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# Terms of Trade and Investment Behaviour in Indian Agriculture: A Cointegration Analysis

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I

INTRODUCTION

The issue of capital formation in Indian agriculture has generated substantial research interest in recent years (Mishra and Chand, 1995; Misra and Hazell, 1996; Dhawan, 1996 a, b; Alagh, 1997; Rao, 1997; Gulati and Bathla, 2001). The main focus of this literature has been on three aspects, viz., (i) the declining trend in public investment since the early 1980s; (ii) the complementary relationship between the public and private sector investment; and (iii) the positive influence of domestic terms of trade on private investment levels in agriculture. In a recent study, Chand (2001) has indicated that both the private and public investment series in India are non-stationary sequences, i.e., they have a unit root in their respective data generating processes. The distinction between deterministic and stochastic trend (unit root) models has considerable bearing for understanding the time-series behaviour of a variable (Nelson and Plosser, 1982; Gil-Alana and Robinson, 1997; Murray and Nelson, 2000). If the private and public agricultural investment variables in India are truly characterised by unit root processes, it implies that as such there do not exist any long-run trend values of these variables. Since regular shocks in the economy can potentially send the variables off on a wholly different path for the rest of the time, there may be a tendency for the variables not to return to their respective long-run trend, and instead drift apart over time.

The presence or absence of unit root in investment series also assumes importance in analysing its relationship with terms of trade (henceforth TOT) in agriculture. So far, the underlying data generating processes of both the investment and TOT series have been assumed to be stationary (absence of a unit root). However, in case this assumption is not valid, standard asymptotic distribution theory cannot be used for the purpose of drawing inference. Because traditional regression analysis in models that include variables with unit root can produce spurious regression results (Granger and Newbold, 1986; Maddala, 1992; Greene, 1997).[1]

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Using similar arguments, Chand (2001) has in fact claimed that the notion of a positive statistical association (i.e., the complementary relationship) between private and public investment levels in Indian agriculture is of spurious nature, since there do not exist any cointegrating relationship between the two. However, Chand (2001) even though used the cointegration approach to reject the complementarity between the public and private investment levels, has continued to use the Ordinary Least Squares (OLS) based regression techniques to analyse the impact of TOT changes upon private investment in agriculture.

It appears that there are a few gaps in the perception about the role that TOT are likely to play on the private investment in Indian agriculture. The caveats are apparent in respect of the following grounds, first, Chand (2001) has used only the Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) tests to examine the stationarity of agricultural investment series. Given the low power of the ADF test, one should also supplement the Phillips-Perron (PP) and Kwiatkowski, Phillips, Schmidt and Shin (KPSS) tests to get a more confirmatory result on the unit root finding.[2] Second, the unit root finding in the agricultural investment variable makes it absolutely necessary to model its relationship with TOT by using the cointegration and error correction approach, and not on the basis of OLS regressions as pursued by Chand (2001) and previous researchers. *Third*, Chand (2001) has used the Engle-Granger's bivariate approach to test for the cointegration between public and private investment in agriculture. It is, however, possible that the inducement effects of public investment upon private investment levels work in combination with the TOT variable, which has often been considered a crucial profitability indicator of productive investment in agriculture.[3] One can, therefore, attempt a more general multivariate cointegration analysis as per the Johansen and Juselius (1990) methodology, to examine the dynamic interplay among private investment, TOT and public investment in agriculture.

Thus, there is a need for further empirical research, particularly with regard to these aspects. This article seeks to fill the gaps in the literature by first undertaking a rigorous examination of the time series properties of private investment, TOT and public investment variables in agriculture, and second, providing an examination of the long-run relationship among them through a multivariate cointegration analysis. It may be crucially noted that even though our analysis could provide insights into all the three aspects that were listed at the outset, the key focus of this paper would centre around the third, i.e., to investigate the likely impact of TOT changes upon private investment in agriculture. The plan for the rest of this paper is as follows. The arguments on the relationship between TOT and agricultural investment as well as the empirical findings reported by the earlier studies are reviewed in Section II. The testing procedures for the presence of unit root in a series are discussed in Section III. The results on the univariate time series properties of agricultural investment and TOT series are provided in Section IV. In Section V, we provide the cointegration results of the agricultural investment model by employing the bivariate and multivariate cointegration framework as per Engle and Granger (1987) and Johansen and Juselius (1990) methodologies, respectively. In consequence to our cointegration results, Section VI provides the short-run Granger causality results derived from modelling the private agricultural investment in the vector auto-regression (VAR) framework. The conclusions are presented in the final section.

## II

## TERMS OF TRADE AND INVESTMENTS IN AGRICULTURE

The early analysis examining the trend and determinants of investment and capital formation in Indian agriculture included Shukla (1968), Srinivasan and Narayana (1977), Mujumdar and Menon (1986), etc.[4] Subsequently, Patnaik (1987), Shetty (1990) and Mallick (1993) indicated adverse agricultural TOT to be one of the reasons for the declining private investment in agriculture.[5] It is however fair to say that a majority of the view in India in this regard has been influenced by the perception that higher prices could stimulate the production by inducing investments in agriculture. This assertion can be linked to the literature that studies the distortions of incentives for agriculture in developing countries (Schultz, 1978, Schiff and Valdes, 1992, Bautista and Valdes, 1993), and maintains that agriculture suffers in the investment allocation because the political process is biased towards the non-agricultural development.[6] It is however important to note that Chakravarty (1974) and Vaidyanathan (1977) took an opposite stand in this respect and contended that escalation of agricultural prices could reduce the public investment in infrastructure through erosion of (industrial) tax revenue led low public savings.[7] Subsequently, Mohan Rao (1993, 1994) and Mohan Rao and Storm (1998) lend support to this view by claiming that hikes in TOT could lead to a shrinkage of public investments in large irrigation projects, rural electrification, transport, storage, agricultural research and extension programmes through fiscal squeezes in the government budget. By quoting evidence from Bhattacharya (1984), Krishnamurthy (1984), Rangarajan and Arif (1990), which reported rising government budget deficit due to agricultural price inflation, and hence a negative relationship between farm prices and public investments (Bhattacharya *et al*., 1994); Mohan Rao and Storm (1998) specified several channels through which the fiscal squeeze may arise. These include, (i) increase in wage costs and simultaneous fall in profit rates of public and private sector, (ii) higher food-subsidy bill and (iii) decline in the effective demand of industrial goods due to eroding purchasing power of the net-buyers of food.

The basic econometric model used to determine the factors influencing private agricultural investment in India included government investment and TOT (relative price) in agriculture as the key explanatory variables. That is, the private agricultural capital formation ($GDCFAGR_{Pvt}$) was postulated as a function of TOT and lagged public capital formation in agriculture ($GDCFAGR_{Pub}$), viz.,

$$\text{GDCFAGR}_{\text{Pvt}} = f(\text{TOT}, \text{GDCFAGR}_{\text{Pub}}) \quad \text{....(1)}$$

$$\text{with}, \; f'_{\text{TOT}} > 0, \; f'_{\text{GDCFAGR-Pub}} > 0$$

The basic model (equation 1) has sometimes been extended to include the impacts of technological development and growth, which are captured through percentage of area under high-yielding varieties and/or growth of real agricultural gross domestic product (GDP), viz., Gulati and Bhide (1993), NCAER (1995), Misra and Hazell (1996). Some of the studies have also included specific components of the publicly provided infrastructure in agriculture, viz. intensity of canal irrigation, power supply, institutional finance, etc. (Rao, 1997; Patnaik and Joshi, 2000; Chand, 2001; Gulati and Bathla, 2001; Roy and Pal, 2002).

Table 1 provides a list of various models along with the results derived from studies that analysed the influence of TOT on private investment in agriculture. As far as the empirical evidence is concerned, initial studies mostly found the impact of TOT to be significantly positive (Krishnamurty, 1984; Storm, 1992 and Wagle, 1994). More specifically, it can be stated that all the studies with the exception of Gandhi (1990, 1996), NCAER (1995), and Kumar (1999) have detected a (statistically) significant positive influence of TOT on private investment in agriculture.

A number of studies have been concerned about the influence of changing TOT - noticed during the post reforms period in India - on private agricultural investment (Misra and Hazell, 1996, Rao, 1997; Misra, 1998; Patnaik and Joshi, 2000; Gulati and Bathla, 2001; Chand, 2001; Roy and Pal, 2002; Misra, 2003). The results from Misra (1998) indicate that the impact of TOT remained significantly positive during 1961-62 to 1995-96. He has therefore claimed that favourable turnaround in agricultural TOT during the process of economic reforms have helped in raising the gross capital formation in Indian agriculture. Hanumantha Rao (1997), on the contrary, maintains that, "…. publicly provided infrastructure in the form of power seems to explain the rise in private investment better than the terms of trade." In another study, Gulati and Bathla (2001) estimate private investment in agriculture as a function of TOT and various components of public sector investment. They used two functional forms to capture public sector investment, viz. investment in physical form (intensity of canal irrigation, power supply, institutional finance) and investment in financial form (cumulative investment in canal irrigation and power sector relevant for agriculture). They find TOT as the most significant variable that influences private investment in agriculture during 1980-81 to 1998-99. Roy and Pal (2002) estimated a simultaneous equation model on the basis of pooled cross-section state level and time series data during 1970-71 and 1998-99, and found a positive relationship between TOT and private investment in agriculture.

TABLE 1. RESULTS OF THE IMPACT OF TOT (RELATIVE PRICE) ON PRIVATE INVESTMENT IN INDIAN AGRICULTURE

| Study (1) | Period (2) | Impact of TOT (3) | Other explanatory variables (4) |
|---|---|---|---|
| Krishnamurty (1984) | 1961-80 | Significant positive | Public investment in agriculture, GDP in agriculture (current and lagged). |
| Gandhi (1990) | 1950-80 | Insignificant positive | Output growth, government capital stock, wage, price of fertiliser, rural saving, co-operative credit to agriculture, commercial bank credit to agriculture, capital stock. |
| Narayana, Parikh and Srinivasan (1991) | 1951-52-1988-89 | Exogenously specified to be positive | None. |
| Kumar (1992) | 1951-52-1988-89 | Significant positive | Agricultural share in GDP. |
| Storm (1993) | 1962-63-1986-87 | Significant positive | Public investment in agriculture. |
| Gulati and Bhide (1993) | 1965-66-1989-90 | Insignificant positive | Agricultural share in GDP, trend, time dummy. |
| Wagle (1994) | 1961-62-1988-89 | Significant positive | Public investment in agriculture lagged dependent variable. |
| NCAER (1995) | 1960-61-1989-90 | Significant positive | Public investments in agriculture, institutional credit to agriculture. |
| Gandhi (1996) | 1952-53-1992-93 | Insignificant negative | Rural saving, co-operative credit to agriculture, HYV use, agricultural wage, commercial bank credit, government capital stock, output growth. |
| Misra and Hazell (1996) | 1960-61-1989-90 | Significant positive | Public investment in agriculture, area under HYV. |
| IEG-DSE (1997) | 1970-71-1994-95 | Significant positive | Public investment in agriculture, real GDP in agriculture. |
| Rao (1997) | 1980-81-1994-95 | Significant positive | Public investment in agriculture, electricity consumption, technology (time). |
| Misra (1998) | 1961-62-1995-96 | Significant positive | Public investment in agriculture, area under HYV, policy dummy. |
| Kumar (1999) | 1970-71-1992-93 | Insignificant | Public investment in agriculture, GDP in agriculture, time dummy. |
| Patnaik and Joshi (2000) | 1970-71-1992-93 | Significant positive | Public investment in agriculture, agricultural GDP, institutional credit (current & lagged). |
| Gulati and Bathla (2001) | 1980-81-1998-99 | Significant positive | Intensity of canal irrigation, power supply and institutional finances. |
| Chand (2001) | 1980-81-1996-97 | Significant positive | Public investments in agriculture, institutional finance. |
| Roy and Pal (2002) | 1970-71-1998-99 | Significant positive | Public investment in agriculture, per hectare agricultural SDP, rural poverty, population growth, rural literacy, area under marginal holdings, input subsidy, institutional credit, road density. |
| Misra (2003) | 1967-68-1997-98 | Significant positive | Public investment in agriculture, crop output, institutional credit, relative price of capital, dummy variable |

*Note:* Gandhi (1990 and 1996) included a nominal price index instead of TOT (relative price), further these results are derived from non-linear estimation.

The results contained in Chand (2001), which indicated a unit root process in both private and public agricultural investment series in India, could have important implications for drawing inferences on the impact of TOT on private agricultural investments. If the random walk characterisation is correct, then the inferences from the agricultural investment model cannot be made in the usual manner, because the OLS based regression estimates may indicate only spurious correlation. Quite surprisingly, Chand (2001) has continued to provide results on the determinants of private investment in agriculture on the basis of OLS regressions. If the private investment series is at all non-stationary, then common perception in this regard suggests that a more appropriate approach will be to proceed with cointegration analysis as discussed in Section V.

## III

## TESTS FOR PRESENCE OF UNIT ROOT

There are several ways of testing for the presence of unit root (Hayashi, 2000; Patterson, 2002). While applying the unit root tests, an important problem arises in view of the poor size and power properties of the DF and ADF tests (Christiano and Eichenbaum, 1990; Cochrane, 1991; Campbell and Perron, 1991; 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. Phillips and Perron (1988) developed a generalisation of the ADF procedure that allows for fairly mild assumptions concerning the distribution of the errors. On the contrary, Kwiatkowski *et al*., (1992), Leyborne and McCabe (1994) and others have developed stationarity tests, where the null hypothesis is that of the stationarity against the alternative of a unit root. The basic idea behind such tests has been to seek for a confirmation of the evidence suggested by the 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. However, there is no *a priori* reason to believe that the tests, which use trend-stationary null against an I (1) alternative, is better than the usual ADF or PP tests. 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 (Schlitzer, 1996; Maddala and Kim, 1998).We briefly discuss the procedure for these three tests.

*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.,

$$\Delta x_t = \beta_0 + \beta_1 x_{t-1} + \beta_2 t + \varepsilon_t \qquad \ldots(2)$$

To test for the presence of unit root in (IV.2), we test the null hypothesis $H_0:\beta_1=0$, against $H_0 : \beta_1 < 0$, with the left-sided critical region and referring to the critical values provided in the $\tau_\tau$ 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). As a result, the application of a sequential procedure has often been suggested while implementing the ADF test. In this study, we have used the sequential testing procedure outlined in Enders (1996). The step-by-step testing procedure involves considering three different regression equations, viz.,

$$\Delta x_t = \beta_0 + \beta_1 x_{t-1} + \beta_2 t + \Sigma_i \gamma_i \Delta x_{t-i} + \varepsilon_t \quad \text{.... (3.1)}$$

$$\Delta x_t = \beta_0 + \beta_1 x_{t-1} + \Sigma_i \gamma_i \Delta x_{t-i} + \varepsilon_t \quad \text{.... (3.2)}$$

$$\Delta x_t = \beta_1 x_{t-1} + \Sigma_i \gamma_i \Delta x_{t-i} + \varepsilon_t \quad \text{.... (3.3)}$$

To examine the presence of unit root, we test the null hypothesis $H_0:\beta_1=0$, in all the three equations by using the $\tau_\tau$, $\tau_\mu$ and $\tau$ statistics, respectively. Several joint F-test can also be employed to gain additional information on the unit root hypothesis.

*Phillips-Perron Test:* One possible weakness in the DF and ADF tests has been that their underlying distribution theories assume that residual errors are statistically independent and have a constant variance. 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: $H_0 : \beta_1=0$, is tested by using $\tau_\tau$ statistics and referring to the critical values of DF tables.

*Kwiatkowski, Phillips, Schmidt and Shin (KPSS) Test:* It has been 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 (Maddala and Kim, 1998). 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 practice 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.

IV

## TEST RESULTS ON TIME SERIES PROPERTIES

For our testing purpose, we use the Central Statistical Organisation's (CSO) series on the real public and private gross domestic capital formation (GDCF) in agriculture at 1980-81 prices.[8] The GDCF series includes gross fixed capital formation (GFCF) plus changes in stocks. Since the break-up between public and private sector GFCF in agriculture is not available, we have used the series on GDCF. That is, the estimates of private sector GDCF in agriculture are derived by subtracting the share of public sector from the total agricultural GDCF. We use two measures to capture agricultural TOT in India, viz., the TOT series based on the ratio of IPD for agriculture to non-agriculture, and the TOT series provided by the Commission for Agricultural Costs and Prices (CACP). While the former TOT series has been used by Misra and Hazell (1996), Misra (1998, 2003) and Roy and Pal (2003), the latter has been used by Gulati and Bathla (2001) and Chand (2001) in the examination of the impact of TOT on private agricultural investment.

### *DF and ADF Test Results*

The results on the application of DF tests for the public, private and total investment as well as two TOT series in India are provided in Table 2. As can be seen, the null hypothesis for the existence of unit root is accepted for each and every series as par the DF test. The Lagrange Multiplier statistic for the first order auto-regressive scheme is insignificant at 10 per cent level of significance.

TABLE 2. DF TEST RESULTS FOR TOT, PUBLIC AND PRIVATE INVESTMENT LEVELS IN AGRICULTURE

| Variables<br>(1) | $\tau_\tau$ ($H_0$: $b_1$=0)<br>(2) | LM Statistics for serial correlation<br>(3) | Inference<br>(4) |
|---|---|---|---|
| Critical value (10 per cent) | -3.18 | 2.71 | |
| Private GDCF in agriculture (1960/61-1995/96) | -1.85 | 0.001 | Accept $H_0$ |
| Public GDCF in agriculture (1960/61-1995/96) | -1.79 | 3.20 | Accept $H_0$ |
| Total GFCF in agriculture (1951/52-1995/96) | -1.28 | 0.01 | Accept $H_0$ |
| TOT based on IPD Series (1951/52 to 1995/96) | -2.35 | 2.53 | Accept $H_0$ |
| TOT based on CACP Series (1952/53 to 1995/96) | -2.21 | 2.39 | Accept $H_0$ |

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

The ADF test statistics for these variables together with the details on the number of lags are provided in Table 3.[9] The non-stationarity hypothesis could not be rejected for any series in the general model, at 10 per cent level of significance. Since the null of a unit root is not rejected for any of the variables 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 series in the model without a time trend. Finally, the null of unit root could not be rejected in the model that is estimated without the trend or drift terms.

TABLE 3. ADF TEST RESULTS FOR TOT, PUBLIC AND PRIVATE INVESTMENT LEVELS IN AGRICULTURE

| Variables | Lags | $\tau_\tau$ $H_0$:=0 | $\Phi_3$ ($H_0$: $b_1$=$b_2$ =0) | $\tau_\mu$ ($H_0$: $b_1$=0) | $\tau$ ($H_0$: $b_1$=0) | Inference |
|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Critical value (10 per cent) | | -3.18 | 5.61 | -2.60 | -1.61 | |
| Private GDCF in agriculture | 3 | -2.28 | 2.72 | -0.31 | 1.53 | Accept $H_0$ |
| Public GDCF in agriculture | 1 | -1.92 | 3.65 | -2.74 | 1.44 | Accept $H_0$ |
| Total GFCF in agriculture | 3 | -2.27 | 3.59 | 0.81 | 1.73 | Accept $H_0$ |
| TOT based on IPD series | 2 | -2.03 | 2.13 | -1.67 | 0.21 | Accept $H_0$ |
| TOT based on CACP series | 1 | -2.64 | 3.52 | -2.63 | -0.13 | Accept $H_0$ |

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

### *4.2 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 equations. The test statistics, $\tau_\tau$ and $\tau_\mu$ used to examine the unit root hypotheses ($H_0$: $b_1$=0), are provided in Table 4. The results indicate that all the concerned variables are non-stationary at the level form.

TABLE 4. PHILLIPS-PERRON TEST RESULTS FOR TOT, PUBLIC AND PRIVATE INVESTMENT LEVELS IN AGRICULTURE

| Variables | $\tau_\tau$ | $\tau_\mu$ | Inference |
|---|---|---|---|
| (1) | (2) | (3) | (4) |
| Critical value (10 per cent) | -3.18 | -2.60 | |
| Private GDCF in agriculture | -1.01 | 0.51 | Accept $H_0$ |
| Public GDCF in agriculture | -2.64 | -2.39 | Accept $H_0$ |
| Total GFCF in agriculture | -2.64 | 0.70 | Accept $H_0$ |
| TOT based on IPD series | -2.50 | -2.29 | Accept $H_0$ |
| TOT based on CACP series | -2.04 | -2.08 | Accept $H_0$ |

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

### *4.3 KPSS Test Results*

The KPSS test results for different series with a lag truncation parameter (l) from l= 0 to l= 4 are given in Table 5. It can be seen that the null of stationarity is rejected for the private and public GDCF series at each values of the lag. The total GFCF series however fail to reject the stationarity hypothesis at each lag-values. The evidence for trend stationarity hypothesis with regard to the TOT series based on IPDs as well as CACP is rejected at lag-values from l= 0 to l= 3, and accepted marginally only at l=4.

TABLE 5. KPSS TEST RESULTS FOR AGRICULTURAL NBTOT INDICES ($H_0$: TREND STATIONARITY)

| Variables (1) | l=0 (2) | l=1 (3) | l=2 (4) | l=3 (5) | l=4 (6) | Inference (7) |
|---|---|---|---|---|---|---|
| Private GDCF in agriculture | 0.65 | 0.34 | 0.23 | 0.18 | 0.16 | Reject |
| Public GDCF in agriculture | 0.25 | 0.16 | 0.12 | 0.10 | 0.09 | Reject |
| Total GFCF in agriculture | 0.22 | 0.13 | 0.10 | 0.09 | 0.08 | Reject |
| TOT based on IPD series | 0.31 | 0.17 | 0.13 | 0.11 | 0.10 | Reject |
| TOT based on CACP series | 0.33 | 0.19 | 0.14 | 0.12 | 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 (per cent): 0.10 0.05 0.025 0.01
Critical Value: 0.11 0.14 0.17 0.21.

A major weakness of the unit root tests arises due to the fact that there is often scope for disagreement among the ADF, PP and KPSS test results (see, e.g. Kwiatkowski *et al.,* 1992; Henricsson and Lundback, 1995; Silvapulle, 1996; Cheung *et al.,* 1995; Schlitzer, 1996, etc.)

To provide a comparison among different tests, we summarise our unit root results in Table 6.

TABLE 6. COMPARISON OF RESULTS FROM ADF, PP AND KPSS TESTS

| Variables (1) | ADF (2) | PP (3) | KPSS (4) |
|---|---|---|---|
| Private GDCF in agriculture | Y | Y | Y |
| Public GDCF in agriculture | Y | Y | Y |
| TOT based on IPD series | Y | Y | Y |
| TOT based on CACP series | Y | Y | Y |

*Note:* "Y" denotes presence of unit root.

It can be seen that the ADF, PP and KPSS tests confirm the non-stationarity hypothesis for the private investment, public investment and TOT series in Indian agriculture. Since the results of the tests are proved to be robust with regard to the choice of unit root tests, it seems safer to rely on the *random walk* feature of the concerned variables in the agricultural investment model.

## V

## COINTEGRATION ANALYSIS

The ADF, PP and KPSS test results indicate that the private investment and TOT series in agriculture that have been used in the past are unit root processes, and therefore raise apprehensions for the estimated results on the influence of TOT on private investment levels in Indian agriculture. As our first step towards modelling the private agricultural investment behaviour in the cointegration framework, we need to investigate on the order of integration of the concerned variables. When the DF and the sequential procedure of the ADF test are applied to the first difference, these sequences are found to be stationary (Table 7). Hence, we infer that the variables are all integrated of the order 1, viz., I (1) processes. We therefore proceed to examine the cointegrating relationship in the agricultural investment model. Our analysis refers to the period from 1960-61 to 1995-96.

TABLE 7. DF AND ADF TEST RESULTS FOR RELEVANT VARIABLES IN FIRST DIFFERENCES

| | DF | Inference | ADF | | | | Inference |
|---|---|---|---|---|---|---|---|
| | | | Lag | $\tau_\tau$ | $\tau_\mu$ | $\tau$ | |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Critical value (10 per cent) | -3.18 | | | -3.18 | -2.60 | -1.61 | |
| Private GDCF in agriculture | -6.32 | Reject $H_0$ | 1 | -4.24 | -4.31 | -3.15 | Reject $H_0$ |
| Public GDCF in agriculture | -5.21 | Reject $H_0$ | 1 | -3.84 | -3.33 | -3.18 | Reject $H_0$ |
| Total GFCF in agriculture | -6.70 | Reject $H_0$ | 1 | -2.77 | -2.46 | -1.65 | Accept $H_0$ |
| TOT based on IPD series | -5.52 | Reject $H_0$ | 1 | -5.79 | -5.85 | -5.90 | Reject $H_0$ |
| TOT based on CACP series | -5.68 | Reject $H_0$ | 3 | -4.08 | -4.15 | -4.21 | Reject $H_0$ |

### *5.1 Bivariate Analysis in Engle-Granger's Framework*

Using the Engle-Granger methodology, a cointegration test between $TOT_t$ and $Z_t$ (an arbitrary policy variable) entails that the residual sequence ($\varepsilon_t$) from the estimated long-run equilibrium relationship given below to be stationary. That is, we first estimate $Z_t = \beta_0 + \beta_1 TOT_t + \varepsilon_t$, , and then test the null hypothesis $H_0 : \alpha = 0$ by using the auto-regression of residuals as, $\Delta\varepsilon_t = \alpha \ \varepsilon_{t-1} + \omega_t$, and using the critical values provided by Engle-Granger. In case, the residuals indicate the presence of serial correlation, we use the ADF test on residuals in the form: $\Delta\varepsilon_t = \alpha\varepsilon_{t-1} + \Sigma_i \beta_i \Delta\varepsilon_{t-1} + \omega_t$ .

#### *5.1.1 Test Results*

We first undertake a bivariate cointegration test between private investment and TOT and also between public investment and TOT, in agriculture. The results of CRDW, DF and ADF tests on specific residuals are provided in Table 8. The idea behind these tests is to find out whether the regression of one integrated variable on the other integrated variable results in stationary residuals. The residual series from each pair of functional specification are generated by running the cointegrating regressions in both the directions. As can be seen, the DF and ADF test results could not reject the non-stationarity of the residuals derived from the regression of private investment and TOT in agriculture.[10] Thus, the Engle-Granger test results would clearly suggest the absence of any cointegrating relationship between the private investment and TOT in agriculture. On the contrary, the null hypothesis of no cointegration is rejected only for the residuals of the regression of TOT (CACP series) on public investment in agriculture.

TABLE 8. ENGLE-GRANGER'S COINTEGRATION TESTS BETWEEN TOT AND PRIVATE INVESTMENT AND BETWEEN TOT AND PUBLIC INVESTMENT IN AGRICULTURE *($H_0$: NO COINTEGRTION)*.

| Cointegrating Regressions (1) | CRDW (2) | DF test statistic (3) | ADF test statistic (4) | Inference (5) |
|---|---|---|---|---|
| Critical Value (10 per cent) | 0.32 | -3.03 | -2.91 | |
| $PVTGDCF_{Agr}$ = f (IPD) | 0.15 | 0.35 | -0.03 (3) | Accept |
| IPD = f ($PVTGDCF_{Agr}$) | 0.45 | -2.58 | -2.47 (2) | Accept |
| $PVTGDCF_{Agr}$ = f (CACP) | 0.13 | 0.44 | -0.09 (3) | Accept |
| CACP = f ($PVTGDCF_{Agr}$) | 0.42 | -2.32 | -2.65 (1) | Accept |
| $PUBGDCF_{Agr}$ = f (IPD) | 0.09 | -1.82 | -1.73 (3) | Accept |
| IPD = f ($PUBGDCF_{Agr}$) | 0.43 | -2.84 | -2.85 (3) | Accept |
| $PUBGDCF_{Agr}$ = f (CACP) | 0.15 | -2.13 | -2.15 (2) | Accept |
| CACP = f ($PUBGDCF_{Agr}$) | 0.49 | -2.75 | -4.39 (3) | Reject |

*Notes:* 1) $PVTGDCF_{Agr}$ and $PUBGDCF_{Agr}$ represent the real private and public gross domestic capital formation in agriculture, respectively. IPD and CACP denote the ratio of IPD for agriculture to that of non-agriculture and the TOT series provided by the CACP (Ministry of Agriculture, Government of India), respectively. 2) Figures in parentheses indicate lag length in the ADF regressions.

The bivariate cointegration results suggest that there is no long-run equilibrium relationship between TOT and private investment in agriculture. It may be noted in this context that the literature on price distortions in (or bias against) agriculture has claimed that price incentives and private investment in agriculture are complementary in nature (Bautista and Valdes, 1993). Now, if this is indeed so, then the inducement effect of TOT changes upon private investment may be effective through its influence on public investments, and the lack of cointegration could have resulted due to the exclusion of a crucial explanatory variable in our system. We therefore undertake multivariate cointegration analysis for the model in the following sub-section.

### *5.2 Multivariate Analysis in Johansen's Framework*

The method of identifying cointegration relationship(s) according to the procedure provided in Johansen (1988) and Johansen and Juselius (1990, 1992) 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:

$$y_t = M + \Sigma_i^k \Pi_i y_{t-i} + E_t, (t = 1, 2...T) \quad \text{....(4)}$$

where, each of $\Pi_i$ 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 (4) in first-difference notation and formulate the error correction representation of $y_t$ as:

$$\Delta y_t = \Gamma_1 \Delta y_{t-1} + ... + \Gamma_{k-1} \Delta y_{t-k+1} + \Pi y_{t-1} + u_t \quad \text{.... (5)}$$

where, $\Pi_i = -(I - \Pi - \ldots - \Pi_i)$;I = 1,…k – 1, $\Pi = -(1 - \Pi_1 - \ldots \Pi_k)$

$\Gamma_i$ 's are (n*n) coefficient matrix for $\Delta y_{t-1}$, i = 1,2,….k-1
$\Pi$ 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 $\Gamma_i$ and $\Pi$ respectively. The cointegration analysis mainly involves examining the impact matrix $\Pi$ to gather information on the long run relationship(s) among variables contained in the $y_t$ vector. That is, if the rank of $\Pi$ 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 the 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.

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:

$$\lambda_{trace} = - T \sum_{i=r+1}^{n} 1n (1 - \lambda_i)$$

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, which is computed as:

$$\lambda_{max} = - T \ 1n (1 - \lambda_{r+1})$$

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

The presence of significant cointegrating vector(s) in the multivariate formulation of private investment model can provide some important indications about the long-run relationship(s) among the concerned variables. The interpretation of our results is discussed in the following sub-section.

### 5.2.1 Test Results

The multivariate cointegration tests in the agricultural investment model has been conducted by considering $z_t$ as an (3*1) column vector of private investment, TOT and public investment levels in agriculture, i.e.,[11]

$$Z_t = (GDCF_{pvt}, TOT, GDCF_{pub})$$

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 9 shows the result. It can be seen that the null hypothesis of non-cointegration could be rejected only marginally by means of the lambda-trace test statistic at 10 per cent level. The lambda-max test statistic on the other hand failed to reject the same hypothesis at the similar level of significance. This apparent contradiction on the decision concerning the presence of cointegrating relations is not uncommon in empirical research. It is generally argued that one should rely more on the evidence based on the maximum-Eigen value test in case there is any conflicting results.[12] Thus, the presence of any significant cointegrating relationship among private investment, TOT and public investment in agriculture would appear to be doubtful.[13] These findings would indicate that it is difficult to establish the presence of any long-run relationship between TOT and private investment or between private and public investment in agriculture on the basis of cointegration analysis.

TABLE 9. JOHANSEN'S COINTEGRATION TEST INVOLVING PRIVATE INVESTMENT, TOT AND PUBLIC INVESTMENT IN AGRICULTURE (SAMPLE: 1960-61 TO 1995-96)

| Hypothesis (1) | $\lambda_{trace}$ (2) | Critical value (1 per cent) (3) | Critical value (5 per cent) (4) | Critical value (10 per cent) (5) | Decision (6) |
|---|---|---|---|---|---|
| $H_0$: r=0, $H_1$:r>0 | 33.10 | 40.19 | 35.07 | 32.09 | Indicates one cointegrating |
| $H_0$: r<1 $H_1$:r>1 | 14.17 | 24.39 | 20.17 | 17.96 | equation at 10 per cent level |
| $H_0$: r<2 $H_1$:r>2 | 1.90 | 12.74 | 9.09 | 7.56 | of significance |
| Hypothesis (1) | $\lambda_{max}$ (2) | Critical value (1 per cent) (3) | Critical value (5 per cent) (4) | Critical value (10 per cent) (5) | Decision (6) |
| $H_0$: r=0, $H_1$:r=1 | 28.93 | 26.41 | 21.89 | 19.79 | Rejects any cointegration at |
| $H_0$: r=1 $H_1$:r=2 | 12.27 | 19.83 | 15.75 | 13.78 | 10 per cent level of |
| $H_0$: r<2 $H_1$:r>2 | 1.90 | 12.74 | 9.09 | 7.56 | significance |

*Note:* (1) Test assumption: no deterministic trend in the data, lag length: 1. (2) We have used the agricultural TOT series based on ratio of IPD.

## VI

## PRIVATE AGRICULTURAL INVESTMENT MODEL IN VAR FRAMEWORK

It is claimed that if the economic model contains cointegrated variables, one is justified in going further and estimating the dynamic relationship that incorporates the equilibrium and also interpret how the short-run adjustments to that equilibrium are made (Granger 1997, Pesaran 1997). This is the second stage of the model building procedure, in which a vector error correction (VEC) model is estimated by imposing cointegrating restrictions among variables contained in the vector autoregression (VAR). The VEC version of private agricultural investment model can be set up by incorporating the lagged first-difference terms and the *error-correction term* (ECT) as follows: [14]

$$\Delta X_t = \alpha_1 + \beta_X e_{t-1} + \Sigma_{i=1}\beta_{11}(i)\Delta X_{t-i} + \Sigma_{i=1}\beta_{12}(i)\Delta TOT_{t-i} + \Sigma_{i=1}\beta_{13}(i)\Delta Y_{t-i} + \varepsilon_{1t}$$
$$\Delta TOT_t = \alpha_2 + \beta_{TOT} e_{t-1} + \Sigma_{i=1}\beta_{21}(i)\Delta X_{t-i} + \Sigma_{i=1}\beta_{22}(i)\Delta TOT_{t-i} + \Sigma_{i=1}\beta_{23}(i)\Delta Y_{t-i} + \varepsilon_{2t}$$
$$\Delta Y_t = \alpha_3 + \beta_Y e_{t-1} + \Sigma_{i=1}\beta_{31}(i)\Delta X_{t-i} + \Sigma_{i=1}\beta_{32}(i)\Delta TOT_{t-i} + \Sigma_{i=1}\beta_{33}(i)\Delta Y_{t-i} + \varepsilon_{3t}$$

where, $X_t$, $Y_t$ and $TOT_t$ represent private investment, public investment and TOT in agriculture, respectively. The error correction term is denoted by: $e_{t-1} = Z_{t-1} - c_1 TOT_{t-1} - c_2 Y_{t-1}$, $c_1$ and $c_2$ are the parameters of the cointegrating vector, and $\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}$ are the white noise disturbances.

Since the evidence on the presence of cointegrating relationship(s) among private investment, TOT and public investment in agriculture is found to be less-convincing, it seems that there is no long-run relationship among them. As a result, there is little meaning in setting up the model in error correction framework. In fact, when we attempt to work out the VEC estimates of the model, the coefficient of the error correction terms (ECT) turns out to be positive (Table 10). These coefficients apparently reflect the short-run deviations of the system from the long-run equilibrium level; thus, the speed of adjustment of any disequilibrium towards the long-run growth path is generally interpreted from these coefficients. In the present case, the positive ECTs would indicate that the short-run disequilibrium adjustment process might not lead the system to a stable long-run level of private investment in agriculture. Further, the VEC results convey that the short-run influences of both TOT and public investments are statistically insignificant in explaining the private investment. On the other hand, agricultural TOT indicated a significant negative influence on public agricultural investments in the short-run.

TABLE 10. ERROR CORRECTION ESTIMATES INVOLVING PRIVATE INVESTMENT, TOT AND PUBLIC INVESTMENT IN AGRICULTURE (SAMPLE: 1951-52 TO 1995-96)

| Variables<br>(1) | Private GDCF in agriculture (ΔPVGDCF)<br>(2) | Terms of trade (ΔTOT)<br>(3) | Public GDCF in agriculture (ΔPBGDCF)<br>(4) |
|---|---|---|---|
| Error Correction Term | 0.16 | 0.001 | 0.04 |
| | (3.09)* | (1.47) | (2.44)* |
| ΔPVGDCF(−1) | -0.38 | 0.001 | -0.08 |
| | (-1.72) * | (0.47) | (-1.31) |
| ΔTOT(-1) | 0.34 | 0.19 | -6.51 |
| | (0.03) | (1.16) | (-2.25)* |
| ΔPBGDCF(−1) | 0.09 | 0.01 | 0.40 |
| | (0.17) | (1.30) | (2.75)* |

*Notes:* (1) * and ** indicates level of significance at 10 and 20 per cent level, respectively.
(2) Normalized Coint. Eqn: PVGDCF = -11229.15 + 91.92 TOT + 3.15 PBGDCF.

### *6.1 Causality Analysis*

We can alternatively model the private agricultural investment behaviour with traditional VAR in first differences involving no long-run elements, i.e., we can determine the short-run causal effects by dropping the error-correction terms from each specification as shown below and then interpret the Granger causality test statistics.

$$\Delta X_t = \alpha_1 + \Sigma_{i=1}\beta_{11}(i)\Delta X_{t-i} + \Sigma_{i=1}\beta_{12}(i)\Delta TOT_{t-i} + \Sigma_{i=1}\beta_{13}(i)\Delta Y_{t-i} + \varepsilon_{1t}$$
$$\Delta TOT_t = \alpha_2 + \Sigma_{i=1}\beta_{21}(i)\Delta X_{t-i} + \Sigma_{i=1}\beta_{22}(i)\Delta TOT_{t-i} + \Sigma_{i=1}\beta_{23}(i)\Delta Y_{t-i} + \varepsilon_{2t}$$
$$\Delta Y_t = \alpha_3 + \Sigma_{i=1}\beta_{31}(i)\Delta X_{t-i} + \Sigma_{i=1}\beta_{32}(i)\Delta TOT_{t-i} + \Sigma_{i=1}\beta_{33}(i)\Delta Y_{t-i} + \varepsilon_{3t}$$

where $X_t$, $Y_t$ and $TOT_t$ represent private investment, public investment and TOT in agriculture, respectively; $\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}$ are the white noise disturbances.

The short-run Granger causality test statistics derived from the multivariate VAR involving private investment, TOT and public investment in agriculture are given in Table 11.[15]

TABLE 11. PAIR WISE GRANGER CAUSALITY TESTS INVOLVING TOT, PRIVATE AND PUBLIC INVESTMENT IN AGRICULTURE (SAMPLE: 1960-61-1995-96)

| Null Hypothesis (1) | Lags (2) | F-Statistics (3) |
|---|---|---|
| TOT does not cause private investment in agriculture | 3 | 1.50 |
| Private investment does not cause TOT in agriculture | 2 | 0.15 |
| Public investment does not cause private investment in agriculture | 3 | 1.21 |
| Private investment does not cause public investment in agriculture | 3 | 2.16 |
| Public investment does not cause TOT in agriculture | 2 | 1.52 |
| TOT does not cause public investment in agriculture | 3 | 3.83* |

*Note:* * indicates statistical significance at 5 per cent level.

The results do not reveal any significant causation from agricultural TOT to private investment levels. On the other hand, there is an indication that rising TOT provides a causal effect on the public investment levels in agriculture. The direction of causality may imply that rising agricultural TOT reduce the government's share of agricultural investment by eroding its fiscal base and enhancing the expenditures, as has been argued by Mohan Rao and Storm (1998). In this context, it may be noted that Desai and Namboodiri (1997) found that improvements in TOT have a net impact that reduces the government expenditure in agriculture.

## VII

## CONCLUSIONS

The issues surrounding the trend and determinants of private capital formation in agriculture have remained a widely researched topic in the literature of agricultural development in India. A significant number of economists have argued that TOT movements in favour of agriculture bear a significant positive influence on the private investment levels. It is further claimed that improvements in agricultural TOT, which followed after the economic reform was introduced in the country in 1991, have promoted the level of private investment in agriculture.

It may be noted in this context that almost all the earlier studies have assumed the underlying data generating process (DGP) of the variables involved in the agricultural investment model to be stationary. We argue that the conventional regression analysis that does not consider the time series properties (viz., examine the presence of stochastic trend) of the variables, may lead to misleading inferences about the influence of TOT on private investment in agriculture. This assertion is further corroborated by some preliminary results provided by Chand (2001), which indicated the presence of unit root (viz., non-stationary DGP) in both the private and public investment data series in Indian agriculture. In this backdrop, the main objective of this paper is to analyse the long-run relationship between the TOT and investment level in Indian agriculture by undertaking cointegration analysis for the period between 1960-61 and 1995-96.

Our analysis begins by first undertaking a rigorous examination of the univariate time series properties of the private investment, TOT and public investment series. The results suggest that the DGP of concerned variables can be characterised by unit root processes. The evidence in favour of the *random-walk* feature appears to be strong considering the fact that both the families of unit root tests (that uses trend-stationary or non-stationary as null hypothesis) have confirmed so. Following our subsequent finding that the variables under consideration are integrated of the same order, viz., I (1), we proceed to examine the presence of long-run relationship(s) underlying the agricultural investment model using cointegration analysis. The bivariate cointegration results indicate the absence of any long-run relationship between TOT and investment level in agriculture. This in turn would suggest that a favourable TOT structure alone may not be effective in sustaining higher agricultural investment in India. Keeping such concerns in mind, we incorporate the public investment variable in combination with TOT in the private investment model. The multivariate cointegration analysis reflects no statistically significant cointegration in Johansen's framework of analysis. The vector error-correction estimates of the model imply that the error-correction mechanism through changes in TOT and public investment will not direct the private investment to converge to its long-term equilibrium level. These findings suggest the absence of any long-run equilibrium relationship among private investment, TOT and public investment in Indian agriculture. The analysis of short run causal effects based on VAR in first differences indicates that a significant causation run from TOT to public investment levels in agriculture.

Overall, the results of this paper cast doubt on the assertion that price reforms are required to maintain the incentive structure so as to enhance the private investment level in agriculture. This finding is in variance with the observation that TOT incentives are essential to stimulate private investment (Gulati and Bathla, 2001; Chand, 2001 and many others), and support the view that price support policies have a limited role in inducing higher private investment in agriculture (Gandhi, 1990, 1996). It may be additionally noted that the results derived from the trivariate cointegration analysis also bear some implications for the existence of a complementary relationship between private and public investment in agriculture.

The lack of any significant cointegrating vector among private investment, TOT and public investment would suggest the absence of any such relation. This however does not mean that such complementarity between the two does not exist. In fact, the absence of such relationship could have occurred due to the weaknesses involved in the cointegration analysis, i.e., the non-cointegratedness may have resulted due to the small sample size or excluded variables in our model. It is possible that the complementary relationship between the private and public agricultural investment works better not in the presence of TOT based incentives but in combination with the non-price (technology) variable. As a possible extension of this study, one can test the inducement effect of public investment on private investment levels by bringing in the role of technology, especially the irrigation variable, in the multivariate cointegration analysis.

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NOTES

1. A spurious regression generally results in an inflated coefficient of determination, and further the task of statistical hypothesis testing becomes problematic in this case due to the fact that the null hypothesis that uses t- and F-tests tends to be over-rejected, suggesting false positive relationship.

2. See, e.g. Maddala and Kim (1998), Hayashi (2000).

3. See Little *et al*. (1970), Lipton (1977), Brown (1978), Bautista and Valdes (1993).

4. The conference volumes of *Indian Journal of Agricultural Economics* for the year 1964, 1965 and 1969 contained even older papers on this theme.

5. The other reasons held responsible for the declining trend in private agricultural investment include: (a) inadequate growth of domestic saving, (b) low productivity and uneconomic farm size in agriculture, (c) sluggish growth in domestic demand, (d) lack of institutional credit and e) slow-down in complementary public investments. Similarly, the fiscal squeeze of the government coupled with rising subsidies and growing expenditures on other heads like the poverty alleviation programmes were attributed for the drop in public investment in agriculture.

6. For example, Brown (1978) maintains that "Higher prices for agricultural products will make at least the non-shadow-priced value of agricultural output greater, and the nominal or financial rate of return to agricultural projects more attractive."

7. Chakravarty's (1974) presumption was based on his *wage goods constraint* hypothesis, which postulated that a favourable agricultural TOT could be instrumental in squeezing the industrial profit and savings through a rise in the *product wage rate*.

8. Almost all the studies with the exception of Chand (2001), Gulati and Bathla (2001) and Roy and Pal (2002) have used the CSO's series on capital formation for the purpose of empirical modelling and estimation. It may be noted that the CSO series has been claimed to be an inadequate indicator of investment in agriculture since it suffers from over- and under-estimation due to methodological reasons (see Mishra and Chand, 1995, Mishra, 1996 for details). For instance, Rao (1997) claimed that the CSO series on public capital formation is a severe under-estimate due to the exclusion of items such as public investments in rural electrification, rural roads, storage and structures, etc. Chand (2001) therefore constructed a new series on public investment in agriculture for the period between 1974-75 to 1996-97, on the basis of considering information on 23 items of capital expenditures as reported in the publication *Finance Accounts* of the Government. On the other hand, Gulati and Bathla (2001) adhered to three different concepts of public capital formation in agriculture. These three alternative series were constructed for the period 1974 to 1998 by incorporating the central and state government's investment in power sector that goes to agriculture including rural electrification. Roy and Pal (2002) have also constructed a new series on public investment in agriculture for the period 1965-66 to 1998-99. The state-wise estimates of private agricultural investment have been constructed by using the All-India Debt and Investment Surveys (RBI-NSSO) in both Chand (2001) and Roy and Pal (2002).

9. 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, the 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).

10. This result is robust for the choice of alternative TOT between the IPD and CACP series.

11. It may be noted that the cointegration tests are valid only for large samples, and further the error-correction estimation requires that the 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.

12. Banerjee *et al.* (1993) has indicated that the result of the maximum Eigen value (lambda-max) test is more reliable in small samples.

13. The results remained unchanged when the TOT series provided by CACP is used in the analysis.

14. In a VEC model, the ECT conveys the long-run causal effects, while the lagged explanatory variables give an indication of short-run adjustments (see Harris, 1995; Enders, 1996 for details).

15. The adequacy of lag-length in these regressions has been determined by AIC and SBC criteria.

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APPENDIX TABLE A-1. REAL INVESTMENT AND TERMS OF TRADE IN INDIAN AGRICULTURE, (1951-52 to 1995-96)

| | Real GDFC in agriculture (Rs. crore)1980-81 | | | NBTOT Series in agriculture base: 1980-81 | |
|---|---|---|---|---|---|
| Year | Public | Private | Total GFC in agricutlure (Rs. crore) | IPD series | CACP series |
| (1) | (2) | (3) | (4) | (5) | (6) |
| 1950-51 | | | 1,224.0 | 101.7 | |
| 1951-52 | | | 1,436.0 | 98.5 | |
| 1952-53 | | | 1,244.0 | 95.3 | 104.4 |
| 1953-54 | | | 1,414.0 | 94.5 | 98.6 |
| 1954-55 | | | 1,367.0 | 79.1 | 99.5 |
| 1955-56 | | | 1,500.0 | 77.8 | 101.6 |
| 1956-57 | | | 1,489.0 | 88.3 | 103.7 |
| 1957-58 | | | 1,473.0 | 87.1 | 102.9 |
| 1958-59 | | | 1,413.0 | 89.2 | 100.7 |
| 1959-60 | | | 1,288.0 | 87.4 | 98.4 |
| 1960-61 | 589.0 | 1,079.0 | 1,585.0 | 81.7 | 90.6 |
| 1961-62 | 600.0 | 1,070.0 | 1,665.0 | 83.8 | 92.3 |
| 1962-63 | 694.0 | 1,154.0 | 1,804.0 | 83.6 | 91.2 |
| 1963-64 | 725.0 | 1,275.0 | 1,939.0 | 92.5 | 83.5 |
| 1964-65 | 765.0 | 1,363.0 | 2,103.0 | 97.6 | 107.7 |
| 1965-66 | 798.0 | 1,510.0 | 2,258.0 | 103.2 | 117.9 |
| 1966-67 | 696.0 | 1,650.0 | 2,313.0 | 112.0 | 129.3 |
| 1967-68 | 688.0 | 1,901.0 | 2,580.0 | 113.2 | 132.4 |
| 1968-69 | 775.0 | 1,919.0 | 2,558.0 | 113.9 | 120.4 |
| 1969-70 | 775.0 | 2,096.0 | 2,754.0 | 112.9 | 116.6 |
| 1970-71 | 789.0 | 1,969.0 | 2,625.0 | 102.9 | 114.5 |
| 1971-72 | 851.0 | 2,073.0 | 2,767.0 | 100.7 | 111.7 |
| 1972-73 | 1,049.0 | 2,131.0 | 2,938.0 | 109.5 | 118.7 |
| 1973-74 | 993.0 | 2,215.0 | 2,902.0 | 119.6 | 125.5 |
| 1974-75 | 919.0 | 2,056.0 | 2,709.0 | 110.0 | 114.5 |
| 1975-76 | 1,041.0 | 2,347.0 | 2,935.0 | 91.9 | 96.9 |
| 1976-77 | 1,378.0 | 2,880.0 | 3,646.0 | 95.5 | 103.8 |
| 1977-78 | 1,534.0 | 2,539.0 | 3,744.0 | 97.5 | 103.9 |
| 1978-79 | 1,697.0 | 3,549.0 | 4,246.0 | 95.4 | 97.8 |
| 1979-80 | 1,772.0 | 3,443.0 | 4,440.0 | 100.1 | 101.5 |
| 1980-81 | 1,817.0 | 2,819.0 | 4,537.0 | 100.0 | 100.0 |
| 1981-82 | 1,878.0 | 2,621.0 | 4,348.0 | 94.8 | 95.0 |
| 1982-83 | 1,857.0 | 2,718.0 | 4,409.0 | 94.8 | 97.0 |
| 1983-84 | 1,843.0 | 2,254.0 | 3,957.0 | 95.0 | 98.9 |
| 1984-85 | 1,822.0 | 2,729.0 | 4,287.0 | 93.9 | 98.5 |
| 1985-86 | 1,631.0 | 2,691.0 | 4,068.0 | 93.1 | 94.4 |
| 1986-87 | 1,428.0 | 2,587.0 | 3,798.0 | 95.8 | 97.7 |
| 1987-88 | 1,458.0 | 2,956.0 | 4,219.0 | 99.7 | 99.5 |
| 1988-89 | 1,362.0 | 2,984.0 | 4,260.0 | 97.0 | 98.7 |
| 1989-90 | 1,156.0 | 3,197.0 | 4,191.0 | 98.5 | 99.1 |
| 1990-91 | 1,154.0 | 3,440.0 | 4,459.0 | 100.2 | 103.1 |
| 1991-92 | 1,002.0 | 3,727.0 | 4,667.0 | 106.3 | 106.2 |
| 1992-93 | 1,061.0 | 4,311.0 | 5,260.0 | 101.9 | 99.2 |
| 1993-94 | 1,153.0 | 4,433.0 | 5,005.0 | 104.4 | 104.1 |
| 1994-95 | 1,316.0 | 4,541.0 | 6,110.0 | 108.8 | 105.2 |
| 1995-96 | 1,268.0 | 5,693.0 | 6,777.0 | 107.8 | 103.3 |

*Source:* CSO's National Accounts Statistics and CACP Report of Ministry of Agriculture, Government of India.