit root (see Sims, 1988 and Doan, 1992) in the equation: $IIP_t = \rho IIP_{t-1} + \varepsilon_t$. The test stastistic is the square of the conventional t-statistic for ρ=1. This is compared with the Schwarz criterion which has an asymptotic Bayesian justification and is considered as the asymptotic Bayesian critical value. This is approximately given by:

$\tau = 2\log(1-\alpha)/\alpha) - \log(\sigma^2_\rho) + 2\log(1-2^{-1/s})$

where $\sigma^2_\rho = \sigma^2 / \Sigma IIP(t-1)^2$, σ^2 is the variance of ε_t and for monthly data s = 12.

'Alpha' gives the prior probability on the stationary part of the prior; the remaining probability is concentrated on ρ = 1. The choice of the prior weight α can have a significant effect on the statistic given above. 'Marginal Alpha' is the value for alpha at which the posterior odds for and against the unit root are even. A higher value of 'marginal alpha' favours the presence of unit root. Since the first and last terms in the expression for the critical value are constant for a given prior and data, a small τ favours no unit root. Therefore if t^2 is greater than τ, we reject the null hypothesis of a unit root.

Sims (1988) notes that it may not be reasonable to treat the prior as uniform over (0,1). Instead, we are interested in the case when the likelihood is concentrated somewhere near one. A lower limit for the stationary part of the prior is also specified such that the prior for ρ is flat on the interval (lower limit, 1.0). The concentration of the prior around 1 increases with the frequency of the data. If the prior is concentrated on (0.5, 1) for annual data, then for monthly data it is on (0.94, 1) where $0.94=0.5^{1/12}$. According to Sims (1988), α = 0.8 is a reasonable choice since for this level the odds between stationarity and the presence of a unit root are approximately even.

4. EMPIRICAL TESTS FOR THE PRESENCE OF PERSISTENCE

Sequential testing is reported in Tables 1a and 1b. The sequential ADF tests display the presence of a unit root for both IIPM (manufacturing) and IIPG (general index) over most of the periods with the exception of 1982-91 for both series and the post-reform period for IIPM. The PP test, on the other hand, rejects the null of a unit root for both series and for all time periods. Monte-Carlo studies by Phillips and Perron (1988) and Schwert (1989), however, show that if negative moving average terms are present in the disturbance terms, the PP test tends to reject the null of a unit root and therefore the ADF test is preferred. Since in most cases we find evidence of negative moving average terms, the ADF results are preferred.

The Bayesian tests based on $\alpha = 0.8$ and lower limit = 0.5 are reported in Tables 3a and 3b. For both manufacturing and the general index , t^2 is less than the Schwarz limit (τ) over the periods 1957-97 and 1957-89. The 'marginal alpha' are above 0.9 for both periods. Therefore, the presence of unit root cannot be rejected. Although the values of marginal alpha are lower for the remaining periods, the null hypothesis of a unit root cannot be rejected for the general index. In the case of the manufacturing index, however, the null of a unit root is rejected for the post-reform period. This is also corroborated by a lower marginal alpha - 0.130.

The results from the ADF, PP and Bayesian tests are summarised in Tables 4a and 4b. For most periods (with the exception of 1982:1 - 1991:12) the Bayesian results correspond to the ADF conclusions.

5. CONCLUSIONS AND IMPLICATIONS

Based on the Bayesian and the ADF tests, the period 1957 - 1997 shows evidence of a unit root, or a permanent component in both IIP - manufacturing and IIP - general index. In the post liberalisation period, however, the Bayesian test shows no evidence of a unit root in IIP - manufacturing while a unit root exists in the general index series. The following inferences can be derived from these results:

- In the post-reform period the manufacturing sector benefited from the partial decontrol of prices in the 80's and complete decontrol in the 90's. Supply side disturbances, therefore, do not seem to play a major role.
- The IIPG during the post-reform period contains a unit root implying that the source of the possible shock lies outside the manufacturing sector. In the pre-reform period, the persistence in IIPG can be attributed to IIPM.

Some policy and welfare implications from the macroeconomic point of view merit mention.

- The presence of a unit root in industrial production implies the presence of persistence, i.e., the movements in the IIP series are not dominated by aggregate demand factors like public investment, fiscal and monetary policies, the income distribution, etc. This contradicts the results of Krishnan and Sen (1995), Krishnan et al. (1992), and Upadhyay (1992). This implies that factors like technological innovation or capital accumulation explain movements in industrial production.
- The presence of persistence during the period January 1965 to December 1977 (arbitrary period for the industrial stagnation) also contradicts the results of earlier studies. For example, Mitra (1977), Nayyar (1978) and Patnaik (1981) conclude that demand disturbances play a major role in explaining the industrial stagnation. Our results show that supply factors may have been more important. This conclusion supports the argument of Ahluwalia (1985) who stresses the supply side factors such as technological stagnation due to the overprotection of industries and poor infrastructure management.
- Supply shocks as evidenced by the presence of persistence, are the most important source of variation in output over long periods, so that most of the observed persistence in output must be the result of persistent productivity shocks (Durlauf, 1989).
- Persistence of demand shocks in IIPM during the post-reform period suggests that the mechanism for correcting market 'failures' such as wage stickiness or the lack of coordination between savings and investment may have worked slowly.
- Demand shocks are less problematic than supply disturbances from the point of view of macroeconomic stabilisation. The demand disturbance of a given magnitude gives rise to lower aggregate welfare costs than does a supply disturbance of equal magnitude (Turnovsky and D'Orey, 1986). The presence of supply shocks over most of the sub-periods therefore implies higher aggregate welfare costs.

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Table 1a

Augmented Dickey-Fuller test for IIP - Manufacturing

	Ho: $\gamma=0$ τ_τ	Ho: $\gamma=\alpha_1=0$ ϕ_3	Ho: $\gamma=0$ τ_μ	Ho: $\gamma=\alpha_0=0$ ϕ_1	Ho: $\gamma=0$ τ
Critical Values: 10% 5%	 -3.13 -3.41	 5.34 6.25	 -2.57 -2.86	 3.78 4.59	 -1.62
1957:1-1997:3	-2.295	2.635	-0.332	9.189	
1957:1-1989:12	-2.132	2.311	-0.595	10.033	
1965:1-1977:12	-1.305	1.203	.0503	5.795	
1982:1-1991:12	-3.768				
1991:6-1997:3	-2.496	3.117	-.827	1.534	1.52

Note: Critical values are from Dickey and Fuller (1981).

Table 1b

Augmented Dickey-Fuller Test for IIP - General Index

	Ho: $\gamma=0$ τ_τ	Ho: $\gamma=\alpha_1=0$ ϕ_3	Ho: $\gamma=0$ τ_μ	Ho: $\gamma=\alpha_0=0$ ϕ_1	Ho: $\gamma=0$ τ
Critical Values: 10% 5%	 -3.13 -3.41	 5.34 6.25	 -2.57 -2.86	 3.78 4.59	 -1.62
1957:1-1997:3	-2.046	2.094	-0.180	13.456	
1957:1-1989:12	-2.137	2.400	-.742	13.015	
1965:1-1977:12	-1.400	1.041	.113	9.410	
1982:1-1991:12	-3.690				
1991:6-1997:3	-2.471	3.822	0.488	2.360	2.14

Table 2a

Phillips-Perron Test for IIP - Manufacturing

	Ho: γ=0 τ_τ
Critical Values: 10% 5%	 -3.13 -3.41
1957:1-1997:3	-7.950
1957:1-1989:12	-6.500
1982:1-1991:12	-7.473
1965:1-1977:12	-7.081
1991:6-1997:3	-5.838

Table 2b

Phillips-Perron Test for IIP - General Index

	Ho: γ=0 τ_τ
Critical Values: 10% 5%	 -3.13 -3.41
1957:1-1997:3	-7.911
1957:1-1989:12	-6.619
1982:1-1991:12	-7.565
1965:1-1977:12	-7.483
1991:6-1997:3	-4.759

Table 3a

Bayesian Unit Root Test for IIP - Manufacturing

(*limit* = *.5*, *alpha* = *.8*)

Years/Test Statistics	Squared t	Schwarz Limit	Marginal Alpha
1957:1-97:3	1.139	10.388	0.953
1957:1-89:12	1.146	10.147	0.947
1965:1-77:12	3.304	7.053	0.565
1982:1-91:12	3.129	7.150	0.640
1991:6-97:3	5.748	5.183	0.130

Table 3b

Bayesian Unit Root Test for IIP - General Index

(*limit* = *.5*, *alpha* = *.8*)

Years/Test Statistics	Squared t	Schwarz Limit	Marginal Alpha
1957:1-97:3	0.678	10.845	0.969
1957:1-89:12	0.791	10.484	0.962
1965:1-77:12	1.867	7.565	0.775
1982:1-91:12	3.345	6.818	0.531
1991:6-97:3	2.975	5.661	0.433

Table 4a

Summary of Results: IIP Manufacturing Index

Sample span	ADF	PP	Bayesian
1957:1 - 1997:3	Y	N	Y
1957:1 - 1989:12	Y	N	Y
1982:1 - 1991:12	N	N	Y
1965:1 - 1977:!2	Y	N	Y
1991:6 - 1997:3	Y	N	N

Note: 'Y' denotes presence of unit root and 'N' no unit root.

Table 4b

Summary of Results: IIP General Index

Sample span	ADF	PP	Bayesian
1957:1 - 1997:3	Y	N	Y
1957:1 - 1989:12	Y	N	Y
1982:1 - 1991:12	N	N	Y
1965:1 - 1977:!2	Y	N	Y
1991:6 - 1997:3	Y	N	Y

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