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Terms of Trade and Supply Response of Indian Agriculture: Analysis in Cointegration Framework

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Abstract

In this paper, we examine the presence of stochastic trend (unit root) and structural break in various agriculture-industry terms of trade series in India. The results suggest that underlying data generating process of terms of trade are most likely non-stationary. We subsequently re-examine the aggregate supply response of Indian agriculture in this light. We investigate the presence of long-run functional relationship(s) underlying the supply response model through cointegration analysis and error correction framework. The multivariate results indicate presence of a cointegrating relationship in the supply response model. The vector error correction estimates suggest that short-run output adjustments are not related to changes in agricultural terms of trade in a temporal causal relationship. However, the short-run deviations in terms of trade from its long-term level create error-correction in the long-term output adjustments through changes in technology (irrigation). This may imply that agricultural growth can respond better if price incentives are combined with investments in irrigation.

JEL Classification: Q11, C22, C32
Keywords: domestic terms of trade, agricultural supply response, unit root, cointegration

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1. Introduction

This paper examines the time series properties of domestic (agriculture-industry) terms of trade (hereafter TOT) in India. A number of studies have examined the data generating process of net barter TOT (NBTOT) between less-developed and developed countries[1], but the possibility of a stochastic trend in domestic NBTOT series has not received much attention. However, many researchers, viz. Krishnan et al [1992], Upadhyay [1992], Sharma and Horvath [1997] and Samanta and Mitra [1998] have found random-walk features in several aggregate price series that are used to construct domestic (agriculture-industry) TOT indices in India, such as wholesale prices, consumer prices or implicit GDP deflators. Recently, Ravallion [1998 a] has claimed that the relative food price variable in India can be represented as an integrated process. It therefore seems appropriate to undertake a rigorous analysis of the time series properties of domestic TOT.

The distinction between deterministic and stochastic trend (unit root) models has considerable bearing for understanding the time series behaviour of TOT. The unit root issue encompasses determining whether random shocks in the economy bear a permanent or temporary impact on TOT fluctuations. If a macro variable is characterised by unit root process, it implies that regular shocks in the economy will produce significant and long-lived effects on the level of the series (Nelson and Plosser 1982, Robertson and Wickens 1997, Gil-Alana and Robinson 1997, Murray and Nelson 2000). The shock persistence feature imparts a tendency for the variable not to return to its long-run trend and instead drift apart over time. A stochastic trend property therefore has certain implications for the usefulness of stabilisation policies targeted towards controlling domestic TOT fluctuations.

The presence or absence of unit root is also of importance in empirical models based on time series data, where the TOT is a significant explanatory variable, such as the models that examine its relationship with supply response, private investment or government expenditure in agriculture, etc.[2] The underlying data generating process of agricultural TOT has been assumed to be stationary

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[1] This include analysis by Spraos [1980], Sapsford [1985], Thirlwal and Bergevin [1985], Grilli and Yang [1988], Cuddington and Urzua [1989], Perron [1990], Powell [1991], Ardeni and Wright [1992], Zivot and Andrews [1992], Sapsford, Sarkar and Singer [1992], Bleaney and Greenaway [1993], Reinhart and Wickham [1994], Sarkar [1994], Sapsford and Balasubramanyam [1994, 1999], Trivedi [1995], Leon and Soto [1995], Newbold and Vougas [1996], Sapsford and Chen [1999], Maizels et al [1998], Chen and Stoker [1998], Lutz [1999] and Bloch and Sapsford [1998, 2000]. The focus in these works involved examining aspects of long run trend, volatility and structural breaks in the NBTOT series.

[2] Refer Deb [2002 a] for a review of various models involving agriculture-industry TOT in India.

(absence of a unit root) in almost all the earlier studies. However, in case this assumption is not valid, standard asymptotic distribution theory can not be used for the purpose of drawing inference. Because traditional regression analysis in models that include variables with unit root can produce "spurious" or "crazy" regression result (Granger and Newbold 1974, Plosser and Schwert 1978, Phillips 1986, Favero 2001). Using this argument, Ravallion [1998 a] has in fact claimed that the notion of a positive statistical association between relative food price and rural poverty in India may be due to a contemporaneous correlation.

In this background, this paper proposes, perhaps for the first time, to examine the hypothesis of supply response in Indian agriculture by employing the cointegration procedure in both bivariate and multivariate framework. The rest of the paper proceeds as follows. The testing procedures for the presence of unit root in a series as well as the limitations of these tests are discussed in section 2. The test results on time series properties of various constructed series on agricultural NBTOT in India are provided in section 3. In consequence to our finding that TOT series has a unit root, some general implication of the unit root feature are discussed in section 4. Section 5 provides a brief review of the previous agricultural supply response analysis. In section 6, we provide a description of the variables and data involved in the present analysis. Section 7 re-examines the agricultural supply response model by employing the bivariate and multivariate cointegration frameworks as per Engle-Granger [1987] and Johansen and Juselius [1990] methodologies, respectively. It may be noted that an exact replication of previous agricultural supply response models using cointegration techniques is not feasible, because the procedures for unit root and cointegration tests are valid only for large samples and the error-correction estimation requires that degrees of freedom should be retained in the system. Hence, our model includes only those variables, which are basic to the system and for which long time series data, are available. Section 8 provides the results of modelling the agricultural supply response in the vector error-correction (VEC) framework. Section 9 summarises.

2. Tests for Presence of Unit Root

Although it has become almost necessary to pre-test for the presence of unit root in applied econometric works, this by no means is a simple exercise. Because, the tests are known to have limitations to discriminate between a unit root and an auto-regressive root that is close to but less than one. As a result, it has not been possible to resolve the difference between a data generating process that is stationary but with strong auto-regressive cycles from one which is purely a non-stationary process. The differentiation between a trend stationary (TS) and difference stationary (DS) representations through statistical tests has remained rather inaccurate, though in principle there is a clear distinction between these two alternatives (Rudebusch 1993, Diebold and Senhadji 1996). It has rather been found that any TS process can be approximated well by a unit root process and any unit root process can similarly be approximated by a TS process, particularly in smaller sized samples. Thus, it has been argued that application of unit root tests without considerations for their low power and for the restrictions that they inevitably impose in a finite sample can in fact be misleading (Cochrane 1991).

2.1. Unit Root Process

The most common approach in determining the trend of sectoral TOT in India has been to estimate an exponential trend line, viz.

$$\ln TOT_t = a + bT + e_t$$

and interpreting a sustained improvement (or deterioration) in TOT depending on whether b > 0 (or b < 0). The statistical behaviour of a random walk (non-stationary process) is different from a stationary data series. The definition of a (weakly) stationary stochastic process for TOT_t requires that: $E[TOT_t]$, Var $[TOT_t]$ and Covar $[TOT_t, TOT_{t+n}]$ are constant for all t. The fluctuations in a stationary series are therefore temporary in nature, and the series can be expected to return to its long run equilibrium level after the effect of random economic shock dies down. On the contrary, both the first and second moments (mean, variance and auto-covariance) of a non-stationary process are not time invariant. Therefore, the future path of a non-stationary variable is known to depend on its previous values, which are acquired from past consequences. As a result, it may drift apart over time and reveal *random walk* behaviour.

It is therefore necessary to take into account the possibility that the underlying (but of course, unknown) data generating process of TOT_t may contain a unit root (due to the presence of stochastic trend). To clarify how the data generating process (DGP) could generate a unit root sequence, consider a first-order auto-regressive (AR-1) scheme for TOT, viz.

$$TOT_t = a_1 TOT_{t-1} + e_t \qquad (1)$$

or, $\Delta TOT_t = b_1 TOT_{t-1} + e_t$, where $b_1 = (a_1 - 1)$

That is, TOT_t is determined by its initial values and a disturbance term, which is a random number with zero mean and unit variance. Now, stationarity requires: $|a_1| < 1$ (or $b_1 < 0$). In other words, if the relevant null hypothesis: $|a_1| = 1$ (or $b_1 = 0$) is accepted, then it is referred as an AR (1) model with unit root.

2.2. Testing Procedure

There are several ways of testing for the presence of unit root (Maddala and Kim 1998, Hayashi 2000, Patterson 2002). We discuss a few of those, which have achieved widespread usage in applied time-series econometric literature.

Dickey-Fuller (DF) Test: The Dickey-Fuller [1979] test can be applied for the first-order auto-regressive model that includes both the drift and linear time trend (t), viz.

$$\Delta TOT_t = b_0 + b_1 TOT_{t-1} + b_2 t + e_t \quad (2)$$

To test for the presence of unit root in (4.2), we test the null hypothesis H_0: $b_1=0$, against H_a: $b_1<0$ with the left-sided critical region and referring to the critical values provided in the τ_τ table.

Augmented Dickey-Fuller (ADF) Test: The augmented Dickey-Fuller [1981] test controls for serial correlation by adding lagged first-differences to the auto-regressive equation. The application of ADF test has been discussed for problems arising due to the deterministic part of regression and selection of appropriate lag lengths (Campbell and Perron 1991, Enders 1996, Harris 1995). These considerations have indicated that the *power* and *size* properties of ADF test may be low due to any inappropriate specification of the ADF regression. As a result, the application of a sequential procedure has often been suggested while implementing the ADF test. We discuss the sequential testing procedure outlined in Enders [1996].[3]

The step by step testing procedure involves considering 3 different regression equations for the TOT_t sequence, viz.

$$\Delta TOT_t = b_0 + b_1 TOT_{t-1} + b_2 t + \Sigma_i c_i \Delta TOT_{t-i} + e_t \quad (3.1)$$

$$\Delta TOT_t = b_0 + b_1 TOT_{t-1} + \Sigma_i c_i \Delta TOT_{t-i} + e_t \quad (3.2)$$

$$\Delta TOT_t = b_1 TOT_{t-1} + \Sigma_i c_i \Delta TOT_{t-i} + e_t \quad (3.3)$$

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[3] The decision tree provided in Enders [1996] is a modified version of the procedure originally suggested by Dolado, Jenkinson and Sosvilla-Rivero [1990]. This sequential testing procedure has not only been considered more logical but also achieved widespread usage.

Both the drift and deterministic trend terms are included in (4.3.1). Equation (4.3.2) leaves out the deterministic trend, whereas (4.4.3) does not include any intercept or trend terms. To examine the presence of unit root, we test the null hypothesis H_0: b_1=0, in all the three equations. The null hypothesis in the least-restrictive model (3.1) is tested by using the τ_τ statistics. If the null of a unit root is rejected, we conclude that TOT_t sequence is not a unit root process. If the null is not rejected, we test for the significance of trend term (b_2) under the null of a unit root by using the $\tau_{\beta\tau}$ statistics. A joint F-test for the hypothesis H_0: $b_1=b_2=0$, can also be performed by using the Φ_3 statistics to gain additional information. If the trend term is significant, we retest for the presence of a unit root by using the normal distribution. If the null of a unit root is rejected, we conclude that the TOT_t series is stationary, otherwise the TOT_t series contains a unit root. When the trend is found to be insignificant in (4.3.1), we estimate (4.3.2) to test for the presence of a unit root by using the τ_μ statistics. If the null is rejected, we conclude that the model does not contain a unit root. If the null of a unit root is not rejected, we test for the significance of the constant (b_0) given b_1=0, by using the $\tau_{\alpha\mu}$ statistics. Additional confirmation of the results can be obtained by testing the hypothesis H_0: $b_0=b_1=0$, by using the Φ_1 statistics. If the drift term is significant, we again test for the presence of a unit root in the same model by using the normal distribution. As before, if the null hypothesis of a unit root is rejected, we conclude that the TOT_t series does not contain a unit root, otherwise the TOT_t series is non-stationary. If the drift is found to be insignificant in (3.2), we use a model without the trend or drift (3.3), and use the τ statistics to test for the presence of a unit root. If the null hypothesis is rejected, we conclude that the TOT_t sequence does not contain a unit root, otherwise the TOT_t is a unit root process.

Phillips-Perron Test: One possible weakness in the DF and ADF tests has been that their underlying distribution theory assume that residual errors are statistically independent and have a constant variance. Therefore, care must be taken to ensure that the error terms are free from serial correlation and heteroscedasticity in these tests. Alternatives approach by Phillips [1987], Perron [1988] and extended by Phillips and Perron [1988] developed test statistics, which involves less-restrictive assumptions on the error process. In this test, a non-parametric correction of the test statistics is carried out to take care of the serial correlation in case the underlying DGP is not an AR-1 process. In this case, the hypotheses: H_0: $b_1 = 0$ and H_0: $b_1 = b_2 = 0$ are tested by using τ_τ and Φ_3 statistics and referring to the critical values of DF tables.

Kwiatkowski, Phillips, Schmidt and Shin (KPSS) Test: It is argued that testing the null of unit root against the alternative of stationarity should necessarily be corroborated with a simultaneous application of a test, where the null hypothesis is that of the stationarity against the alternative of a unit root (Charemza and Syczewska 1998, Maddala and Kim 1998). Stationarity tests of this kind have been developed by Kwiatkowski et al [1992], Leyborne and McCabe [1994], and others. The basic idea behind such tests has been to seek for a confirmation of the evidence suggested by standard ADF and PP tests. That is, when both the group of tests agree on the nature of the stochastic process, one can reach a conclusive answer about the random walk behaviour. Among this category of unit root tests, the one suggested by Kwiatkowski et al [1992], commonly referred to as KPSS test has been widely used in applied works. Kwiatkowski, et al [1992] maintained that the standard practise of taking the null hypothesis to be I (1) rather than I (0), might itself have led to a bias in favour of the unit root hypothesis. They therefore proposed an I (0) test, which define the null as a zero variance in a random walk model.

Perron's Test Allowing for Structural Change: The presence of a *structural break* in the deterministic trend of a series has often been argued to lead to misleading conclusions on unit root tests. It has been claimed that in case there is a structural break in the series, both ADF and PP test statistics are biased towards non-rejection of the unit root hypothesis when in fact there is no unit root (Perron 1989, Rapport and Reiciline 1989). In fact, Perron's [1989] result suggested that contrary to the claim by Nelson and Plosser [1982], macro economic variables are trend stationary processes with structural break(s).[4]

Perron [1989] considered a one time change occurring at time T_B ($1 < T_B < T$) in the structure of a given series of size T+1. Here, T_B refers to the time of break, i.e. when a change is noticed in the parameters of trend function. Out of the 3 different models considered by him, the first model is referred to as "crash" model, which

[4] It may be mentioned that, Perron's [1989] method of testing for unit root in the presence of structural break considered only known break dates. Recent advances have considered the cases of an endogenous rather than exogenous selection of break date (Christiano 1992, Zivot and Andrews 1992, Banerjee, Lumsdaine and Stock 1992, Perron 1994, Ben David and Pappel 1995, Nunes, Newbold and Kuan 1997), and also the possibility of multiple break dates (Lumsdaine and Pappel 1997).

allows a one-time change in the intercept of trend function. The second model referred to as the "changing growth" model considers a change in the slope of trend function. The last model simultaneously allowed both the effects, viz. a sudden change in the level followed by a different growth path. The 3 models are as follows:

$$\Delta TOT_t = b_0 + b_1 TOT_{t-1} + b_2 t + \Sigma_i c_i \Delta TOT_{t-i} + d_1 D(T_B)_t + d_2 D(U)_t + e_t \quad (4.4.1)$$

$$\Delta TOT_t = b_0 + b_1 TOT_{t-1} + b_2 t + \Sigma_i c_i \Delta TOT_{t-i} + d_2 D(U)_t + d_3 DT^* + e_t \quad (4.4.2)$$

$$\Delta TOT_t = b_0 + b_1 TOT_{t-1} + b_2 t + \Sigma_i c_i \Delta TOT_{t-i} + d_1 D(T_B)_t + d_2 D(U)_t + d_4 DT_t + e_t \quad (4.4.3)$$

where, $D(T_B)_t$ = 1 if t = T_B + 1, 0 otherwise.

$D(U)_t$ = 1 if t > T_B, 0 otherwise.

DT^* = (t - T_B) if t > T_B, 0 otherwise.

and, DT_t = t if t > T_B, 0 otherwise.

The hypotheses to be tested are: H_0: b_1=0, b_2=0, d_2=0;

H_0: b_1=0, b_2=0, d_3=0;

and H_0:b_1=0, b_2=0, d_4=0;

The unit roots proposition considering a given break in the TOT series is tenable if the null is accepted as per the critical values provided by Perron [1989].

2.3. Limitations of Unit Root Tests

While applying the unit root tests, an important problem arises in view of the poor size and power properties of the ADF and PP tests (Schwert 1987, 1989, West 1988, Christiano and Eichenbaum 1990, Cochrane 1991, Stock 1991, Campbell and Perron 1991, Blough 1992, Rudebusch 1992, 1993, Diebold and Senhadji 1996). The power and size problems signify that they have the tendency to under-reject the null when it is false, and over-reject the null when it is actually true, respectively. Further, the deterministic part of ADF regressions and selection of lag lengths have been found to make the unit root tests very sensitive. Now, there is no *a priori* reason to believe that the tests, which use trend-stationary null against the I (1) alternative (viz. KPSS 1992), are better than the usual ADF test. Maddala and Kim [1998] have in fact indicated that the KPSS variety of tests has the same poor power properties as the ADF test. Hayashi [2000] has claimed that these varieties of tests are still relatively underdeveloped, and do not have good finite-sample properties. In view of the limitations of the two families of tests, it is argued that using both the families of tests together is better than using either test alone.

3. Test Results on Time Series Properties of Terms of Trade

Several series on the agricultural-industry NBTOT that have been provided by different researchers as well as government agencies in India are included in Appendix Table: A-1.[5] The trend analyses performed by previous studies have indicated the absence of any distinct long-run trend and also trend reversions in these NBTOT series. Preliminary examination of the levels-plot and the residual-plot after de-trending indicated sufficient irregular fluctuations in all the NBTOT series. We therefore proceed to apply various unit root tests to the agricultural NBTOT series constructed by Tyagi [1987], Mungekar [1992], Palanivel [1999], Thamarajakshi [1994] and the series provided by the Commission for Agricultural Costs and Prices (CACP) at the Ministry of Agriculture (Government of India). These five NBTOT series are available for a longer time period as compared to the recent government series provided by Directorate of Economics and Statistics (Ministry of Agriculture). The longer time-span in these series improves the power of unit root tests and also allows us to test for the possibility of major structural breaks. We also consider a NBTOT series based on the ratio of implicit price deflator of agriculture to non-agriculture, which is similar to the one used by Misra and Hazel 1996 and Misra 1998.

3.1. DF and ADF Test Results

The results on the application of DF tests for the six NBTOT series are provided in Table 1. As can be seen, the null hypothesis for the existence of unit root is accepted for each and every series. The Lagrange Multiplier statistic for first order auto-regressive scheme is insignificant in most cases at 10% level of significance.

Table 1: DF Test Results for NBTOT Indices.

NBTOT Series	τ_τ (H_0: b_1=0)	LM Statistics for Serial Correlation	Inference
Critical Value (10%)	*-3.18*	*2.71*	
Tyagi Series (1952/53-1983/84)	-1.78	2.34	Accept H_0
Mungekar Series (1953/54-1980/81)	-1.42	1.26	Accept H_0
Thamarajakshi Series (1951/52-1991/92)	-1.94	0.43	Accept H_0
Palanivel Series (1950/51-1987/88)	-2.11	1.96	Accept H_0
CACP Series (1952/53-1998/99)	-2.28	1.91	Accept H_0
IPD Series (1950/51-1996/97)	-2.48	3.72	Accept H_0

Note: DF tests have been applied to different series provided in Appendix Table: A-1.

[5] See Deb [2002 a] for details on the method of construction and movements over time of various agriculture-industry NBTOT series in India, and also for a description on the use of these NBTOT series in various analytical models.

The ADF test statistics for these NBTOT series together with the details on number of lags are provided in Table 2.[6] The non-stationarity hypothesis is accepted for all the NBTOT series at 10% level of significance. Since the null of a unit root is not rejected for any of the series in the general model, we proceed to examine the stationarity property with smaller models. The null hypothesis H_0: b_1=0, is accepted for all the NBTOT series in the model without a time trend. The drift term was found to be significant in the Tyagi, Palanivel, CACP and IPD series. Finally, the null of unit root could not be rejected in the model that is estimated without the trend or drift terms. Both the DF and ADF results would indicate that various NBTOT series that have been used in the past are all unit root processes, thus carrying the attendant qualifications for estimation.

Table 2: ADF Test Results for NBTOT Indices.

NBTOT Series	Lags	τ_τ $H_0 := 0$	Φ_3 (H_0: b_1=b_2 =0)	τ_μ (H_0: b_1=0)	τ (H_0: b_1=0)	**Inference**
Critical Value (10%)		*-3.18*	*5.61*	*-2.60*	*-1.61*	
Tyagi Series	1	-2.18	2.53	2.28	-0.20	Accept H_0
Mungekar Series	1	-1.73	1.76	-1.71	-0.01	Accept H_0
Thamarajakshi Series	2	-1.26	0.85	1.30	0.39	Accept H_0
Palanivel Series	1	-2.30	2.68	-2.27	-0.39	Accept H_0
CACP Series	1	-2.63	3.46	-2.66	0.03	Accept H_0
IPD Series	2	-2.12	2.31	-1.76	0.11	Accept H_0

Note: ADF tests have been applied to different series provided in Appendix Table: A-1.

3.2. Phillips-Perron Test Results

The PP tests have been performed by using alternate models that considers the presence and absence of trend in the regression. The test statistics, τ_τ, τ_μ and τ, used to examine the unit root hypotheses (H_0: b_1=0), are provided in Table 3. The results confirm that various agricultural NBTOT series in India have a unit root.

[6] In using the ADF test, a major decision is involved with regard to the selection of lag length in the test regressions. For determining the optimal lag structure, we start with a relatively long lag length and pare down the model by using information from the usual t-test and F-test. Once the tentative lag length has been determined, diagnostic checking for serial correlation has been conducted by using the Lagrange Multiplier statistics. Finally, the adequacy of chosen lag length for each NBTOT series has also been verified using the Akaike's information criterion (AIC) and Schwartz' Bayesian criterion (SBC).

Table 3: Phillips-Perron Test Results for NBTOT Indices.

NBTOT Series	τ_τ	τ_μ	τ	Inference
Critical Value (10%)	*-3.18*	*-2.60*	*-1.61*	
Tyagi Series (1952/53 to 1983/84)	-1.98	-1.98	-0.19	Accept H_0
Mungekar Series (1953/54 to 1980/81)	-1.81	-1.97	-0.01	Accept H_0
Thamarajakshi Series (1952 to 1991/92)	-1.32	-1.35	0.38	Accept H_0
Palanivel Series (1950/51 to 1987/88)	-2.11	-2.09	-0.36	Accept H_0
CACP Series (1952/53 to 1997/98)	-2.04	-2.08	0.03	Accept H_0
IPD Series (1950/51 to 1996/97)	-2.50	-2.29	-0.08	Accept H_0

Note: PP tests have been applied to different series provided in Appendix Table: A-1

3.3. KPSS Test Results

The KPSS test results for different agricultural NBTOT series with a lag truncation parameter (l) from l= 0 to l= 4 are given in Table 4. We find that the null of stationarity is consistently rejected at each value of the lag for both Thamarajakshi and Palanivel series at 10% level of significance. The evidence for trend stationarity hypothesis with regard to the NBTOT series based on IPDs as well as CACP series is rejected at values of lag from l= 0 to l= 3, and accepted marginally only at l=4).

Table 4: KPSS Test Results for NBTOT Indices, (H_0: trend stationarity)

NBTOT Series	L=0	l=1	l=2	l=3	L=4	Inference
Palanivel Series	0.46	0.26	0.19	0.16	0.14	Reject
Thamarajakshi Series	0.64	0.35	0.25	0.20	0.17	Reject
CACP Series	0.33	0.19	0.14	0.12	0.10	Reject
Ratio of IPDs	0.31	0.17	0.13	0.11	0.10	Reject

Note: 1) The series have been used with the constant and trend model.
2) "l" represents the number of lags.
3) Significance Level (%): 0.10 0.05 0.025 0.01
Critical Value: 0.11 0.14 0.17 0.21

3.4. Perron's Test Results Allowing for Structural Break

The unit root hypothesis for agricultural NBTOT series is also examined that incorporates a *structural break* following Perron [1989]. The selection of break date(s) is exogenous and associated with major events that could have created a change in the respective trend functions of agricultural and manufacturing TOT. We have considered three alternative break dates to allow for structural break in agricultural NBTOT. These are: 1963/64 (marked by a drastic agricultural price rise due to production shortfall and otherwise bad agricultural year), 1974/75 (marked with declining agricultural prices coupled with an upward pressure in industrial prices after the *oil price shock*) and 1990/91 (the launching of major economic reforms).[7] The individual plot of different NBTOT series also makes one suspect that a structural change had occurred around these dates.[8]

The Perron's test results for various NBTOT series are provided in table 5. Note, however, that these procedures are valid only for large samples, so that their application to the Tyagi and Mungekar series may be dubious. The unit root hypothesis in the presence of structural break at a known date is accepted for the agricultural NBTOT series of Mungekar, Thamarajakshi and most probably for the NBTOT series of CACP and series based on IPDs. On the contrary, results from the Tyagi and Palanivel series would indicate that TOT variable is trend stationary process, if one allows a single change in the intercept or slope of the trend function.

Table 5: Perron's Test Allowing for Structural Break in NBTOT Indices.

NBTOT Series	Model 1.	Model 2.	Model 3.	Inference
Tyagi Series				
Break date: 1963/64 (λ = 0.25)	-4.66*	-6.39*	-4.51*	Reject
Break date: 1974/75 (λ = 0.72)	-2.24	-2.87	-2.48	Accept
Mungekar Series				
Break date: 1963/64 (λ = 0.39)	-3.27	-2.39	-3.36	Accept
Break date: 1974/75 (λ = 0.79)	-3.15	-2.98	-2.82	Accept
Thamarajakshi Series				
Break date: 1963/64 (λ = 0.29)	-3.04	-3.55	-3.14	Accept
Break date: 1974/75 (λ = 0.58)	-2.39	-2.79	-2.72	Accept
Palanivel Series				
Break date: 1963/64 (λ = 0.37)	-4.74 *	-5.11 *	-5.17 *	Reject
Break date: 1974/75 (λ = 0.66)	-3.03	-4.04 *	-3.65	Reject
CACP Series				
Break date: 1963/64 (λ = 0.26)	-2.75	-4.74 *	-2.95	Reject
Break date: 1974/75 (λ = 0.49)	-2.74	-3.59	-3.01	Accept
Break date: 1990/91 (λ = 0.83)	-2.24	-2.26	-2.24	Accept
Ratio of IPDs				
Break date: 1963/64 (λ = 0.29)	-3.37	-3.01	-3.03	Accept
Break date: 1974/75 (λ = 0.53)	-2.69	-4.07 *	-3.46	Reject
Break date: 1990/91 (λ = 0.87)	-2.01	-2.02	-1.99	Accept

*Note: * indicates rejection of unit rot hypothesis at 10% level of significance.*

3.5. Comparison of the Results of Various Tests

There is often scope for disagreement among the ADF, PP and KPSS test results of unit root hypothesis, which is in fact a major weakness of these tests. To provide a

[7] Both the wholesale price and minimum support price of agricultural commodities fluctuated noticeably during these years (refer Government of India's Economic Survey, *specific issues*).
[8] See Deb [2002 a].

comparison among different tests, we summarise our unit root results in table 6. As can be seen, the ADF, PP and KPSS tests indicate non-stationarity of the TOT series provided by Thamarajakshi, Palanivel, and the one based on ratio of IPD. Thus, the evidence in favour of random-walk behaviour of Indian agriculture-industry TOT variable would appear to be somewhat strong.

Table 6: Comparison of Results from ADF, PP and KPSS Unit Root Tests on Agricultural NBTOT Series.

NBTOT Series	ADF	PP	KPSS
Palanivel Series	Y	Y	Y
Thamarajakshi Series	Y	Y	Y
Ratio of IPDs	Y	Y	Y

Note: "Y" denotes presence of unit root.

However, the unit root test results for agricultural TOT in the presence of a structural break are somewhat ambiguous (table 7). In this context, assuming that the NBTOT variable is non-stationary for the purpose of our subsequent analysis will be safer than presuming the opposite.[9] This is because when a series is actually stationary, the regression results based on first differences or error-correction mechanism will still be valid and consistent, but they will be less efficient. On the other hand, postulating stationarity when the series is actually non-stationary leads to invalid inferences drawn on the basis of standard asymptotic results (the "spurious regression" problem).

Table 7: Comparison of Results from Perron's Test on Agricultural NBTOT Series.

NBTOT Series	Results
Tyagi Series	TS process with a break after 1963/64.
Mungekar Series	Unit Root Process.
Thamarajakshi Series	Unit root Process.
Palanivel Series	TS process with a break after 1963/64 or 1974/75
CACP Series	TS process with a break after 1963/64.
Ratio of IPDs	TS process with a break after 1974/75.

4. Implications of Random-Walk Behaviour

It is argued that the time series movement of most macro-economic variables is not mean reverting and bears a stochastic trend feature (Stock and Watson 1988,

[9] It may be noted that the DF and ADF test results on the first difference of each of these TOT series rejected the null hypothesis for a unit root, thereby indicating that these TOT series are all integrated of order 1, viz. I(1) processes. These results are not reported here.

Schwert 1992, Phillips 1992, Fatas 2000).[10] This feature has become a crucial issue in the analysis of time series fluctuations in macro-economic and financial data. According to Quah [1992], stochastic trend behaviour could imply that:

1) the permanent component in the fluctuation of the variable is highly volatile, and

2) regular shocks in the economy will result in permanent increase in the level of the series.

It is argued that the shock persistence feature is due to a combination of demand shocks with transitory effects and supply shocks with extremely persistent effects (Nelson and Plosser 1982, Krishnan et al 1992 Reinhart and Wickham 1994, Murray and Nelson 2000). The long run growth according to these observation results from the real supply or technology shocks rather than demand or monetary shocks. This perception is similar to the one provided in real business cycle (RBC) models which held that business fluctuations are exogenously determined by the rate of technological progress, viz. exogenous productivity shocks. Though, supply based shocks featured prominently in the explanations for persistent fluctuations, several studies have claimed that the demand shocks can also be persistent (Delong and Summers 1988, King et al 1991, Shapiro 1992). It is argued that shocks occurring due to changes in preference, technology and resource allocation can influence both the supply and demand sides (Plosser 1989). Romer [1989] has in fact provided evidence that the permanent component of demand shocks can also be a necessary part of the persistence feature. Further work in this area has indicated that shocks due to changes in government expenditure in the economy can generate random fluctuations (Aiyagiri, Christiano and Eichenbaum 1992, Christiano and Eichenbaum 1992, Baxter and King 1993). Subsequently, the determination of relative importance of permanent and transitory shocks in the macro economic fluctuations has remained crucial (Romer 1996). The results by Cochrane [1994], Gali [1999] and Issler and Vahid [2001] contend that transitory shocks are more important than previously thought.

It may be further noted that the RBC explanation of persistence is based on the assumption that, technology is exogenous to the economic system. Plosser [1989], Stadler [1986, 1990] and Fatas [2000] carried out their analysis by considering that the stochastic trend feature is an endogenous response of

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[10] Starting with Nelson and Plosser [1982], the evidence of random walk behavior for various macro-economic series have been provided by Mankiw and Shapiro [1985], Stock and Watson [1986, 1988],

technology to business cycles. Their results indicate that the aggregate demand disturbances that were traditionally considered to be temporary are capable of generating permanent effects in the case of endogenous growth.
On the other hand, Durlauf's [1989] explanation behind shock persistence is based on "co-ordination failures" in the economy, i.e. the incomplete (or missing) markets and the presence of externalities (or complementarities) are emphasised as explanations for random fluctuations.

It therefore appears that the recognition of shock-persistence feature in TOT series bears certain implications in view of the objective of achieving price stability, which are:

1) certain policy interventions would be required to control the random fluctuations in TOT and stabilise them back to their long run growth path,

2) the feasibility of such stabilisation schemes would primarily be determined by whether the effect of common economic shocks bear a temporary or permanent impact on the TOT fluctuations.

The random fluctuations in agricultural prices could be occurring due to the variations in domestic production levels caused by weather and other supply-side factors. Parikh [1999] has in fact claimed that agricultural price inflation in India is largely supply-determined, resulting due to crop failure and bad supply management. However, the government policies towards procurement and price support-programmes can also contribute to certain price fluctuations. It is also possible that the year-to-year revision in procurement prices leave a mark on the agricultural price movements.

Further, along with the globalisation of economies, the level of domestic prices has become prone to external factors like fluctuations in world prices and exchange rate fluctuations. The efficiency of a price stabilisation policy can therefore depend much on realising the possible source of random fluctuations. A strong persistence feature may require permanent adjustments and implementation of structural policies. In this respect, a policy that is directed towards promoting technology, development of market-supporting infrastructure, access to credit and reduction of production risks are crucial. On the other hand, taxes or subsidies on foreign trade can be a principal mechanism for stabilising domestic prices if the instability is arising from external sources. Thus, the demand management side is

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Campbell and Mankiw [1987a, 1987b], Murray and Nelson [2000] and many others.

also relevant since certain fiscal and monetary policies may associate important supply-side effects.

5. Agricultural Supply Response Model

The aggregate supply response in agriculture has remained a crucial research issue associated with domestic TOT in India. A number of studies maintain that pricing policies are biased against agriculture in developing countries. Therefore *setting the price right* is considered an effective mechanism so as to expand the agricultural growth (Schultz 1964, 1978, Lipton 1977, Brown 1978, Kruger, Schiff and Valdes 1988, 1991, Schiff and Valdes 1992a, 1992b, Kruger 1992, Bautista and Valdes 1993). They argue that favourable TOT is a strategic necessity for technology adoption as well as mobilisation of higher investment levels in a transforming agriculture. An alternate body of opinion claims that non-price factors (mainly technology, infrastructure, research and extension) are more important in sustaining agricultural growth (Dantwala 1967, De Janvry 1986, Streeten 1987, Mellor 1988, Chibber 1988 b).

The impact of TOT on agricultural production is generally examined by the Nerlovian supply response model, which relates agricultural output to TOT and some non-price technology variable:

$$Q = f(TOT, Z), \quad \text{with, } f'_{TOT} > 0, \text{and } f'_Z > 0 \tag{5}$$

where, Q, TOT and Z represent real output, TOT effect and indicator of technology (or structural) variable in agriculture.

The supply responses at the individual crop(s) level have been studied by Krishna [1967], Herdt [1970], Cummings [1975], Askari and Cummings [1976, 1977], Bond [1983], Gulati and Sharma 1990 and others. On the other hand, Krishna [1982], Delgado and Mellor [1984], Binswanger [1990], Schiff and Valdes [1992 a], Bautista and Valdes [1993], Schiff and Montenegro [1995] and many others have examined the output response for the aggregate agricultural sector. The results generally indicate that the aggregate response in agriculture is much lower than the response of individual crops. This may be due to the fact that the supply of land is relatively inelastic in many developing countries. Further, the aggregate supply response may be low in countries with a large number of subsistence farmers, who do not market their crops. On the contrary, the impact of technology and other structural variables was regularly found to be more superior in sustaining the aggregate agricultural growth (Krishna 1982, Delgado and Mellor 1984, de Janvry 1986, Binswanger et al 1987, Chibber 1988 a, Mohan Rao 1989 a, Binswanger 1990, Faini 1992).

In the Indian context, initial studies by Mishra and Sinha [1958], Madan [1958] had asserted that there was no positive supply response to prices in the subsistence agricultural sector. Subsequent analysis by Krishna [1963, 1967] and Dharm Narain [1965] lend support to the view that technology variables are more helpful in boosting agricultural growth. Thamarajakshi [1977] and Krishna [1982] reported a statistically significant and effective positive relation between aggregate farm output and the *supply shifter* variable (irrigation). But as far as the effect of TOT on output is concerned, while Thamarajakshi [1977] could not detect any statistically significant impact, Krishna [1982] observed a marginal impact of TOT.[11] However, subsequent opinions on this issue have argued that both price and non-price factors are strategically important for promoting higher agricultural growth (Mohan Rao 1989b, Storm 1997, Mohan Rao and Storm 1998). Table 8 provides a list of selective studies on aggregate agricultural supply response in India.

Table 8: Results of Aggregate Agricultural Supply Response Studies in India.

Study	Period	Impact of TOT	Significant Non-price variable	Other Remarks
Thamarajakshi [1977]	1951/52-73/74	Insignificant negative		
Krishna [1982]	1951/52-75/76	Marginally significant positive	Irrigation, Rainfall	
Thamarajakshi [1994]	1967/68-90/91	Insignificant negative	Technology captured by time	
Palanivel [1995]	1951/52-87/88	Significant positive	Irrigation, Rainfall, TFP in Agriculture, Lagged output	
Misra and Hazell [1996]	1952/53-88/89	Significant positive	Gross cropped area, Area under HYV, Interaction between TOT and technology	Significantly negative coefficient for interaction term between TOT and technology (HYV)
Mungekar [1997]	1970/71-90/91	Insignificant negative	Irrigation, Rainfall, Area under HYV, Fertiliser use, Productivity in agriculture	
Desai and Namboodiri [1997 a]	1951/52-65/66 & 1966/67-89/90	Significant negative	Agricultural production, Farm size, Infrastructure for marketing, Rural roads	
Misra [1998]	1967/68-95/96	Significant positive	Area under HYV, Rainfall, Interaction between TOT and technology, Policy dummy	Significantly negative coefficient for interaction term between TOT and technology (HYV)

Note: Desai and Namboodiri [1997 a] analysed supply response of agricultural marketable surplus.

[11] They have an identical functional specification of the supply response model covering a comparable sample period, viz. early-50's to mid-70's. However, while Thamarajakshi [1977] included a time trend variable to accommodate the impact of farm technology, Krishna [1982] had specific variables like the percentage of area irrigated and also weather index. The TOT series used in both the studies came from Thamarajakshi [1977].

The supply response issue has become more important in India since the introduction of agricultural reforms designed to turn the sectoral TOT in favor of agriculture (Hanumantha Rao and Gulati 1994, Singh 1995, Pursell and Gulati 1995, Ahluwalia 1996, Gulati 1996, Hanumantha Rao 1998, Dev and Ranade 1999).[12] However, even recent evidence on supply response in India seems to reaffirm the importance of non-price factors in sustaining agricultural growth (Thamarajakshi 1994, Subramanian 1994, Palanivel 1995, Desai and Namboodiri 1997a Mungekar 1997, Storm 1997). A different view has been put forward by Misra and Hazell [1996] and Misra [1998], who argue that favourable shifts in TOT noticed after the onset of economic reforms have helped to raise overall agricultural production in India. However, Desai and D'Souza [1999] have contested the reasoning of the work by Misra [1998].[13]

A possible shortcoming of the supply response studies in India has been that the non-price technology variable determines the agricultural output growth independent of the price of output, i.e. the influence of prices on farm technology spread and adoption is neglected. Thus, if favourable TOT - as has been argued by many induce technological change in agriculture - then this approach may underestimate the long-run responsiveness to price. A useful approach would be to incorporate technological change dependent on price in the supply response analysis.

6. Variables and Data

We use two measures of aggregate agricultural production levels in India, viz. an index of agricultural production, and an index of agricultural value added output at constant prices. The series on all-India index number of agricultural production (all crops) has been derived from the publications of Directorate of Economics and Statistics (DES), Ministry of Agriculture, Government of India. While the index of real agricultural output in value terms has been derived by utilising the Central Statistical

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[12] Further discussions as to how the adjustment programmes address to correct distortional pricing policies in developing agriculture are provided in World Bank [1986], Chibber [1988b], Anderson [1992], Faini [1992] and Goldin and Winters [1992] and UN [1998].

[13] Desai and D'Souza [1999] pointed out several analytical misconceptions contained in Misra's [1998] work. They particularly argued that his interpretation of an "interaction term" (involving price and technology instruments) in the supply response equation is faulty. A discussion on the introduction and assessment of such interaction terms can be found in Schiff and Montenegro [1995]. In fact, contrary to one's expectations, a significantly negative coefficient for the interaction term between

Organisation's (CSO) series on value added in agriculture at 1980/81 prices. The NBTOT series that has been used in this study is based on the ratio of IPD for agriculture to non-agriculture. Misra and Hazell [1996] and Misra [1998] have used this type of TOT series in the analysis of aggregate supply response of Indian agriculture. The relatively large number of observations in the NBTOT series based on IPDs enable us to carry out the cointegration tests and subsequently formulate error correction version of the supply response model.

It has been found that on the whole, irrigation remains to be the most important supply-shifter variable in the Indian supply response studies (Abler and Sukhatme 1996). Thus, to capture the impact of technology in agriculture, we include the area under gross irrigation as a proxy. Data on gross irrigated area as estimated by DES have been derived from various issues of Fertiliser Statistics, Fertiliser Association of India. The series on total irrigated area ('000 hectares) is used after converting it to an indexed series with 1980/81 as base. Our analysis refers to the period from 1951/52 to 1995/96. It may be noted that other non-price variables, e.g. area under HYV, fertiliser use, infrastructure for marketing, etc. could not be included due to the short nature of these series and also to retain degrees of freedom in the present error correction version of supply response model.

7. Cointegration Analysis

As our first step towards modelling in the cointegration framework, we need to investigate on the order of integration of the concerned variables. The DF and ADF test results in levels and in first differences are given in Table 9. The null hypotheses of a unit root are accepted for all the variables in level form. When the sequential procedure of ADF tests is applied to the first difference, these sequences are found to be stationary. Hence, we infer that the variables are all integrated of order 1, viz. I (1) processes. We therefore proceed to examine the cointegrating relationship in the agricultural supply response model.

TOT and technology (HYV) reported in Misra and Hazell [1996] and Misra [1998], would imply that price and non-price factors are not complementary but substitute to each other.

Table 9: DF and ADF Test Results for Relevant Variables in Levels and in First Differences.

Variables	Levels			First Difference		
	DF	ADF	Inference	DF	ADF	Inference
Index of Agricultural Production (IAP)	-2.71	-0.98 (2)	Accept H_0	-9.59	-5.22 (3)	Reject H_0
Index of Agricultural Value Added (GVA)	-2.33	-0.85 (2)	Accept H_0	-9.46	-5.43 (3)	Reject H_0
Index of Irrigated Area (GIA)	-1.54	-1.23 (1)	Accept H_0	-8.78	-5.65 (1)	Reject H_0
NBTOT Series based on ratio of IPD (IPD)	-2.48	-2.12 (2)	Accept H_0	-5.58	-5.94 (1)	Reject H_0
CACP series on NBTOT (CACP)	-2.28	-2.63 (1)	Accept H_0	-5.97	-4.22 (3)	Reject H_0

Note: The numbers inside the bracket indicate lag length in the ADF regressions.

7.1. Bivariate Analysis in Engle-Granger's Framework

According to Engle and Granger [1987], two I (1) variables, viz. x_t and $y_{t)}$ are cointegrated, if there exists any such "*b*" so that: $(y_t\text{-}bx_t) = u_t$ is also I (0). The idea of cointegration between two non-stationary series meant that each of the variables reveal a tendency to converge systematically in the long-run, even if they may drift apart in the short-run. Using the Engle-Granger methodology, a cointegration test between TOT_t and Z_t (an arbitrary policy variable) entails that the residual sequence (e_t) from the estimated long-run equilibrium relationship given below to be stationary.

$$Z_t = b_0 + b_1 TOT_t + e_t \qquad (6)$$

The null H_0: a_1=0 is tested using the autoregression of residuals as follows:

$$\Delta e_t = a_1 e_{t-1} + w_t \qquad (7)$$

and using the critical values provided by Engle-Granger. In case, the residuals as per equation (7) indicate the presence of serial correlation, we use the ADF test on residuals in the following form:

$$\Delta e_t = a_1 e_{t-1} + \Sigma_i b_i \Delta e_{t-1} + w_t \qquad (7.1)$$

7.1.1. TEST RESULTS

We first undertake a bivariate cointegration test between output level and TOT effect in agriculture and between investment level and TOT effect in agriculture. The results of DF, ADF and CRDW tests on specific residuals are provided in table 10.

Table 10: Engle-Granger's Bivariate Cointegration Tests between TOT and Output in Agriculture, (H_0: no cointegrtion).

Cointegrating Regressions	CRDW	DF test statistic	ADF test statistic	Inference
Critical Value (10%)	0.32	-3.03	-2.91	
IPD = f (IAP)	0.44	-2.33	-2.03 (2)	Accept
IAP = f (IPD)	0.13	-1.05	-0.48 (2)	
IPD = f (GVA)	0.43	-2.31	-2.02 (2)	Accept
GVA = f (IPD)	0.11	-0.89	-0.44 (2)	
CACP = f (IAP)	0.44	-2.27	-2.68 (3)	Accept
IAP = f (CACP)	0.06	-0.19	0.31 (1)	
CACP = f (GVA)	0.44	-2.26	-2.68 (3)	Accept
GVA = f (CACP)	0.05	0.01	0.14 (3)	

Note: 1) IPD and CACP represent the ratio of IPD for agriculture to that of non- agriculture and the NBTOT series provided by the CACP (Ministry of Agriculture, GOI; whereas IAP and GVA denote index of agricultural production and index of real agricultural value added, respectively.
2) The numbers inside the brackets indicate lag length in the ADF regressions.

We have run the co-integrating regression in both directions for each specification. Non-stationarity of the residuals could not be rejected for any specification at 10% level of significance. The null hypothesis stating no cointegration between the variables is therefore accepted in the Engle-Granger test. The aspect of non-cointegratedness bears the implication that no long run equilibrium relationship could exist between TOT and output level in agriculture. However, it is possible that the impact of TOT on agricultural output works in combination with technology variables. The lack of cointegration can therefore be due to the exclusion of important explanatory variables in our system. We therefore undertake a multivariate cointegration analysis for the supply response model by incorporating the technology (irrigation) variable. The advantage of a multivariate cointegration analysis is that it tests for the possibility of more than one cointegrating relationship among the variables.

7.2. Multivariate Analysis in Johansen's Framework

We use the procedure provided in Johansen [1988] and Johansen and Juselius [1990, 1992] to determine the cointegrating relationship(s) in a multivariate framework. The method of identifying cointegration is briefly outlined here. If we consider y_t to be an (n*1) vector of non-stationary I(1) variables, then the unrestricted vector autoregression (VAR) of y_t upto k lags can be specified as:

$$y_t = M + \Sigma_i^k \Pi_i y_{t-i} + E_t, (t = 1,2....T) \quad (8)$$

where, each of Π_i is an (n*n) matrix of parameters, E_t is an identically and independently distributed n-dimensional vector of residuals and M is an (n*1) vector of constants.

We can express (8) in first-difference notation and formulate the error correction representation of y_t as:

$$\Delta y_t = \Gamma_1 \Delta y_{t-1} + ... + \Gamma_{k-1} \Delta y_{t-k+1} + \Pi y_{t-1} + u_t \qquad (9)$$

where, $\Gamma_i = -(I - \Pi - ... - \Pi_i); i = 1,...k-1, \Pi = -(1 - \Pi_1 - ...\Pi_k$

Γ_i 's are (n*n) coefficient matrix for $\Delta y_{t-1}, i = 1,2,...k-1$

Π is an (n*n) coefficient matrix for the variables in y_{t-1},

u_t is an (n*1) column vector of disturbance terms.

This specification conveys information about both the short and long-run adjustments to changes in y_t through the estimates of Γ_i and Π respectively. The cointegration analysis mainly involves examining the impact matrix Π to gather information on the long run relationship(s) among variables contained in the y_t vector. That is, if the rank of Π matrix (denoted by r) is equal to zero, the impact matrix is a null vector. This means that there is no cointegration at all, since there is no linear combination of y_t that are I(0). In this case, the appropriate model is a VAR in first differences involving no long-run elements. If II has a full rank (i.e. r = n), then the vector process of y_t is stationary. Which implies that there is no problem of spurious regression and the appropriate modelling strategy is to estimate the traditional VAR in levels. But, if 0 < r < n, there exists r cointegrating vectors. It can be said that r linearly independent combinations of the variable in y_t are stationary along with (n-r) non-stationary vectors. The coefficient matrix II can be factored into$\alpha\beta'$, where both α and β are (n * r) matrices of rank r (0 < r < n) and β' is the transpose of β. The cointegrating vector β has the property that β' y_t is stationary even if y_t itself is nonstationary. The matrix "α" measures the strength of the cointegrating vector as it represents the speed of adjustment to disequilibrium.

Johansen [1988] derived two likelihood ratio test statistics to test for the number of cointegrating vectors. The null hypothesis of r cointegrating vectors against the alternative of more than r cointegrating vectors is tested by using the lambda-trace statistics which is given by:

$$\lambda_{trace} = -T\Sigma_{i=r+1}^{n} \ln(1 - \widehat{\lambda}_i)$$

On the other hand, the null of r cointegrating vectors against the alternative of (r+1) cointegrating vectors is tested by using the lambda-max statistics that is computed as:

$$\lambda_{\max} = -T \ln(1 - \widehat{\lambda}_{r+1})$$

where, $\lambda_i s$ are the estimated eigen values (characteristic roots) obtained from the Π matrix, and T is the number of usable information.

The presence of significant cointegrating vector(s) in the multivariate formulation of agricultural supply response model can provide some important indications as to the long-run relationship(s) among concerned variables. The interpretation of the test results carried out on the model is discussed in the following sub-section.

7.2.1. TEST RESULTS

The multivariate cointegration results in the supply response model have been derived by considering y_t as an (3*1) column vector of real output, TOT and irrigation intensity in agriculture, i.e.

$$y_t = (Q_{t,} TOT_t, Z_t)$$

In applying this test, the lag-length is specified using the AIC and SBC criterion, and also by using the LM test (AR-1) for detecting residual serial correlation. As in the unit root tests, lags are not deleted if their exclusion introduced serial correlation. Table 11 shows the result. The hypothesis of non-cointegration can be rejected at 5% level, since both the lambda-trace and lambda-Max test statistic indicated that agricultural output, TOT and technology (irrigation) are cointegrated. In other words, the variables are bound together by a stationary long-run relationship.

The cointegration analysis in the supply response model has also been performed by considering alternate proxies for the agricultural output and NBTOT series. That is, we have alternatively included the index of agricultural production (IAP) and index of real gross value added output (GVA) on agricultural output. Similarly, we have considered the TOT series based on ratio of IPDs for agriculture to non-agriculture and the CACP series on agricultural NBTOT. Thus, we have attempted four VAR models in total by considering two different measures each for agricultural output and TOT. Both the lambda-trace and lambda-Max statistic in all the specifications indicated the presence of only one co-integrating equation.

Table 11: Johansen's Cointegration Test involving Production, NBTOT and Gross Irrigated Area in Agriculture (sample: 1951/52 to 1995/96).

Hypothesis	λ_{trace}	Critical Value (5%)	Critical Value (10%)	Decision
H_0: r=0, H_1:r>0	52.43	34.01	41.07	Indicates one cointegrating equation
H_0: r<1 H_1:r>1	14.56	19.96	24.60	
H_0: r<2 H_1:r>2	8.29	9.24	12.97	
Hypothesis	$\lambda_{\max}$	**Critical Value (5%)**	**Critical Value (10%)**	**Decision**
H_0: r=0, H_1:r=1	37.87	21.89	23.84	Indicates one cointegrating equation
H_0: r=1 H_1:r=2	6.27	15.25	17.62	
H_0: r<2 H_1:r>2	8.29	9.09	10.71	

Note: 1) test assumption: no deterministic trend in the data, lag length = 1. 2) We have used the index of real value added output (GVA) in agriculture and the TOT series based on ratio of IPD.

It is claimed that testing for cointegration is only one part of a strategy for model building (Granger 1997, Pesaran 1997). If there is cointegration, we are justified in going further and estimating not only the cointegrating relationship but also the dynamic relationship that incorporates both the equilibrium and how the short-run adjustments to that equilibrium are made. This is the second stage of our model building procedure, in which an error-correction model is estimated.

8. Supply Response Model in Error Correction Framework

Since variables in the agricultural supply response model are cointegrated, an error-correction representation would be a more appropriate modelling strategy to capture the short- and long run dynamics in the model. There are two characteristics of an error-correction model (ECM). First, an ECM is dynamic in the sense that it involves lags of the dependent and explanatory variables, it thus captures the short-run adjustments to changes particular adjustments in to past disequilibria and contemporaneous changes in the explanatory variables. Second, the ECM is transparent in displaying the cointegrating relationship between or among the variables.

We set up the agricultural supply response model in VEC framework as follows:

$$\Delta Q_t = a_1 + b_Q e_{t-1} + \Sigma_{i=1} b_{11}(i)\Delta Q_{t-i} + \Sigma_{i=1} b_{12}(i)\Delta TOT_{t-i} + \Sigma_{i=1} b_{13}(i)\Delta Z_{t-1} + e_{1t}$$

$$\Delta TOT_t = a_2 + b_{TOT} e_{t-1} + \Sigma_{i=1} b_{21}(i)\Delta Q_{t-i} + \Sigma_{i=1} b_{22}(i)\Delta TOT_{t-i} + \Sigma_{i=1} b_{23}(i)\Delta Z_{t-1} + e_{2t}$$

$$\Delta Z_t = a_3 + b_Z e_{t-1} + \Sigma_{i=1} b_{31}(i)\Delta Q_{t-i} + \Sigma_{i=1} b_{32}(i)\Delta TOT_{t-i} + \Sigma_{i=1} b_{33}(i)\Delta Z_{t-1} + e_{3t}$$

where, $e_{t-1} = y_{t-1} – c_1\ TOT_{t-1} – c_2\ Z_{t-1}$ is the error correction term, c_1 and c_2 are the parameters of the cointegrating vector, and e_{1t}, e_{2t} and e_{3t} are the white noise disturbances.

That is, we impose cointegrating restrictions among variables in the VAR for estimating a vector error-correction (VEC) version of agricultural supply response model (table 12). Significant causal effects in the VEC based models can take place either through the joint significance of lagged first-difference terms or through the *error-correction term* (ECT). The ECT conveys the long-run causal effects, while the lagged explanatory variables give an indication of short-run adjustments. The coefficients of ECT contain the information about whether the past values of variables affect the current values of the variable under study. A significant coefficient implies that the past equilibrium errors play a role in determining the current outcomes.

The estimated cointegrating vectors are given economic interpretation by normalising on the agricultural output variable. This normalised equation is obtained from reduced form of the VAR, and may represent the demand, supply or some complicated interaction between the two. The estimated cointegrating equation which appears at the bottom of Table 12, shows signs on the variable that are consistent with the agricultural supply model, i.e. the coefficient of the technology variable has a positive sign and the coefficient of TOT has a negative sign. The normalised cointegrating equations indicate that technology (irrigation availability) has a strong long-term relationship with agricultural output.

Table 12: Error Correction Estimates involving Production, NBTOT & Gross Irrigated Area in Agriculture (sample: 1951/52 to 1995/96).

Variables	Index of Agricultural Production (ΔQ)	Terms of Trade (ΔTOT)	Index of Gross Irrigated Area (ΔGIA)
Error Correction Term	-0.001 (-2.19) *	-0.001 (-0.71)	-0.002 (-7.19) *
$\Delta Q(-1)$	-0.40 (-2.37) *	-0.11 (-0.66)	0.02 (0.32)
$\Delta TOT(-1)$	0.07 (0.44)	0.09 (0.60)	0.05 (1.01) **
$\Delta GIA(-1)$	0.13 (0.21)	-0.30 (-0.51)	-0.38 (-2.25) *

*Note: 1) * and ** indicates significance at 10% and 20% level, respectively.*
2) Normalized Cointegrating. Equation: GVA = 2061.87 - 25.42 TOT + 19.04 GIA

The VEC results convey that the short-run influences of both TOT and irrigation are statistically insignificant in explaining agricultural output decisions. On the other hand, agricultural TOT indicated a somewhat significant causation (significant at a lower level of significance) for the growth of irrigation intensity in the short-run. Our results did not change after substituting different proxies for agricultural TOT or output level in the VEC model.[14] We find that the ECTs are statistically significant in both the agricultural output and irrigation equations in the VEC model. The significance of ECTs implies the presence of causal relations from independent variables to the dependent variable, even in the case when the lagged independent variables are individually insignificant. On the other hand, the ECT in agricultural TOT equation is statistically insignificant and no significant causation can be seen in this equation. This would tend to suggest that agricultural TOT is econometrically exogenous as indicated by the statistical insignificance of ECT as well as lagged independent variables. This would mean that the endogenous short-run changes in agricultural TOT do not have a tendency to bring the system back to long-run equilibrium. This aspect might signify that agricultural TOT is the initial receptor of exogenous shock(s) in the VEC model of supply response. That is, short-run fluctuations in agricultural TOT are generated by exogenous factors, viz. year-to-year revision in support prices rather than market determined forces. So that, production decisions in agriculture do not respond to the administratively controlled price fluctuations in a homogeneous manner. As a result, deviation of agricultural output from its long-run equilibrium level does not have a significant tendency to adjust to changes in agricultural TOT. However, although output adjustments are not related to changes in TOT in the short-run, the long-run movements in agricultural output has been found to be causally related with the dynamic interplay of TOT and technology (irrigation) variable. We observe that the coefficient for short-run causal effect of TOT is close to be statistically significant in the irrigation equation. Thus, an incentive TOT structure may actually be contributing towards technology adoption in agriculture, which in turn moves the system to the long-run equilibrium level. That is, the short-run deviation in TOT from its long-run level creates error-correction in the long-term output adjustments through changes in other variables (viz., technology).

Of particular interest in VEC based models are the sign and magnitude of the coefficients of ECTs, because they apparently reflect the short-run deviations of the system from the long-run equilibrium level. The equilibrating mechanism, in other

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[14] The alternate VEC models were formulated using different measures of the agricultural output and NBTOT series.

words the speed of adjustment of any disequilibrium towards the long-run growth path is generally interpreted from these coefficients. In the present case, we observe a negative coefficient of the ECT in the agricultural output equation. This negative coefficient could signify that shocks in the price and non-price variables would reinforce the output level to converge to its long-run equilibrium level. That is, if agricultural output in the past has moved below (above) the steady state growth path, the interplay between TOT and technology would raise (diminish) the subsequent output deviations so that it converges to a stable equilibrium.

9. Summary and Implications

It is argued that the instability of domestic TOT has an impact on various key indicators of the economy. It is therefore important to gather a sense of the nature of TOT fluctuations based on a historical data set. In this chapter, we examine the time series properties of TOT by utilising various agriculture-industry TOT series in India. Our test results indicate that the data generating processes of various TOT series appears to be characterised by a stochastic trend (unit root). The random-walk feature in agricultural TOT has been confirmed by both the families of unit root tests that considers trend-stationary or non-stationary as null hypothesis. If our inferences in regard to the random walk nature of TOT are valid, it could imply that specific policy actions might be necessary to stabilise the volatility in TOT. That is, the recognition of shock-persistence behaviour in TOT may signal that supply-side (structural) policies are required to stabilise the random fluctuations in TOT.[15]

Following our finding that agricultural TOT can be represented by a stochastic trend, we examine the implications of this for the agricultural supply response model in India, i.e. we explore the presence of long-run relationship(s) underlying the model using cointegration analysis and error-correction framework. The bivariate results between TOT and output level in agriculture (in Engle-Granger's framework) reflect no statistically significant cointegration. The non-cointegratedness indicates that no direct long-run relationship exists between TOT and output level in Indian agriculture. This in turn would suggest that a favourable TOT structure alone may not be effective in sustaining higher agricultural growth.

[15] In this context, it may be mentioned that Panda, Darbha and Parikh [1999] have earlier pointed out the limitations of monetary policy in controlling agricultural price fluctuations in India.

Keeping such concerns in mind, we performed an exercise by incorporating the technology variable (irrigation) in combination with TOT in the agricultural supply response model. The multivariate cointegration analysis (in Johansen's framework) indicates the presence of a stationary long-run relationship in the supply response model. We set up the agricultural supply response model in vector error correction (VEC) framework to capture the short- and long run dynamics of the model. The results indicate that agricultural TOT is econometrically exogenous in the VEC version of agricultural supply response model, i.e. the short-run deviations in TOT from its long-term trend do not bear any direct causality for the long-run output adjustments in agriculture. The non-response of output to changes in TOT possibly implies that fluctuations in agricultural price are exogenously generated by administrative factors rather than market determined forces. However, changes in TOT create short-run adjustments in other variable (technology adoption in agriculture as captured by gross irrigated area), so that the long-run growth of agricultural output in India is determined by the dynamic interplay of TOT and technology variables. Overall, the results suggest that "*getting agricultural TOT high*" may not translate into faster growth in agriculture. Instead, it seems that growth in agricultural output may respond better if specific technology (structural) variables are concomitantly combined with the price incentives.

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Table 5: Indices for Net Barter Terms of Trade for Indian Agriculture, base 1980/81.

	(1) Tyagi [1987] series.	(2) Mungekar [1992] series.	(3) Palanivel [1992] series.	(4) Thamarajakshi [1994] series.	(5) CACP series.	(6) DES Series (base: 1981/82)	(7) Ratio of Implicit Price Deflators (Agr.vs.Non-Agr.)	(8) Ratio of Implicit Price Deflators (Agr.vs.Economy)
1950/51	-	-	116.62	-	-	-	101.67	100.74
1951/52	-	-	110.39	96.88	-	-	98.54	99.34
1952/53	104.35	-	93.24	95.43	-	-	95.27	97.82
1953/54	98.63	92.58	93.96	99.78	-	-	94.50	97.50
1954/55	99.54	94.80	84.95	93.31	-	-	79.07	89.41
1955/56	101.60	90.14	91.97	91.19	-	-	77.82	88.27
1956/57	103.67	93.91	93.22	98.55	-	-	88.30	94.16
1957/58	102.86	90.92	91.25	94.76	-	-	87.12	93.31
1958/59	100.69	89.92	93.99	97.88	-	-	89.20	94.58
1959/60	98.40	96.46	93.67	97.88	-	-	87.37	93.39
1960/61	90.61	97.12	89.89	96.21	-	-	81.71	90.09
1961/62	92.33	94.02	89.29	96.88	-	-	83.82	91.10
1962/63	91.18	94.57	87.83	95.32	-	-	83.57	90.63
1963/64	83.51	91.69	94.87	93.76	-	-	92.49	95.81
1964/65	107.67	98.01	107.55	104.57	-	-	97.58	98.70
1965/66	117.87	106.09	114.74	110.14	-	-	103.22	101.80
1966/67	129.32	115.39	131.16	118.39	-	-	112.04	106.62
1967/68	132.42	122.92	131.03	120.29	-	-	113.22	106.88
1968/69	120.39	116.94	118.47	111.93	-	-	113.87	107.37
1969/70	116.61	116.50	115.97	120.96	-	-	112.87	106.87
1970/71	114.55	114.95	116.53	122.52	114.55	-	102.87	101.58
1971/72	111.68	110.30	114.04	115.94	111.68	-	100.69	100.39
1972/73	118.56	106.87	118.91	119.06	118.67	-	109.45	105.35
1973/74	125.54	115.17	132.32	128.99	125.54	-	119.64	110.48
1974/75	114.43	123.59	113.73	125.31	114.55	-	109.95	105.63
1975/76	96.91	120.38	97.06	113.15	96.91	-	91.91	95.19
1976/77	103.89	104.54	105.86	111.37	103.78	-	95.47	97.22
1977/78	104.01	110.30	100.75	116.50	103.89	-	97.50	98.50
1978/79	97.82	104.65	97.40	111.48	97.82	-	95.37	97.14
1979/80	101.49	94.24	103.19	106.91	101.49	-	100.13	100.08
1980/81	100.00	100.00	100.00	100.00	100.00	-	100.00	100.00
1981/82	94.96	-	95.22	100.22	94.96	100.00	94.80	96.71
1982/83	97.02	-	95.21	102.23	97.02	103.04	94.85	96.66
1983/84	98.63	-	97.14	108.14	98.85	103.27	95.04	96.83
1984/85	-	-	97.83	108.14	98.51	105.86	93.91	96.01
1985/86	-	-	92.84	102.12	94.39	105.52	93.10	95.38
1986/87	-	-	96.82	101.56	97.71	107.89	95.78	97.12
1987/88	-	-	101.26	109.81	99.54	109.81	99.68	99.78
1988/89	-	-	-	109.48	98.74	110.82	97.00	97.97
1989/90	-	-	-	105.46	99.08	112.06	98.55	99.00
1990/91	-	-	-	106.24	103.09	114.88	100.20	100.14
1991/92	-	-	-	112.82	106.19	119.05	106.27	104.31
1992/93	-	-	-	-	99.20	117.14	101.85	101.28
1993/94	-	-	-	-	104.12	116.80	104.44	103.08
1994/95	-	-	-	-	105.15	120.18	108.79	106.05
1995/96	-	-	-	-	103.32	118.60	107.80	105.65
1996/97	-	-	-	-	106.19	115.90	104.49	103.28
1997/98	-	-	-	-	101.72	115.22	-	-
1998/99	-	-	-	-	110.19	-	-	-

Source: worked out from Tyagi [1987], Mungekar [1992], Palanivel [1992], Thamarajakshi [1994], GOI [1999] and various issues of CACP Reports.

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