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A perspective on food policies evolution and poverty in the Indian Republic (1950-2001)

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Abstract

This paper analyses the rural food sector of the Indian Republic in an intertemporal growth context. A model is developed which includes the government's conflict between its poverty reducing attempts through public distribution of food, subsidized issue and support food prices and long term developmental goals. The ARDL cointegration procedure for mixed order dynamic processes identifies the major determinants of rural head count poverty for the period, 1953-2000.

The long run elasticity estimates clearly show the real consumer subsidised issue price and the real producer support price dominate the quantity effects of the per capita public distribution on rural head count poverty. Development expenditure and measures of productivity and demographic supply are also found to be important determinants of long run rural poverty.

In contrast, the real issue and producer prices do not have easily identifiable influences on the short run equilibrating adjustments in rural poverty. The model predicts that rural head count poverty, which at 27.6% in 2000 is below trend, will increase to between 29.1 % to 30.3% in 2001. The significant cause of the projected increase is the sizeable increase in the issue price of rice (relative to the CPI for agricultural workers) from 1999 to 2000.

The paper argues that, while productivity and demographic supply improvements are important, real issue and support prices for the major staples, wheat and rice are also key determinants of long term trends in rural poverty. However, because these relative prices have complicated short term effects, the authorities should not manipulate real foodgrain issue and producer prices to achieve short term goals. Pricing policies should be designed to achieve desired long term resource allocation.

Keywords

1950, indian, 2001, perspective, policies, food, republic, poverty, evolution

Disciplines

Business | Social and Behavioral Sciences

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A PERSPECTIVE ON FOOD POLICIES EVOLUTION AND POVERTY IN THE INDIAN REPUBLIC (1950-2001)

E. J. Wilson and D. P. Chaudhri

ABSTRACT

This paper analyses the rural food sector of the Indian Republic in an intertemporal growth context. A model is developed which includes the government's conflict between its poverty reducing attempts through public distribution of food, subsidized issue and support food prices and long term developmental goals. The ARDL cointegration procedure for mixed order dynamic processes identifies the major determinants of rural head count poverty for the period, 1953-2000.

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In contrast, the real issue and producer prices do not have easily identifiable influences on the short run equilibrating adjustments in rural poverty. The model predicts that rural head count poverty, which at 27.6% in 2000 is below trend, will increase to between 29.1% to 30.3% in 2001. The significant cause of the projected increase is the sizeable increase in the issue price of rice (relative to the CPI for agricultural workers) from 1999 to 2000.

The paper argues that, while productivity and demographic supply improvements are important, real issue and support prices for the major staples, wheat and rice are also key determinants of long term trends in rural poverty. However, because these relative prices have complicated short term effects, the authorities should not manipulate real foodgrain issue and producer prices to achieve short term goals. Pricing policies should be designed to achieve desired long term resource allocation.

Keywords: Economic growth, poverty, foodgrain issue prices, support prices, cointegration.

JEL Classification: O11, Q18, C22.

Introduction

The Model

The analytic model is developed to explore the relationships between rural poverty and food policies in a dynamic growth context. The model extends Chaudhri and Wilson (2000) to explicitly incorporate the roles of relative prices in production and consumption. The prices of interest are minimum production support prices and maximum issue prices for food grains. The rural sector is characterised to comprise households who use labour, capital and land to produce agricultural output. The representative rural household is assumed to select the time path of real consumption, denoted c , to maximise intertemporal utility:

$$u(c) = \int_0^{\infty} u[c(t)] e^{-\rho t} dt$$

where $u(c)$ is a concave instantaneous utility function with $u(0) = 0$, $u(c) > 0$, $u'(c) < 0$ and ρ is an (assumed constant) discount rate. The household budget constraint is:¹

$$\dot{k} + c = wl_n + rk + d - \tau$$

On the net income side, w is the real rural wage rate for the household labour (l_n) employed, whilst rk represents the rural household's income return from holding capital (k) with r the real interest rate. Given our focus on rural poverty we assume that land ownership is not significant for the typical household and borrowing is not readily available.² Government transfers, in the form of public distribution received

¹ The prime represents differentiation with respect to the relevant explanatory variable, for example $u'(c) = \partial u(c) / \partial c$. The dot above the variable represents differentiation with respect to time, $\dot{k} = \partial k / \partial t$. The time subscript will be discarded where possible, in order to simplify the notation.

² Whilst it is possible to include land ownership and household borrowing in the model, we wish to keep the analysis simple. An example how this may be done is to include borrowing, \dot{b} , on the right hand side of the constraint with the cost of borrowing, rb , on the left-hand side. In order to ensure model stability it would become necessary to restrict borrowings, \dot{b} , to be less than capital formation, \dot{k} in net present value terms. That is, $\int_0^{\infty} \dot{b}(t) e^{-\rho(s-t)} ds < \int_0^{\infty} \dot{k}(t) e^{-\rho(s-t)} ds$.

by the rural household are represented by d , whilst τ is the tax paid by the household to the authorities. Rural household income from production, in the form of wage income and the return to capital will be equal to household production:³

$$wl_n + rk = y$$

We also make the simplifying assumption that a proportional tax rate ($0 < \alpha_r < 1$) applies to total household income (y) net of transfers. Substituting for τ in gives the modified budget constraint:

$$\dot{k} + c = \alpha y + d \quad 0 < \alpha < 1$$

with $\alpha = 1 - \alpha_r$.

Now the income from production comprises income from purchases by the government, y_s at minimum support price, p_s and open market sales of production, y_{ns} at market price p^* :

$$\begin{aligned} y &= \frac{y_{ns} p^*}{p^*} + \frac{y_s p_s}{p^*} \\ &= y_{ns} + y_s \frac{p_s}{p^*} \end{aligned}$$

Substituting for y in the budget constraint gives:

$$\dot{k} + c = \alpha \left(y_{ns} + y_s \frac{p_s}{p^*} \right) + d$$

The right hand side of the budget constraint therefore shows the rural household income (net of taxes) comprises returns to factors of production from sales to the open market and the government plus any transfers in the form of public distribution received.

The left hand side shows that rural production may be consumed, c or invested, \dot{k} . Now consumption expenditure comprises purchases from the government, c_I at the maximum issue price, p_I plus purchases from the open market, c_{nl} at free market price p^* . Consumption is therefore given by:

$$c = c_{nl} + c_I \frac{p_I}{p^*}$$

³ As explained earlier, given our focus on the rural poor, we make the simplifying assumption that rural households do not own land and therefore do not receive any returns from it.

and the budget constraint becomes:

$$\dot{k} + \left(c_{nl} + c_l \frac{p_l}{p^*} \right) = \alpha \left(y_{ns} + y_s \frac{p_s}{p^*} \right) + d.$$

The government budget constraint includes the government purchases of food grains at the minimum support price (on the left hand side) and government sales at the maximum issue price (on the revenue side):

$$g_i + y_s \frac{p_s}{p^*} + d = \tau + c_l \frac{p_l}{p^*}$$

The other factors include government investment expenditure, g_i on infrastructure development projects and outlays consisting of transfers in the form of public distribution, d .⁴

Household production is assumed to be a function of household labour, l_n , capital, k and land, l_l :⁵

$$y = f \left(A, l_n, k, l_l, g_i, \frac{p_s}{p^*} \right)$$

Importantly the production function also includes the effects of total factor productivity, A , government investment expenditure, g_i and the relative minimum support price, p_s/p^* .

Appendix A1 details the Hamiltonian maximisation of household intertemporal utility, $u(c)$ with respect to the household budget constraint. This derives the important solution for q :

$$q = \int_0^\infty (\alpha f'_k + d'_k) e^{-r(s-t)} ds$$

where $f'_k = \partial f / \partial k$ and $d'_k = \partial d / \partial k$ denote the marginal products of capital in terms of production and public distribution.

⁴ Outlays may also include government consumption expenditure on goods and services broadly defined to include spending on public service wages. Consistent with the exclusion of borrowing by the rural household we assume for simplicity a balanced budget. This is not unrealistic in that large budget deficits are not a feasible over the longer term for a developing country.

⁵ The production function is assumed to be well behaved: $x(0) = x_0$, $f'_x > 0$, $f''_x < 0$, $\lim_{x \rightarrow 0^+} f'_x = \infty$ and $\lim_{x \rightarrow \infty} f'_x = 0$ where $f'_x = \partial f / \partial x$, $f''_x = \partial^2 f / \partial x^2$, $\forall x \in \{A, l_n, k, l_l, g_i, T\}$.

Substituting for q gives capital formation as a function of the net present values of the marginal product of capital in production and public distribution:

$$\dot{k} = \Phi \left[\int_0^{\infty} (\alpha f'_k + d'_k) e^{-r(s-t)} ds \right]$$

The rural household labour relationship can also be simply obtained in terms of the marginal products from the Hamiltonian first order condition for the rural wage, $w = \alpha f'_{l_n} + d'_{l_n}$. Solving this condition for the demand for labour, l_n^d , gives:

$$l_n^d = w (\alpha f'_{l_n} + d'_{l_n})^{-1}$$

We hypothesise that labour supply, l_n^s will be a function of supply side effects like rural population, n , the literacy rate, lit , the number of children, n_c and poverty, p . Equilibrium employment, l_n is therefore determined by:

$$\begin{aligned} l_n &= w \left[\alpha f'_{l_n} \left(A, l_n, k, l_i, g_i, \frac{p_s}{p^*} \right) + d'_{l_n} \right]^{-1} \\ &= l_n^s(n, lit, n_c, p) \end{aligned}$$

with real wage:

$$w = \left[\alpha f'_{l_n} \left(A, l_n, k, l_i, g_i, \frac{p_s}{p^*} \right) + d'_{l_n} \right] \times l_n^s(n, lit, n_c, p)$$

These relationships explicitly show the importance of the marginal product and total factor productivity in the determination of the agricultural output. Importantly an increase in the relative minimum support price, p_s/p^* will lead to an increase output via the production function, an increase in the marginal product of capital, f'_k and therefore in Tobin's q and investment, \dot{k} . The subsequent increase in the demand for labour will further increase employment and output.

On the demand side, the optimum growth in rural household consumption can be easily determined by substituting out the costate variable in the Hamiltonian maximisation to give:⁶

⁶ The elasticity of marginal utility with respect to consumption term is given by $\frac{-1}{\theta} = \frac{cu''(c)}{u'(c)}$.

$$\frac{\dot{c}}{c} = \theta \left[\left(\alpha \left(\frac{\partial y_{ns}}{\partial k} + \frac{\partial}{\partial k} \left(y_s \frac{p_s}{p^*} \right) \right) + d'_k \right) - \rho \right],$$

The growth in consumption is therefore an inverse function of the rate of time preference, ρ and a positive function of any marginal product from public distribution. The other terms on the right hand side show that consumption growth is also a function of the marginal products of capital for non-price supported output, $\partial y_{ns}/\partial k$ and for minimum support price output:

$$\frac{\partial}{\partial k} \left(y_s \frac{p_s}{p^*} \right) = \frac{\partial y_s}{\partial k} \frac{p_s}{p^*} + y_s \frac{\partial (p_s/p^*)}{\partial k}.$$

This latter marginal product is weighted by the relative minimum support price. An increase in the support p_s relative to the general price level, p^* will therefore cause an increase in the growth in consumption:

$$\frac{\partial \dot{c}/c}{\partial p_s/p^*} > 0$$

The optimum growth in consumption on the left hand side of the relationship can also be expressed in terms of maximum issue prices:

$$c = c_{nl} + c_l \frac{p_l}{p^*}$$

Consider the *ceteris paribus* case where none of the right hand variables change, then consumption growth must be constant. An increase in relative prices, p_l/p^* will therefore require the level of consumption, c_l and/or c_{nl} to fall:

$$\frac{\partial p_l}{\partial t} p^{*-1} > 0 \Rightarrow \frac{\partial c_l}{\partial t}, \frac{\partial c_{nl}}{\partial t} < 0 \text{ such that } \dot{c} = c_0$$

In summary, the model importantly shows that changes in relative prices will affect consumption and production. However it should be noted that these effects are varied and can be complicated in their transmission.

It is now necessary to link consumption with poverty in order to facilitate analyse of the effects on rural poverty. This is easy because poverty is conceptualised in terms of nutritional requirements. We therefore define the measure of rural poverty, p as a function of rural household consumption, out of household production, which is below a conventionally accepted minimum, c_{min} :

$$p = -\psi(c_0) \quad c_0 < c_{min} \quad (15)$$

Taking the inverse function $c = -\varphi(p)$ and rearranging the household budget constraint, $c = -\dot{k} + w l_n + r k + d - \alpha_r y$, we can substitute poverty for consumption and after some manipulation (detailed in Appendix A2) derive the level of poverty at time t_0 :

$$\therefore p(t_0) = -\varphi^{-1} \left\{ \pi \left[h(t_0) + k(t_0) + d(t_0) - \alpha_r y(t_0) \right] \right\}$$

$$\text{where: } \pi = \left\{ \int_0^\infty e^{\int_0^s [\theta[\rho - \alpha f'_k(s) + d'_k(s)] - r(s)] ds} dt \right\}^{-1}.$$

This relationship shows that the present value of rural poverty at time t_0 is an inverse function of rural household wealth, which comprises the sum of net present values of human capital, $h(t_0) = \int_0^\infty w(t) l_n(t) e^{-\int_0^t r(s) ds} dt$ and physical capital effects, $k(t_0)$. Poverty is also inversely affected by the public distribution to rural households $d(t_0)$, net of the present value of taxation, $\alpha_r y(t_0)$. In addition, increases in the marginal product of capital in production, f'_k will further decrease rural poverty by reducing the value of the π parameter. It has been shown that increases in the marginal product of capital will also increase Tobin's marginal valuation of capital, q , the rate of capital formation, \dot{k} and therefore the stock of capital, k . Since:

$$f'_k = \frac{\partial}{\partial k} \left(y_s \frac{p_s}{p^*} \right) = \frac{\partial y_s}{\partial k} \frac{p_s}{p^*} + y_s \frac{\partial (p_s/p^*)}{\partial k}$$

it is clear that increases in the relative minimum support price, p_s/p^* will decrease rural poverty in complicated ways via these channels.

The effects of the maximum issue price can be seen from the inverse function:

$$c = \left(c_{nt} + c_t \frac{p_t}{p^*} \right) = -\varphi(p)$$

when substituted into the consumption growth equation:

$$\frac{\partial [\varphi(p)] / \partial t}{\varphi(p)} = \theta [\rho - (\alpha f'_k + d'_k)]$$

As previously argued, increases in the relative issue prices, p_I/p^* , conditional on unchanged right hand variables (and therefore constant consumption growth) imply that the levels of consumption, c_I and/or c_{nI} must fall.

In summary, the real minimum support price and maximum issue price are important but complex determinants of rural poverty. These transmission channels are numerous and an example highlights possible policy formulation trade-offs. For a given taxation regime $0 < a_t < 1$, it has been shown that an increase in the real minimum support price, p_s/p^* or a decrease in the real maximum issue price, p_I/p^* will initially increase consumption and reduce rural poverty. However the fiscal budget constraint:

$$g_i + y_s \frac{p_s}{p^*} + d = \tau + c_I \frac{p_I}{p^*}$$

shows that government investment expenditure, g_i and/or public distribution, d must ultimately fall, depending on the induced relative changes in real output, y , and tax receipts, $\alpha_t y$. Any reduction in government investment in infrastructure will offset the previous increase in the marginal productivity of capital, defined earlier as $f'_k \left(A, l_n, k, l_I, g_i, \frac{p_s}{p^*} \right)$. Investment will therefore be reversed in line with the lower marginal value of capital in the form of Tobin's q . This will importantly reduce the rate of decline in rural poverty.

So the improvement in real prices will cause an initial decrease in rural poverty. However, the new long run steady state will also change and any decrease in government infrastructure investment will reduce capital formation. The new steady state for rural poverty may be higher or lower than the old steady state. It is also important to note that the dynamic adjustment will be slower than for the original. So even if the new steady state level of rural poverty is lower, the decrease in poverty will be slower from the higher initial starting point. One way to increase the fall in poverty in this situation is to increase total factor productivity, A , or the supply of factors of production, l_n, k or l_I . Another possibility is to increase human capital, h .

To summarise, an increase in public distribution will have complicated effects on rural poverty for a given tax regime. The additional resources flowing to agricultural households may allow an initial increase in consumption and reduction in

poverty. However the diversion of resources away from the provision of public infrastructure in the longer term will reduce marginal productivity and therefore the growth rate of capital formation and consumption over time. The possibly higher or lower steady state poverty outcome poses a real dilemma for a government, which has little scope for deficit financing and a relatively underdeveloped tax system. The authorities, whilst knowing that support prices for rural poor producers and consumers may slow growth, have little option if the level of poverty is high and widespread.

Tests for Non-stationarity

The results of the Augmented Dickey-Fuller (ADF) regressions are shown in Table 1. The two columns report the test statistic, ϕ , for two regressions, the first includes a constant whilst the second includes a constant and trend.⁷ The following variables; Rural Head Count Poverty, Public Distribution per Capita, Producer Price of Wheat/CPI for Agricultural Labourers, Development Expenditure per Rural Person/CPI for Agricultural Labourers, Gross Crop Area, and Proportion of Area Irrigated all appear to be I(1). The only unambiguously stationary variable is Net Availability of Food Grains per Capita. The supply side variables; Rural Population, Rural Labour Force/Rural Population, and Children (<15 years old)/Population are all I(2).

The remaining seven variables have ambiguous results indicating a possible mix of I(0), I(1) or I(2) properties.⁸ Food Grain Production/Rural Labour Force, CPI for Agricultural Labourers, Issue Price of Rice/CPI for Agricultural Labourers, and Issue Price of Wheat/CPI for Agricultural Labourers appear I(1) when the ADF regression includes an intercept and I(0) when an intercept and trend are included. The Producer Price of Rice/CPI for Agricultural Labourers and Fertilizer Use per Hectare variables appear to be I(0) with an intercept and I(1) when an intercept and trend are included in the regression. These variables appear to be sensitive to the presence of the trend. Disconcertingly, the Literacy Rate appears to be I(2) when only the intercept is included and I(0) when the intercept and trend are include.

⁷ The maximum lag for the VAR was set to 2. The optimum lag of the VAR (denoted by the value of the superscript P in Table 1) was selected according to the Akaike Information criterion (AIC) and the Schwarz Bayesian criterion (SBC).

⁸ Testing for the stationarity of variables is complicated by the small sample which results in low power in the Augmented Dickey-Fuller (ADF) test.

The Phillips-Perron non-parametric test (PP) was performed on these seven variables in order to clarify the ambiguous ADF results. The test statistic used the Newey-West correction to the variance matrix with Bartlett weights and window size five. The non-parametric test statistic for Food Grain Production/Rural Labour Force reduced to -3.034 when an intercept is included, which is greater in absolute value than the unchanged critical value of -2.923 . The variable therefore changed from $I(1)$ for the ADF test to $I(0)$ for the PP test, consistent to the $I(0)$ ADF finding for the regression which included an intercept and trend. The test statistic for the Literacy Rate also reduced dramatically from -0.770 to -3.318 which now rejected the null hypothesis of the variable being $I(1)$. This variable therefore changed from the ADF finding of $I(2)$ to PP $I(0)$, again consistent with the $I(0)$ finding for the regression which included both an intercept and trend. The PP results for these two variables did not change the ADF results of $I(0)$ when the trend was added to the regression. The new test statistic for the Producer Price of Rice/CPI for Agricultural Labourers variable decreased to -4.225 when an intercept and trend were included in the regression. This is less than the critical value of -3.505 which changed the variable from ADF $I(1)$ to PP $I(0)$. Again, this new $I(0)$ result became consistent with the ADF and PP $I(0)$ result for the regression which included only the intercept. The non-parametric test therefore unambiguously found these three variables to be stationary in levels, $I(0)$, at the five percent level of significance.

The variable, Fertilizer Use per Hectare remained $I(0)$ when the intercept was included. However the non-parametric test statistic of -2.938 was close to the critical value of -2.924 . The statistic increased to -2.902 when the window size for the calculation of the Bartlett weights was increased from five to eight. This indicated the variable may be $I(1)$, consistent with the ADF and PP findings of $I(1)$ when an intercept and trend are included in the regression.

The PP test statistic was not significantly different from the ADF statistic for the remaining three variables; CPI for Agricultural Labourers, Issue Price of Rice/ CPI for Agricultural Labourers, and Issue Price of Wheat/ CPI for Agricultural Labourers. These variables therefore appear to be $I(1)$ when a trend is excluded from the regression and $I(0)$ when the trend is included.

A summary of the combined results of the ADF and PP tests are included in Table 2 for the regressions which include an intercept and a trend. The results from the regression which exclude the trend are not reported. There are two reasons for

this, the first recognizes the suspected presence of structural change in the time series which biases these tests towards not rejecting the non-stationary null hypothesis of $I(1)$ (Perron, 1989). The above PP test corrections and the focus on the regression with intercept and trend means that six of the seven ambiguous variables according to the ADF test are classified as $I(0)$. The second reason for only reporting the results for the regressions which include both intercepts and trends relate to our intention to identify the growth rates and possible structural change in the variables in the next section. In this regard, care needs to be exercised in defining non-stationarity. Consider the regression equation used to conduct the test for stationarity of the variable $x_t = \log X_t$:

$$x_t = \beta_0 + (1 - \phi) \beta_1 t + \phi x_{t-1} + \sum_{i=1}^p \phi_i x_{t-i} + \varepsilon_t \quad \forall t = 1, 2, \dots, n$$

This equation allows for stochastic drift, β_0 and deterministic trend, β_1 . The test on the size of $\phi \leq 1$ determines whether the variable x_t is stationary or not. However the t -statistic is non-normal in large samples and so the equation needs to be transformed to first difference:

$$\Delta x_t = \beta_0 + (1 - \phi) \beta_1 t + (1 - \phi) x_{t-1} + \sum_{i=1}^p \gamma_i \Delta x_{t-i} + \varepsilon_t \quad \forall t = 1, \dots, n$$

The ADF and PP tests on the size of ϕ determine the stationary properties of variable x_t . The tests are conducted with a parametrically (ADF) and non-parametrically (PP) adjusted t -statistic. If ϕ is not significantly different from unity then the variable is classified as non-stationary $I(1)$. This gives:

$$\Delta x_t = \beta_0 + \sum_{i=1}^p \gamma_i \Delta x_{t-i} + \varepsilon_t \quad \forall t = 1, \dots, n.$$

For the case of $p = 0$ the relationship reduces to $\Delta x_t = \beta_0 + \varepsilon_t$. Now:

$$\Delta x_t = x_t - x_{t-1} = \log X_t - \log X_{t-1} = \log \frac{X_t}{X_{t-1}} = \beta_0$$

which describes the annual proportional rate of growth, β_0 of the variable X_t . When

$p > 0$ the rate of growth is: $\beta_0 \left(1 - \sum_{i=1}^p \gamma_i \right)^{-1}$. These variables are described as first difference stationary with non-zero drift and Table 2 labels them as stationary drift.

The variables which are found to be I(2) are also characterized by $\varphi = 1$ so the relationship can also be expressed as $\Delta^2 x_t = \beta_0 + \varepsilon_t$. The parameter β_0 therefore describes the acceleration or deceleration of the proportional rate of growth of the variable X_t . These variables are second difference stationary with non-zero growth and are labeled as stationary growth in drift.

When φ is significantly less than unity, $\varphi < 1$, the variables are said to be I(0). The equation:

$$x_t = \beta_0 + (1 - \varphi) \beta_1 t + \varphi x_{t-1} + \sum_{i=1}^p \varphi_i x_{t-i} + \varepsilon_t \quad \forall t = 1, 2, \dots, n$$

becomes:

$$x_t = \beta_0 + \beta_1 t + \varepsilon_t \quad \forall t = 1, \dots, n.$$

Therefore:

$$x_t - x_{t-1} = \frac{\log X_t}{\log X_{t-1}} = \beta_1$$

which describes the proportional annual trend rate of growth, β_1 of the variable X_t . This growth is labeled as stationary trend in Table 2 and it is important to note that these I(0) variables are not stationary in absolute values. Rather, they have positive or negative growth but are stationary around a non-zero trend, t . These important characteristics of the specification which includes a trend will now be examined in terms of rates of growth and structural change.

Table 1
Augmented Dickey-Fuller Tests for Stationarity ¹

| | Intercept included ² | | | Intercept and trend included ³ | | | | |
|---|---------------------------------|---------------------|-----------------------|---|---------------------|-----------------------|---------------------|------|
| | ϕ_x^P | $\phi_{\Delta x}^P$ | $\phi_{\Delta^2 x}^P$ | ϕ_x^P | $\phi_{\Delta x}^P$ | $\phi_{\Delta^2 x}^P$ | | |
| Rural head count poverty ⁴ | 0.011 ⁰ | -7.850 ⁰ | | I(1) | -2.238 ⁰ | -7.930 ⁰ | I(1) | |
| Food grain production/ rural labour force | -1.144 ² | -7.658 ¹ | | I(1) | -4.158 ⁰ | | I(0) | |
| Net availability of food grains per capita | -6.144 ⁰ | | | I(0) | -6.681 ⁰ | | I(0) | |
| Public distribution per capita | — .858 ¹ | -6.325 ⁰ | | I(1) | -3.184 ¹ | -6.574 ⁰ | I(1) | |
| CPI for agricultural labourers | 0.402 ⁰ | -6.047 ⁰ | | I(1) | -4.431 ¹ | | I(0) | |
| Producer price of rice/ CPI for agric. labourers | -3.251 ⁰ | | | I(0) | -3.034 ⁰ | -6.640 ¹ | I(1) | |
| Producer price of wheat/ CPI for agric. labourers | -2.335 ⁰ | -8.920 ⁰ | | I(1) | -3.103 ⁰ | -8.915 ⁰ | I(1) | |
| Issue price of rice/ CPI for agric. labourers | -2.512 ⁰ | -5.562 ² | | I(1) | -4.972 ² | | I(0) | |
| Issue price of wheat/ CPI for agric. labourers | -1.780 ⁰ | -7.299 ¹ | | I(1) | -4.599 ¹ | | I(0) | |
| Rural population | -2.431 ¹ | -0.773 ⁰ | -7.525 ⁰ | I(2) | -0.181 ¹ | -2.776 ⁰ | -7.530 ⁰ | I(2) |
| Rural labour force/ Rural population | -2.517 ¹ | -1.894 ⁰ | -6.437 ⁰ | I(2) | -2.294 ¹ | -2.161 ⁰ | -6.461 ⁰ | I(2) |
| Literacy rate | -0.770 ¹ | -2.351 ⁰ | -6.859 ⁰ | I(2) | -4.067 ¹ | | | I(0) |
| Children (<15 years old)/ Population | 1.011 ¹ | -1.700 ¹ | -9.064 ⁰ | I(2) | -1.697 ¹ | -3.130 ⁰ | -8.938 ⁰ | I(2) |
| Development expenditure per rural person/ CPI for agricultural labourers | -2.108 ⁰ | -7.041 ⁰ | | I(1) | -2.413 ⁰ | -5.832 ² | | I(1) |
| Gross crop area | -2.889 ¹ | -12.82 ⁰ | | I(1) | -1.775 ¹ | -7.860 ¹ | | I(1) |
| Proportion of area irrigated | 0.795 ¹ | -11.83 ⁰ | | I(1) | -3.007 ¹ | -11.85 ⁰ | | I(1) |
| Fertilizer use per hectare | -4.263 ⁰ | | | I(0) | -0.572 ⁰ | -6.326 ⁰ | | I(1) |

Notes:

¹ The maximum lag for the VAR was set to 2. The superscript ^p denotes the optimum lag of the VAR according to the AIC and SBC measures.

² The critical value for the variables in levels (x) is -2.923, in first difference (Δx) is -2.924, and in second difference ($\Delta^2 x$) is -2.926.

³ The critical value for the variables in levels (x) is -3.505, in first difference (Δx) is -3.507, and in second difference ($\Delta^2 x$) is -3.509.

⁴ The critical values for the variables (x) are -2.924/ -3.507 and (Δx) are -2.926/ -3.509 for the regression which includes an intercept/ intercept and trend.

Table 2
Tests of Stationarity Results¹
 (Intercept and trend included in the regression)²

Stationary Trend: I(0)

Food grain production/ rural labour force
 Net availability of food grains per capita
 CPI for agricultural labourers³
 Producer price of rice/ CPI for agricultural labourers
 Issue price of rice/ CPI for agricultural labourers³
 Issue price of wheat/ CPI for agricultural labourers³
 Literacy rate

(First difference) Stationary Drift: I(1)

Rural head count poverty
 Public distribution per capita
 Producer price of wheat/ CPI for agric. labourers
 Development expenditure per rural person/ CPI for agricultural labourers
 Gross crop area
 Proportion of area irrigated
 Fertilizer use per hectare

(Second difference) Stationary Growth in Drift: I(2)

Rural population
 Rural labour force/ Rural population
 Children (<15 years old)/ Population

Notes:

- ¹ Based on the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests (1988) at the 5% level of significance.
- ² The results reported here are for the tests based on regressions which included an intercept and trend. All of these results are consistent with the findings based on regressions including only an intercept, except for the three variables subject to Note ³.
- ³ These variables were found to be ADF I(1) when the regression included an intercept and no trend. However they were found to be PP I(0).

Trends and Structural Change

Two types of tests were conducted to detect structural change in the variables. The first involved identifying significant changes in the calculated trends in each variable. The second used the Brown, Durban and Evans (BDE, 1975) cumulative sum of the recursive residuals tests. Both tests involve the OLS estimation of the trend in each time series. As explained in the previous section the variables which were found to be $I(0)$ have the regression specification:

$$x_t = \beta_0 + \beta_1 t + \varepsilon_t \quad \forall t = 1, \dots, n.$$

The annual average rate of growth is simply calculated as: $\Delta x_t = \log \frac{X_t}{X_{t-1}} = \beta_1$

Variables found to be $I(1)$ have the VAR specification:

$$\Delta x_t = \beta_0 + \sum_{i=1}^p \gamma_i \Delta x_{t-i} + \varepsilon_t \quad \forall t = 1, \dots, n$$

with stationary rates of drift given by: $\beta_0 \left(1 - \sum_{i=1}^p \gamma_i \right)^{-1}$. Similarly the appropriate VAR specification for $I(2)$ variables is:

$$\Delta^2 x_t = \beta_0 + \sum_{i=1}^p \gamma_i \Delta^2 x_{t-i} + \varepsilon_t \quad \forall t = 1, \dots, n$$

with stationary rates of growth in drift: $\beta_0 \left(1 - \sum_{i=1}^p \gamma_i \right)^{-1}$.

The OLS estimates of these rates are presented in Table 3 for the whole sample 1951 to 2001 and for five sub-samples. Table 3a includes the estimates for all the $I(0)$ variables whilst Tables 3b and 3c present the results for the $I(1)$ and $I(2)$ variables. The growth rates in Table 3b are estimated using the $I(0)$ estimation procedure. This is done in order to make comparisons with Tables 3a and 3c. The non-stationary variables were then estimated using the appropriate $I(1)$ process and are reported in Table 3c.^{9, 10} The growth rates which are significantly different from zero (at the five percent level) are marked with an asterisk. The estimates in bold

⁹ The parameter p was selected as the optimum lag determined by the Akaike Information criterion (AIC) and the Schwarz Bayesian criterion (SBC) measures in the ADF regressions.

¹⁰ The $I(2)$ variables were estimated using the $I(1)$ procedure because they appeared over differenced at $I(2)$. It is possible that the interpolation of data has incorrectly led to the conclusion these variables are $I(2)$.

denote the average growth rates for each decade which are significantly different from the average rate for the whole period 1951 to 2001.

In all, 85 of the 102 estimates (85%) in Tables 3a and 3b were found to be significantly different from zero at the five percent level. These table also show that 63 of the 85 sub-periods growth rates (74%) are significantly different from the average growth rate. Note that the periods 1961-1970 and 1991-2001 have the most rates which are different from the average growth rates for the whole period (fifteen and sixteen out of seventeen respectively). The decade 1951-1960 has the next most differences (thirteen out of seventeen) with relatively few significant differences for the periods 1971-1980 and 1981-1990 (nine and ten out of seventeen). The number of bold entries in the table demonstrate significant structural change has occurred for all variables during the early period 1951 to 1970 and recently from 1991 to 2001. The growth rates in Table 3c are remarkably similar in value to those in Table 3b. However their standard errors are much larger in Table 3c which results in few estimates which are significantly different from zero and from the average growth rates, for the full sample 1951 to 2001.

Let us now consider a few examples from Table 3. The Net Availability of Food Grains per Capita listed in Table 3a shows a significant (at the five percent level) average increase of 0.19% per annum over the full period 1951 to 2001. The first sub-period 1951-1960 had significantly above average growth, followed by significantly below average growth during 1961-1970. This pattern was repeated for the last two sub-periods where the growth of 0.69% in 1981-1990 reversed dramatically to -0.97% during 1991-2001. The Issue Price of Rice/ CPI for Agricultural Laborers experienced significant negative average growth over the full sample 1951 to 2001. However there were also large variations across sub-periods. The decades 1951-1960 and 1971-1980 had above average growth which fell in the last period to -5.21% per annum which is significantly below the average rate.

The Rural Head Count Poverty variable in Table 3c shows a non-significant average reduction of 1.10% per annum over the full period 1951 to 2000.¹¹ The period 1951-1970 is characterized by an average annual positive growth rate (which is not significantly different from zero). However the negative growth increases to -1.76% and then -3.42% per annum for the decades 1971-1980 and 1981-1990 (which are

¹¹ The last observation for the Rural Head Count Poverty variable is 2000. All of the other variables have observations for 2001.

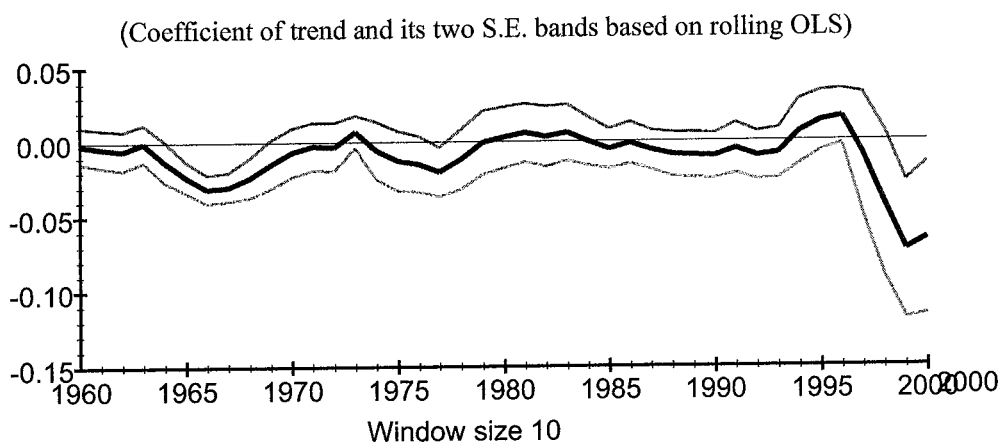
significantly less than zero). It is important to note that the growth rate is not significantly different from zero for the final sub-period 1991-2000.

Figure 1 shows the estimates of β_1 derived from rolling OLS regressions:

$$x_t = \beta_0 + \beta_1 t + \varepsilon_t \quad \forall t = 1, \dots, n$$

with ten year windows for the variable the Issue Price of Rice/ CPI for Agricultural Laborers. The average growth rates for the ten year periods are shown on the graph at the last year of each period. Note that the average annual growth rates are significantly negative for the periods 1957-1966 and 1958-1977 with a sharp decline during 1990-2001. This accords with the results shown in Table 3a for this variable.

Figure 1
Issue Price of Rice/ CPI for Agricultural Labourers
Rolling OLS Estimates of Trend Growth (β_1)



The growth rates for Rural Head Count Poverty were calculated using rolling OLS of the form (with $p = 0$):

$$\Delta x_t = \beta_0 + \sum_{i=1}^p \gamma_i \Delta x_{t-i} + \varepsilon_t \quad \forall t = 1, \dots, n$$

The estimates for β_0 are shown in Figure 2. The significant negative growth in the 1970s and 1980s is evident, although the standard error bands increase dramatically in the 1980s and 1990s so that the growth rate becomes not significantly different from

zero. Given these variations it is necessary to further explore the stability of the rates of growth for the variables within the sub-periods.

Figure 2
Rural Head Count Poverty
Rolling OLS Estimates of Trend Growth (β_0)

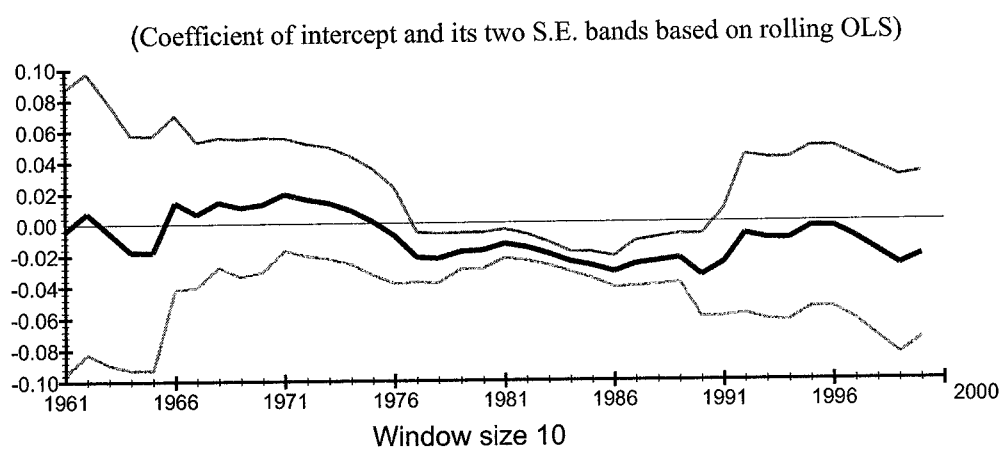


Table 3a
Average Annual Rates of Growth (β_1)
 (% per annum)

| | Variable | 1951-2001 | 1951-60 | 1961-70 | 1971-80 | 1981-90 | 1991-2001 |
|--|----------|-----------|--------------|--------------|--------------|---------------|---------------|
| Stationary Trend: I(0)^{1,2} | | | | | | | |
| Food grain production/ rural labour force | LX26 | 1.12* | 0.74 | 3.40* | 1.11* | 0.71* | -0.43* |
| Net availability of food grains per capita | LX16 | 0.19* | 1.46* | -0.53 | -0.34 | 0.69* | -0.97* |
| CPI for agricultural labourers | LX8 | 6.79* | 1.01* | 8.09* | 6.07* | 6.46* | 6.18* |
| Producer price of rice/ CPI for agric. labourers | LX27 | -0.25* | -0.18 | -0.59 | 0.72 | -0.77* | 1.39* |
| Issue price of rice/ CPI for agric. labourers | LX19 | -0.95* | -0.18 | -0.67 | 0.27 | -1.01* | -5.21* |
| Issue price of wheat/ CPI for agric. labourers | LX20 | -1.75* | -1.19* | 0.91* | -1.41* | -2.20* | -5.36* |
| Literacy rate | LX9 | 2.33* | 4.34* | 1.97* | 2.35* | 1.81* | 2.25* |

Notes:

¹ The growth rate $\Delta x_t = \beta_1$ is calculated from the regression: $x_t = \beta_0 + \beta_1 t + \varepsilon_t \quad \forall t = 1, \dots, n$.

² Growth rates figures in bold are significantly different from the average rate of growth for the period 1951-2001 at the 5% level of significance.

* Denotes average annual growth rates which are significantly different from zero at the 5% level of significance.

Table 3b
Average Annual Rates of Growth (β_1)
 (% per annum)

| | Variable | 1951-2001 ¹ | 1951-60 | 1961-70 | 1971-80 | 1981-90 | 1991-2001 ¹ |
|---|----------|------------------------|---------------|---------------|---------------|---------------|------------------------|
| (First Difference) Stationary Drift: I(1)^{2,3} | | | | | | | |
| Rural head count poverty | LRHCP | -1.05* | 1.27 | 3.51* | -1.59* | -3.22* | -4.06* |
| Public distribution per capita | LX23 | 1.33* | -5.44 | 8.33* | 1.46 | 0.54 | -4.01* |
| Producer price of wheat/ CPI for agric. labourers | LX28 | -1.03* | -1.09* | 0.93* | -0.89 | -2.00* | 1.37* |
| Development expenditure per rural person/ CPI for agricultural labourers | LX21 | 3.79* | 9.91* | -0.48 | 10.56* | 3.89* | -6.54* |
| Gross crop area | LX3 | 0.30* | 1.68* | 0.65* | 0.50* | -0.16 | -0.11 |
| Proportion of area irrigated | LX5 | 1.94* | 0.54* | 2.68* | 2.31* | 1.73* | 1.96* |
| Fertilizer use per hectare | LX7 | 10.55* | 15.42* | 20.88* | 8.70* | 7.54* | 3.01* |
| (Second Difference) Stationary Growth in Drift: I(2)^{2,3} | | | | | | | |
| Rural population | LX15 | 1.83* | 1.88* | 1.98* | 1.80* | 1.79* | 1.65* |
| Rural labour force/ Rural population | LX24 | -0.35* | 1.19* | -2.39* | -0.17* | 0.45* | 0.41* |
| Children (<15 years old)/ Population | LX22 | -0.37* | -0.02 | 0.29* | -0.93* | -0.34* | -0.57* |

Notes:

¹ The sample for Rural head count poverty is 1951-2000 inclusive.

² The growth rate $\Delta x_t = \beta_1$ is calculated from the regression: $x_t = \beta_0 + \beta_1 t + \varepsilon_t \quad \forall t = 1, \dots, n$.

³ Growth rates figures in bold are significantly different from the average rate of growth for the period 1951- 2001 at the 5% level of significance.

* Denotes average annual growth rates which are significantly different from zero at the 5% level of significance.

Table 3c
Average Annual Rates of Growth (β_0)
 (% per annum)

| | Variable | 1951-2001 ¹ | 1951-60 | 1961-70 | 1971-80 | 1981-90 | 1991-2001 ¹ |
|--|----------|------------------------|--------------|---------------|---------------|--------------|------------------------|
| (First Difference) Stationary Drift: I(1) ^{2,3} | | | | | | | |
| Rural head count poverty | LRHCP | -1.10 | 0.80 | 1.24 | -1.76* | -3.42* | -2.17 |
| Public distribution per capita | LX23 | -1.12 | -7.49 | 3.69 | 3.08 | -1.53 | -4.08 |
| Producer price of wheat/ CPI for agric. labourers | LX28 | -0.80 | -2.26 | -0.26 | -1.71 | -1.59 | 1.87 |
| Development expenditure per rural person/ CPI for agricultural labourers | LX21 | 3.41 | 8.64 | 2.63 | 8.27 | 3.84 | -6.25 |
| Gross crop area | LX3 | 0.40 | 1.61 | 0.71 | 0.16 | 0.12 | -0.44 |
| Proportion of area irrigated | LX5 | 1.77* | 0.41 | 2.33* | 1.99* | 1.77* | 2.05* |
| Fertilizer use per hectare | LX7 | 10.15* | 12.80* | 19.68* | 8.40* | 7.99* | 2.30* |
| (Second Difference) Stationary Growth in Drift: I(2) ^{2,3} | | | | | | | |
| Rural population | LX15 | 1.82* | 1.87* | 1.97* | 1.82* | 1.79* | 1.67* |
| Rural labour force/ Rural population | LX24 | -0.10 | 1.19* | -2.04* | -0.39 | 0.39* | 0.42* |
| Children (<15 years old)/ Population | LX22 | -0.35* | -0.01 | 0.26* | -0.81* | -0.50* | -0.58* |

Notes:

¹ The sample for Rural head count poverty is 1951-2000 inclusive.

² The growth rate β_0 is calculated from the regression $\Delta x_t = \beta_0 + \sum_{i=1}^p \gamma_i \Delta x_{t-i} + \varepsilon_t$.

The optimum value of p is selected according to the Akaike Information criterion (AIC) and the Schwarz Bayesian criterion (SBC).

³ Growth rates figures in bold are significantly different from the average rate of growth for the period 1951- 2001 at the 5% level of significance.

* Denotes average annual growth rates which are significantly different from zero at the 5% level of significance.

The second group of tests to detect structural change in the variables used the Brown, Durban and Evans (BDE, 1975) tests on the regression specification:

$$x_t = \beta_0 + \beta_1 t + \varepsilon_t \quad \forall t = 1, \dots, n$$

for the I(0) variables and on:

$$\Delta x_t = \beta_0 + \sum_{i=1}^p \gamma_i \Delta x_{t-i} + \varepsilon_t \quad \forall t = 1, \dots, n$$

where the variables are I(1) or I(2).¹² The BDE tests were performed by calculating the annual cumulative sum of the recursive residuals (CUSUM) and the cumulative sum of the squares of the recursive residuals (CUSUMQ) for each regression. The graphs in the Appendix (Figures B1 to B17) plot the test statistics for each year with the straight lines representing the five percent levels of significance. A structural change occurs in the year when the test statistic crosses a line of significance. It is generally acknowledged that the CUSUM plots tend to characterize systematic changes in the regression specification whereas the CUSUMQ plots tend to detect sudden changes in parameter constancy.¹³ Table 4 summarises the results from Figures B1 to B17 in the Appendix for all the variables. All variables experienced structural change except Food Grain Production per Rural Labour Force, Development Expenditure per Rural Person/CPI for Agricultural Labourers, Gross Crop Area, and Fertilizer Use per Hectare.

Consider the examples in Figures 3 and 4 which are reproduced from the Appendix. The CUSUMQ plots in Figure 3 clearly show that the Issue Price of Rice/CPI for Agricultural Labourers experienced structural changes in 1969 and 1998. Table 3a shows the change in average growth rates during 1971-1980 were significantly above average values in 1951-1960 and 1961-1970. The relative sharp and significantly negative average growth rate of -5.21% per annum for the last period 1991-2001 is striking.

Examination of Figure 4 shows that according to the CUSUMQ plots, Rural Head Count Poverty experienced significant structural breaks in 1956 and 1973. This agrees with the Table 3c reporting of significant negative average growth of -1.76% per annum during 1971-1980 and -3.42% during the period 1981-1990.

¹² The value of p was set to zero for the BDE stability tests.

¹³ *Vide* Pesaran and Pesaran (1997, p. 114)

Figure 3
Issue Price of Rice/ CPI for Agricultural Labourers
Plot of Cumulative Sum of Squares of Recursive Residuals

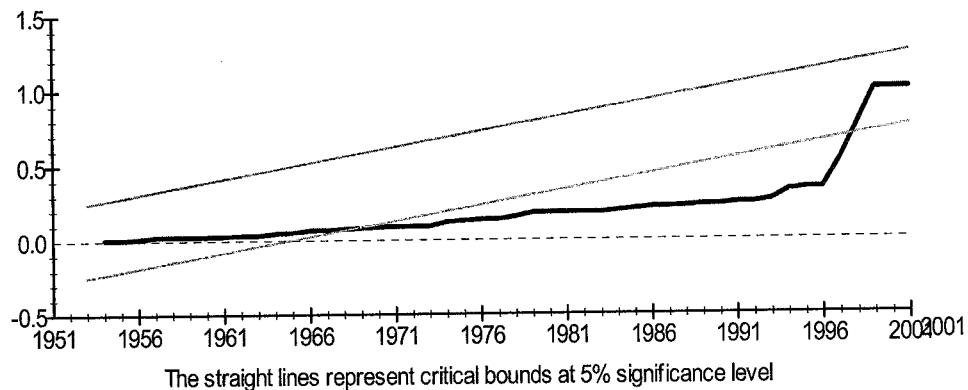


Figure 4
Rural Head Count Poverty

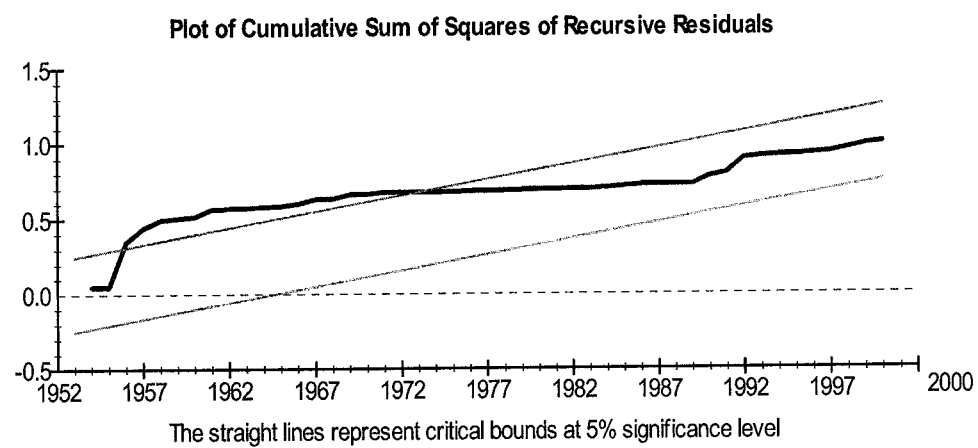


Table 4
BDE Tests of Structural Change ¹
(years where the structural change occurred) ²

| | CUSUM ³ | CUSUMQ ³ |
|---|--------------------|---------------------|
| Stationary Trend ⁴ | | |
| Food grain production/ rural labour force | — | — |
| Net availability of food grains per capita | 1975, 83 | — |
| CPI for agricultural labourers | 1966 | — |
| Producer price of rice/ CPI for agric. labourers | 1999 | 1992 |
| Issue price of rice/ CPI for agric. labourers | — | 1969, 98 |
| Issue price of wheat/ CPI for agric. labourers | — | 1971, 98 |
| Literacy rate | 1971 | — |
| (First Difference) Stationary Drift ⁵ | | |
| Rural head count poverty ⁶ | — | 1956, 73 |
| Public distribution per capita | 1964, 69 | 1957, 82 |
| Producer price of wheat/ CPI for agric. labourers | — | (1976) |
| Development expenditure per rural person/ CPI for agricultural labourers | — | — |
| Gross crop area | — | — |
| Proportion of area irrigated | — | 1974 |
| Fertilizer use per hectare | — | — |
| (Second Difference) Stationary Growth in Drift ⁵ | | |
| Rural population | 1996 | 1969, 94 |
| Rural labour force/ Rural population | 1965, 84 | 1965, 85 |
| Children (<15 years old)/ Population | — | 1969, 71 |

Notes:

¹ Brown, Durban and Evans (1975).

² The years when the CUSUM and CUSUMQ test statistics cross the 5% lines of significance are listed.

³ Cells including the symbol “—” indicate no structural change was detected at the 5% level of significance.

⁴ The BDE test was performed on the regression: $x_t = \beta_0 + \beta_1 t + \varepsilon_t$

⁵ The BDE test was performed on the regression: $\Delta x_t = \beta_0 + \sum_{i=1}^p \gamma_i \Delta x_{t-i} + \varepsilon_t$.

⁶ The sample for Rural Head Count Poverty is 1951-2000 inclusive.

Estimation

The findings of mixed trends in the variables, many of which have experienced significant structural change, is problematic for estimation and inference purposes. The difficulty relates to the uncertainty of the stationarity of the variables due to the observed differences between the ADF and the non-parametric PP test statistics. We do not wish to incorrectly assume that variables are $I(0)$ when they are in fact non-stationary because we will obtain spurious econometric relationships. On the other hand, the presence of structural change can bias the tests towards incorrectly not rejecting the null hypothesis of non-stationarity (Perron, 1989). These variables may appear $I(1)$ when they are actually stationary and first differencing them is inappropriate. The CUSUMQ findings also indicate another problem whereby time series relationships may be subject to non-constant variances (heteroscedasticity). The difficulties of making valid statistical inferences are significant under these circumstances.

It was therefore decided to adopt the autoregressive distributed lag (ARDL) cointegration estimation procedure detailed in Pesaran and Pesaran (1997). This method is appropriate for variables which are mixtures of $I(0)$, $I(1)$ and higher. The VAR is estimated over possible lags p for the dependant variable y_t and all possible lags q_i for the k explanatory variables, x_{it} :

$$\alpha L^p y_t = \beta_0 + \sum_{i=1}^k \beta_i L^{q_i} x_{it} + \varepsilon_t \quad \forall t = 1, \dots, n$$

where $\alpha L^p = 1 - \alpha_1 L - \alpha_2 L^2 - \dots - \alpha_p L^p$ with $L^p y_t = y_{t-p}$ and

$$\beta_i L^{q_i} = \beta_{i0} + \beta_{i1} L + \beta_{i2} L^2 + \dots + \beta_{iq_i} L^{q_i} \quad \forall i = 1, 2, \dots, k$$

The optimum lags were selected according to well known model selection Akaike Information criterion (AIC) and the Schwarz Bayesian criterion (SBC). These estimated optimum lags, \hat{p} for the dependant variable and \hat{q}_i for the $i = 1, 2, \dots, k$ explanatory variables, reflect the underlying dynamic properties of the model. The long run elasticities can be determined by:

$$\hat{\gamma}_i = \frac{\hat{\beta}_{i0} + \hat{\beta}_{i1} + \dots + \hat{\beta}_{i\hat{q}_i}}{1 - \hat{\alpha}_1 - \dots - \hat{\alpha}_{\hat{p}}} \quad \forall i = 1, 2, \dots, k$$

which derives the long run cointegrating relationship:

$$y_t - \hat{\gamma}_0 - \hat{\gamma}_1 x_{1t} - \hat{\gamma}_2 x_{2t} - \dots - \hat{\gamma}_k x_{kt} = \varepsilon_t \quad \forall t = 1, 2, \dots, n$$

with constant term: $\hat{\gamma}_0 = \frac{\hat{\beta}_0}{1 - \hat{\alpha}_1 - \dots - \hat{\alpha}_p}$.

Simple OLS regressions indicated that the following variables were important determinants of Rural Head Count Poverty. They are: Food Grain Production/Rural Labour Force, Producer Price of Rice/CPI for Agricultural Labourers, Issue Price of Rice/CPI for Agricultural Labourers, Public Distribution per Capita, Development Expenditure per Rural Person/CPI for Agricultural Labourers, and Rural Labour Force/Rural Population. The high degree of collinearity between the wheat and rice prices in terms of the producer and issue prices meant that the prices for only one commodity could be included in the regressions. The rice prices tended to have more power in explaining Rural Head Count Poverty and were therefore included at the expense of the wheat prices. The effects of the variables, Gross Crop Area, Proportion of Area Irrigated, and Fertilizer Use per Hectare appeared to be captured by the macroeconomic variables like Food Grain Production/Rural Labour Force and Development Expenditure per Rural Person/CPI for Agricultural Labourers. Similarly, the effects of the supply side variables, Literacy Rate, Rural Population, and Children (<15 years old)/Population were proxied by the Rural Labour Force/Rural Population and Food Grain Production/Rural Labour Force variables.

The results of the ARDL regressions are summarised in Table 5. The columns labelled AIC present the estimates for the VAR where the lags were selected according to the Akaike Information criterion (AIC). The right hand columns present the estimates for the lags chosen by the Schwarz Bayesian criterion (SBC). The AIC lag specification is ARDL(1, 1, 1, 2, 1, 2, 0), where the numbers represent the lags for the variables which are listed in the same order as for Table 5. Compare this with the SBC lag specification of ARDL(1, 0, 0, 1, 1, 2, 0). The SBC tends to define more parsimonious specifications and note that many of the standard errors of the estimates in Table 5 are relatively larger due to the smaller number of lags included in the regression.

Both ARDL regressions have high adjusted coefficients of determination which indicate good fits of the data. The Chi squared and F diagnostic statistics on the AIC and SBC regressions show no serial correlation is present, the functional forms are appropriate and the residuals do not depart from normality (all at the five percent level). These findings are surprising given the previously identified presence of structural changes in the variables. The mixed order ARDL specifications appear to appropriately include these dynamic effects. The AIC regression has a marginally higher adjusted coefficient of determination of 0.941 whilst the SBC F test statistic is larger, reflecting the fewer explanatory variables included.

An important check of the validity of this ARDL cointegration procedure is to test for stationarity of the residuals ε_t in:

$$y_t - \hat{\gamma}_0 - \hat{\gamma}_1 x_{1t} - \hat{\gamma}_2 x_{2t} - \dots - \hat{\gamma}_k x_{kt} = \varepsilon_t$$

for both the AIC and SBC cases. The Chi squared, F and Durbin h statistics all indicate no serial correlation. The ADF test statistic is calculated as -7.521 for the AIC regression and $-X.XXX$ for the SBC regression. The standard ADF tables are inappropriate here because the critical values for this test of cointegration depend on the number of $I(1)$ variables included in the ARDL regressions. The Charemza and Deadman (1992) tables only go up to eight included variables (excluding intercept) whereas the AIC and SBC regressions include fourteen and eleven explanatory variables respectively. Simple extrapolation of the Charemza and Deadman critical values for fourteen and twelve variables imply that the residuals are $I(0)$ as required.¹⁴

The estimated coefficients of 0.5946 (AIC) and 0.6387 (SBC) on the one period lag of the Rural Head Count Poverty variable in the ARDL specifications are significantly different from zero and unity.¹⁵ This indicates the dependent variable, Rural Head Count Poverty, is fractionally integrated and confirms the validity of the adopted ARDL cointegration estimation procedure.

¹⁴ The Charemza and Deadman (1992) tables list the 95% lower critical values for 50 observations with intercept as -3.76 for two variables included, -4.30 for four variables, -4.78 for six variables and -5.17 for eight variables. Simple extrapolation implies the critical values for fourteen and twelve included variables are will be approximately 5.60 , which is less than the value of six.

¹⁵ The presence of a lagged dependent variable on the right hand side increases the goodness of fit.

Table 5
Autoregressive Distributed Lags (ARDL) Elasticity Estimates ¹

| <i>Dependent variable: Rural head count poverty</i> <i>All variables are in Naperian logs</i> | AIC ² | | SBS ² | |
|--|--|-------------------|--|----------------------|
| | $\hat{\beta}$ | $t_{\hat{\beta}}$ | $\hat{\beta}$ | $t_{\hat{\beta}}$ |
| Rural head count poverty ($t-1$) | 0.5946 | 6.718*** | 0.6387 | 7.748*** |
| Food grain production/ rural labour force | -0.3312 | -2.770*** | -0.3261 | -2.627** |
| Food grain production/ rural labour force ($t-1$) | -0.1747 | -1.273 | | |
| Producer price of rice/ CPI for agricultural labourers | -0.2479 | -0.174 | -0.1643 | -1.295* ³ |
| Producer price of rice/ CPI for agricultural labourers ($t-1$) | -0.2622 | -1.838* | | |
| Issue price of rice/ CPI for agricultural labourers | -0.0906 | -1.136 | -0.0093 | -0.123 |
| Issue price of rice/ CPI for agricultural labourers ($t-1$) | 0.4227 | 3.691*** | 0.2268 | 3.210*** |
| Issue price of rice/ CPI for agricultural labourers ($t-2$) | -0.1693 | -1.722* | | |
| Public distribution per capita | -0.1081 | -2.165** | -0.0678 | -1.516 |
| Public distribution per capita ($t-1$) | 0.1196 | 2.678** | 0.1101 | 2.476** |
| Development expenditure per rural person/ CPI for agricultural labourers | -0.1686 | -4.193*** | -0.1551 | -3.995*** |
| Development expenditure per rural person/ CPI for agricultural labourers ($t-1$) | 0.1995 | 3.580*** | 0.1846 | 3.363*** |
| Development expenditure per rural person/ CPI for agricultural labourers ($t-2$) | -0.8860 | -2.152** | -0.1037 | -2.663** |
| Rural labour force/ Rural population | -0.7052 | -2.299** | -0.5368 | -2.392** |
| Constant | -0.4803 | -0.708 | 0.2481 | 0.389 |
| <i>Sample is 1953 to 2000 (n = 48)</i> | $\bar{R}^2 = 0.941$ $F_{14,33} = 54.332$ | | $\bar{R}^2 = 0.935$ $F_{14,33} = 62.501$ | |
| | Durbin h -statistic = -0.895 | | Durbin h -statistic = -0.032 | |

Notes:

¹ The AIC and SBC criteria were used to select the optimum values of the ARDL. A one year lag is denoted by ($t-1$) whilst a two year lag is denoted by ($t-2$).

² *** represents significant at the 1% level; ** represents significant at the 5% level; * represents significant at the 10% level.

³ The t statistic becomes -1.8494* with the Newey-West heteroscedastic consistent estimate of the variance (using Bartlett weights with truncation point of ten).

Overall, the estimated elasticities have expected signs and plausible sizes.¹⁶ There is a degree of inertia in the poverty variable where a one percent decrease in rural poverty in the previous year will flow through to a further 0.59% to 0.64% decrease in Rural Head Count Poverty in the next year.¹⁷ However the explanatory variables are also shown to be important determinants of rural poverty and the distributed lag ensures they will have enduring effects.

Comparison of the estimated coefficients (which are significantly different from zero) show a degree of robustness over the two specifications. The major differences occur for the Producer Price of Rice/CPI for Agricultural Labourers variable which has an SBC estimated elasticity of -0.1643 in the current year, whilst the AIC estimate is larger at -0.2622 in the previous (lagged one) year. The one year lag of the SBC Issue Price of Rice/CPI for Agricultural Labourers elasticity is 0.2268. The corresponding AIC elasticity is larger at 0.4227 although the second period lag elasticity is -0.1693 which gives a comparable net effect of 0.2534 over the two periods. The Public Distribution per Capita elasticities for the AIC regression are mostly self cancelling whilst the SBC estimate is clearly positive at 0.1101 for the one year lag. The AIC and SBC elasticities for Development Expenditure per Rural Person/CPI for Agricultural Labourers are similar for the current and one year lag. However the AIC two year lag estimate of -0.8860 is much larger than that for the SBC two year lag of -0.5368. Both criteria explain an interesting cyclical behaviour of the effects of real development expenditure on rural poverty. The AIC current year elasticity estimate of -0.7052 for Rural Labour Force/Rural Population variable is also larger than the SBC estimate of -0.5368.

These results provide important evidence that the real producer price for rice and the real issue price for rice can significantly affect the level of Rural Head Count Poverty. These real price effects dominate the quantity effects described by the public distribution variable. The other variables, including rural labour productivity, supply side factors and development expenditure, are also found to be important determinants of rural poverty.

The long run elasticities were calculated using the relationship:

$$\hat{\gamma}_i = \frac{\hat{\beta}_{i0} + \hat{\beta}_{i1} + \dots + \hat{\beta}_{i_q}}{1 - \hat{\alpha}_1 - \dots - \hat{\alpha}_p} \text{ and the estimates are shown in Table 6. The estimated}$$

¹⁶ Except for the AIC zero (or SBC positive) effect of public distribution on rural poverty.

¹⁷ According to the AIC and SBC specifications, respectively.

elasticities for Food Grain Production/Rural Labour Force range from -1.248 (AIC) to -0.903 (SBC) and are both significant at the five percent level. The long run elasticity for the Producer Price of Rice/CPI for Agricultural Labourers of -0.708 is significant at the ten percent level for the AIC regression. The Issue Price of Rice/CPI for Agricultural Labourers elasticity is significant and of the expected positive sign, ranging from 0.407 for the AIC regression to 0.602 for the SBC regression.

Public Distribution per Capita appears to have no significant effect on Rural Head Count Poverty in the long run. The elasticity of -0.205 for Development Expenditure per Rural Person/CPI for Agricultural Labourers is significant at the one percent level for the SBC regression. The estimates for the Rural Labour Force/Rural Population elasticities are significant at the five percent level and have large negative values of -1.739 for the AIC regression and -1.486 for the SBC regression.

Table 6
Long Run Elasticity Estimates¹

| <i>Dependent variable: Rural head count poverty</i> <i>All variables are in Naperian logs</i> | AIC² | | SBS² | |
|--|------------------------|--------------------|------------------------|--------------------|
| | $\hat{\gamma}$ | $t_{\hat{\gamma}}$ | $\hat{\gamma}$ | $t_{\hat{\gamma}}$ |
| Food grain production/ rural labour force | -1.248 | -2.40** | | -2.16** |
| Producer price of rice/ CPI for agric. labourers | -0.708 | -1.93* | -0.454 | -1.26 |
| Issue price of rice/ CPI for agric. labourers | 0.407 | 2.41** | 0.602 | 3.79*** |
| Public distribution per capita | 0.028 | 0.33 | 0.117 | 1.23 |
| Development expenditure per rural person/ CPI for agricultural labourers | -0.143 | -1.57 | -0.205 | -2.80*** |
| Rural labour force/ Rural population | -1.739 | -2.44** | -1.486 | -2.44** |
| Constant | -1.185 | -0.68 | 0.687 | 0.40 |

Sample is 1953 to 2000 (n = 48)

Notes:

¹ The AIC and SBC criteria were used to select the optimum values of the ARDL regressions which were used to calculate the long run elasticities.

² *** represents significant at the 1% level; ** represents significant at the 5% level; * represents significant at the 10% level.

Table 7
Short Run Error Correction Elasticity Estimates ¹

| <i>Dependent variable: ΔRural head count poverty</i> <i>All log variables are differenced: ³</i> | AIC ² | | SBS ² | |
|--|-------------------------|------------------------|-------------------------|------------------------|
| | $\hat{\beta}_{t0}$ | $t_{\hat{\beta}_{t0}}$ | $\hat{\beta}_{t0}$ | $t_{\hat{\beta}_{t0}}$ |
| Δ Food grain production/ rural labour force | -0.331 | -2.77*** | -0.326 | -2.63** |
| Δ Producer price of rice/ CPI for agric. labourers | -0.025 | -0.17 | -0.164 | -1.30 |
| Δ Issue price of rice/ CPI for agric. labourers | -0.091 | -1.14 | -0.009 | -0.12 |
| Δ^2 Issue price of rice/ CPI for agric. labourers ⁴ | 0.169 | 1.72* | | |
| Δ Public distribution per capita | -0.108 | -2.17** | -0.068 | -1.52 |
| Δ Development expenditure per rural person/ CPI for agricultural labourers | -0.169 | -4.19*** | -0.155 | -4.00*** |
| Δ^2 Development expenditure per rural person/ CPI for agricultural labourers ⁴ | 0.089 | 2.15** | 0.103 | 2.66** |
| Δ Rural labour force/ Rural population | -0.705 | -2.30** | -0.537 | -2.39** |
| Constant | -0.480 | -0.71 | 0.248 | 0.39 |
| ecm_{t-1} | -0.405 | -4.58*** | -0.361 | -4.38*** |
| <i>Sample is 1953 to 2000 (n = 48)</i> | $\bar{R}^2 = 0.621$ | | $\bar{R}^2 = 0.584$ | |
| | $F_{9,38} = 10.118$ | | $F_{8,39} = 9.637$ | |

Notes:

¹ The AIC and SBC criteria were used to select the optimum values of the ARDL regressions which were used to calculate the short run error correction elasticities.

² *** represents significant at the 1% level; ** represents significant at the 5% level; * represents significant at the 10% level.

³ The first differences of the logged variables are defined as $\Delta x_{it} = x_{it} - x_{it-1}$.

⁴ The second differenced variables are defined as $\Delta^2 x_{it} = x_{it-1} - x_{it-2}$. The formula used to calculate the coefficients of these variables is $\sum_{j=1}^{q_i-1} \hat{\beta}_{ij}^*$.

The error correction mechanism explains the reactions of Rural Head Count Poverty, y_t to divergences of the model away from the long run cointegrating relationship. The error correction mechanism (ecm) is defined as:

$$ecm_t = y_t - \gamma_0 - \gamma_1 x_{1t} - \gamma_2 x_{2t} - \dots - \gamma_k x_{kt}$$

where the short run dynamics of the model are defined for the AIC and SBC cases (where $\hat{p} = 1$):

$$\Delta y_t = (1 - \alpha_1) ecm_{t-1} + \sum_{i=1}^k \beta_{i0} \Delta x_{it} - \sum_{i=1}^k \sum_{j=1}^{\hat{q}_i-1} \beta_{ij}^* \Delta x_{i,t-j} + \varepsilon_t$$

with:

$$\begin{aligned} \beta_{i1}^* &= \beta_{i,\hat{q}_i} + \beta_{i,\hat{q}_i-1} + \dots + \beta_{i,3} + \beta_{i,2} \\ \beta_{i2}^* &= \beta_{i,\hat{q}_i} + \beta_{i,\hat{q}_i-1} + \dots + \beta_{i,3} \\ &\vdots \quad \quad \quad \vdots \quad \quad \quad \ddots \\ \beta_{i,\hat{q}_i-1}^* &= \beta_{i,\hat{q}_i} \end{aligned}$$

The estimates of these short run equilibrating dynamic processes are shown in Table 7. The AIC and SBC error corrections are both significant, have the correct sign and imply relatively fast returns to equilibrium.¹⁸ This is an important finding which corroborates the successful dynamic tracking of Rural Head Count Poverty using the ARDL procedure when the time series have experienced significant temporal structural change.

Now compare Tables 6 and 7 to establish the intertemporal influences of these variables on rural poverty. First, the real issue price and real producer price for rice do not appear to have important influences on the short run equilibrating adjustments in Rural Head Count Poverty. However Table 6 clearly shows that these real prices (particularly the issue price) are important determinants of rural poverty in the long run. This has important consequences for policy makers in that the authorities should not manipulate real foodgrain issue prices and producer prices to achieve short term economic and social goals. Rather these pricing policies should be used to achieve long run goals by providing appropriate signals to achieve desired long run resource allocations.

In comparison to the real price effects, changes to foodgrain quantities, measured in terms of per capita public distribution, have limited effects on rural poverty in the short run with no recognised long run effects. Conversely, real development expenditure (per rural person) has strong short run cyclical effects on rural poverty but weak long run effects (where these cyclical effects appear to net out). Finally, both the productivity measure (Food Grain Production/Rural Labour

¹⁸ This is consistent with the finding of the relatively high degree of inertia in Rural Head Count Poverty from the ARDL regressions.

Force) and the supply side proxy (Rural Labour Force/Rural Population) are significant determinants of Rural Head Count Poverty in the short and long runs.

In order to further demonstrate how important these effects can be, consider a one period forecast of the two models selected by the AIC and SBC criteria. We have annual data for all the variables from 1951 to 2001 inclusive with the exception of Rural Head Count Poverty, which only goes up to 2000. We therefore use the ARDL model to dynamically forecast the rural poverty variable for the year 2001. The forecast for the AIC specification is shown in Figure 5 whilst the SBC model forecast is shown in Figure 6. Each figure includes two forecasts, the first in levels:

$$y_t = \hat{\alpha}_1 \hat{y}_{t-1} + \hat{\beta}_0 + \sum_{i=1}^k \hat{\beta}_i L^{\hat{q}_i} x_{it} + \hat{\varepsilon}_t$$

and the second in terms of rates of change:

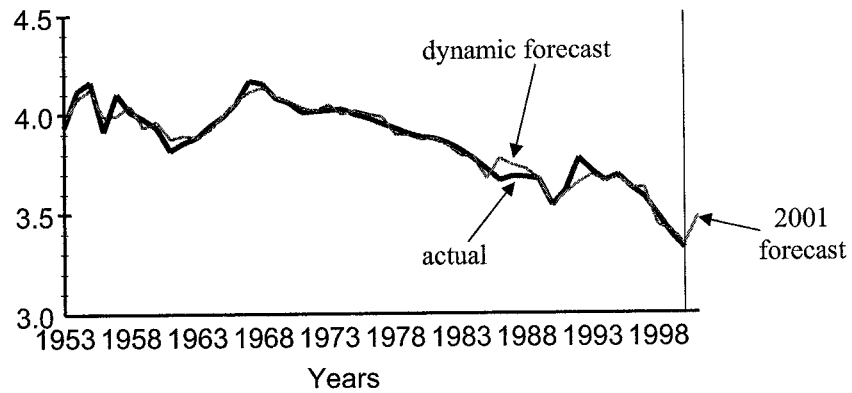
$$\Delta y_t = (1 - \hat{\alpha}_1) \widehat{ecm}_{t-1} + \sum_{i=1}^k \hat{\beta}_{i0} \Delta x_{it} - \sum_{i=1}^k \sum_{j=1}^{\hat{q}_i-1} \hat{\beta}_{ij}^* \Delta x_{i,t-j} + \hat{\varepsilon}_t$$

for $\hat{p} = 1$.

The figures clearly show how well the predicted variables track the actual rural poverty data in levels and growth rates (which is reflected in the high adjusted coefficients of determination measures). However there are exceptions in the 1980s and the 1990s with the dynamic forecasts over, and under, predicting the actual values. Note that the AIC and SBC forecasts for 2001 predict increases in the level of Rural Head Count Poverty, which counter the continuing declines in previous years.

The predictions are alarming when viewed as the change in the rural poverty measure where the negative growth rates become positive for 2001, especially for the AIC specification. This model estimates that Rural Head Count Poverty will increase by 16.2% in one year from 27.6% in 2000 to 30.3% in 2001! The model selected by the SBC measure predicts a smaller but nonetheless significant 5.3% increase in Rural Head Count Poverty from 27.6% to 29.1%.

Figure 5
Dynamic Forecasts of the Level of the Log of Rural Head Count Poverty
AIC Specification



Dynamic Forecasts of the Growth in the Log of Rural Head Count Poverty
AIC Specification

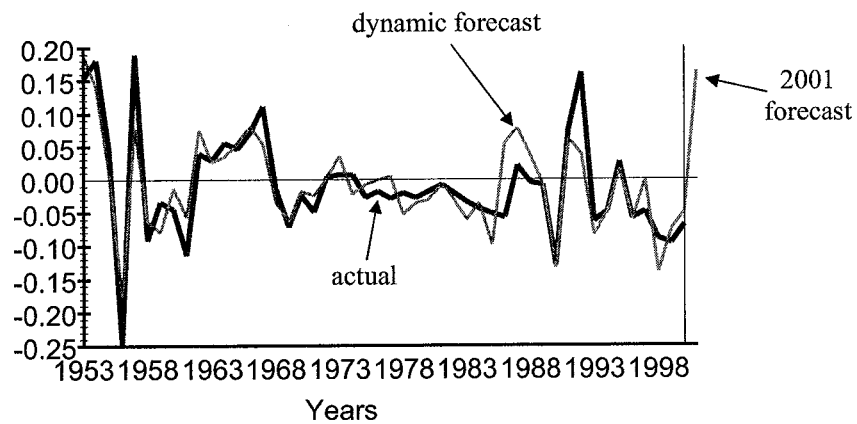
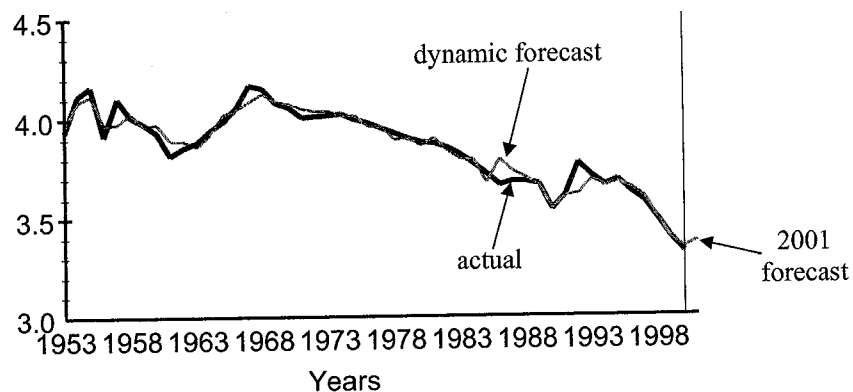


Figure 6
Dynamic Forecasts of the Level of the Log of Rural Head Count Poverty
SBC Specification



Dynamic Forecasts of the Growth in the Log of Rural Head Count Poverty
SBC Specification

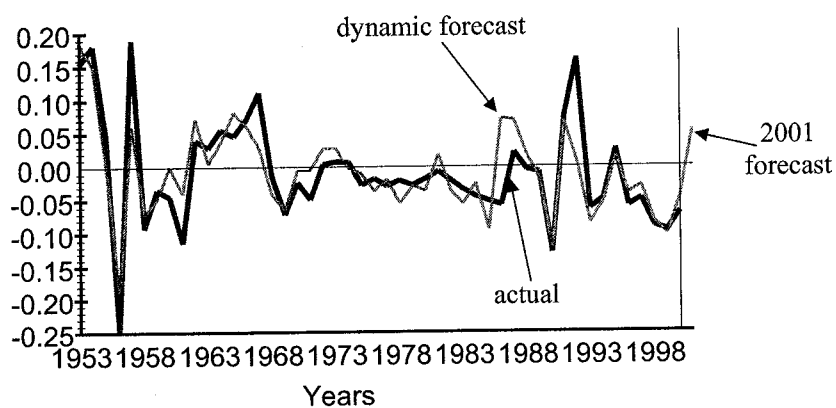


Table 8
Forecast Increases in Rural Head Count Poverty for 2001

| Relative contributions to the forecast change | AIC ¹ | | | | SBS ¹ | | | |
|---|--|------------|---|------------|--|------------|---|------------|
| | contribution to ecm_{t-1} ² | | contribution to 'dynamic variables' effect ³ | | contribution to ecm_{t-1} ² | | contribution to 'dynamic variables' effect ³ | |
| | Percent points | Proportion | Percent points | Proportion | Percent points | Proportion | Percent points | Proportion |
| Food grain production/ rural labour force | 0.36 | 4.6 | -1.93 | -23.0 | 0.19 | 3.4 | -1.90 | 402.2 |
| Producer price of rice/ CPI for agricultural labourers | 6.46 | 82.5 | -0.06 | -0.7 | 3.09 | 53.5 | -0.42 | 88.7 |
| Issue price of rice/ CPI for agricultural labourers | -0.20 | -2.5 | 8.28 | 98.6 | -0.22 | -3.8 | 0.01 | -2.6 |
| Public distribution per capita | -0.27 | -3.5 | 0.52 | 6.2 | -0.85 | -14.7 | 0.33 | -69.6 |
| Development expenditure per rural person/ CPI for agricultural labourers | -0.47 | -6.0 | 1.90 | 22.6 | -0.51 | -8.8 | 1.74 | -368.8 |
| Rural labour force/ Rural population | 4.60 | 58.7 | -0.31 | -3.7 | 2.92 | 50.6 | -0.24 | 50.1 |
| Constant | -2.64 | -33.7 | | | 1.14 | 19.7 | | |
| Total ecm_{t-1} contribution to forecast change | 7.83 | 100.0 | | | 5.77 | 100.0 | | |
| Total 'dynamic variables' contribution | 8.40 | ← | 8.40 | 100.0 | -0.47 | ← | -0.47 | 100.0 |
| Total forecast percent increase = ecm_{t-1} percentage points + 'dynamic variables' percentage points | 16.24% = 7.83 + 8.40 | | | | 5.30% = 5.77 - 0.47 | | | |

Notes:

¹ The optimum values of the ARDL were selected according the AIC and SBC criteria.

² The values show the contributions of the variables to the total value of the error correction mechanism (ecm_{t-1}) in both percentage points and proportions.

³ The values show the contributions of the variables to the total 'dynamic variables' effect in both percentage points and proportions.

The predicted increase in rural poverty is unexpected for two reasons, first the reversal in sign and second in terms of the magnitude of the forecast increase. Rural Head Count Poverty has been declining monotonically since 1992 (with the single one-off exception in 1995) and the predicted increase ranges from what we will call the low (SBC) estimate of around 5% to the high (AIC) estimate of over 15%.¹⁹ This contrasts with our previously discovered high degree of inertia in the changes to Rural Head Count Poverty where we reported in Table 5 that around 59% to 64% of the previous year's rural poverty will continue in the next year.

The relative contributions to the projected increases are detailed in Table 8 for the two ARDL regression specifications selected according to the AIC and SBC measures. Consider the error correction representation with $\hat{p} = 1$:

$$\Delta y_t = (1 - \hat{\alpha}_1) \widehat{ecm}_{t-1} + \sum_{i=1}^k \hat{\beta}_{i0} \Delta x_{it} - \sum_{i=1}^k \sum_{j=1}^{\hat{q}_i-1} \hat{\beta}_{ij}^* \Delta x_{i,t-j} + \hat{\varepsilon}_t.$$

This dynamic specification identifies two contributions to the forecast increase in Rural Head Count Poverty, Δy_t . The first is the increase due to the error correction mechanism $(1 - \hat{\alpha}_1) \widehat{ecm}_{t-1}$ where:

$$\widehat{ecm}_{t-1} = y_{t-1} - \hat{\gamma}_0 - \hat{\gamma}_1 x_{1,t-1} - \hat{\gamma}_2 x_{2,t-1} - \dots - \hat{\gamma}_k x_{kt-1}.$$

The second is due to what we will call the 'dynamic variables' effect:

$$\sum_{i=1}^k \hat{\beta}_{i0} \Delta x_{it} - \sum_{i=1}^k \sum_{j=1}^{\hat{q}_i-1} \hat{\beta}_{ij}^* \Delta x_{i,t-j}.$$

These two growth components are shown at the bottom of Table 8 for the AIC and SBC specifications. The columns in Table 8 show the contributions of the variables to these overall growth forecasts. These contributions are shown in terms of percentage points and the proportion of the total. For the AIC specification it is evident that the large forecast increase of 16.24% comprises 7.83% from the error correction mechanism and 8.40% from the 'dynamic variables' effect.

Since the error correction is the difference between the actual rural poverty ratio and the long run cointegrating relationship, it is therefore a measure of short run disequilibrium. That is to say that the actual value of rural poverty for 2000 is below the estimated long run rate of decline, as determined by the long run cointegrating vector. The Producer Price of Rice/CPI for Agricultural Labourers is the major

¹⁹ The ratio increased from 38.74% in 1994 to 39.75% in 1995. However it fell in the following year, 1996 to 37.46%.

determinant of this disequilibrium, contributing 6.46 percentage points or 82.5% of the total 7.83 percentage points error correction contribution to the forecast increase in rural poverty. The Rural Labour Force/Rural Population variable is the other major contributor with 58.7% of the total 7.83 percentage points.

The contribution of the dynamic variables to the forecast increase in rural poverty is 8.40 percentage points and the main contributor to this is the Issue Price of Rice/CPI for Agricultural Labourers. This variable contributes 8.28 percentage points which is 98.6% of total forecast increase. The important roles of relative prices are again highlighted by these empirical explorations. Consider the time series of the Issue Price of Rice/CPI for Agricultural Labourers in Figure 7. It can be seen that there have been large variations in this relative price since the mid 1990s and this is the major contributor to the forecast increase in rural poverty. The dynamic AIC specification reported in Table 5 includes a two period lag on this price and the large increase in the price from 1999 to 2000 therefore affects the forecast of rural unemployment for 2001. **Indeed almost all of the projected increase from the dynamic variables is due to this very large price increase. Again we repeat the warning that it is inappropriate to actively manipulate real production and issue prices to achieve short run policy objectives.**

The SBC specification projects a smaller, yet still significant increase in Rural Head Count Poverty of 5.30% in 2001. The error correction contributes 5.77 percentage points whilst the dynamic variables subtract 0.47 percentage points. The reason for the lower contribution of the dynamic variables is the more parsimonious SBC specification which did not select lags for the real issue price of rice variable. Restricting the relative prices to contemporaneous within year effects reduces their importance in determining rural poverty. However, there is still a significant error correction disequilibrium effect of 5.77 percentage points. Similar to the AIC specification, the Producer Price of Rice/CPI for Agricultural Labourers variable contributes 53.5% of the total disequilibrium whilst Rural Labour Force/Rural Population contributes 50.6%.

This finding reinforces the AIC result which shows that actual Rural Head Count Poverty in 2000 is below that level consistent with the long run equilibrium relationship defined by the long run elasticities (presented in Table 6) for Food Grain Production/Rural Labour Force, Producer Price of Rice/CPI for Agricultural

Labourers, Issue Price of Rice/CPI for Agricultural Labourers, and Rural Labour Force/Rural Population.²⁰

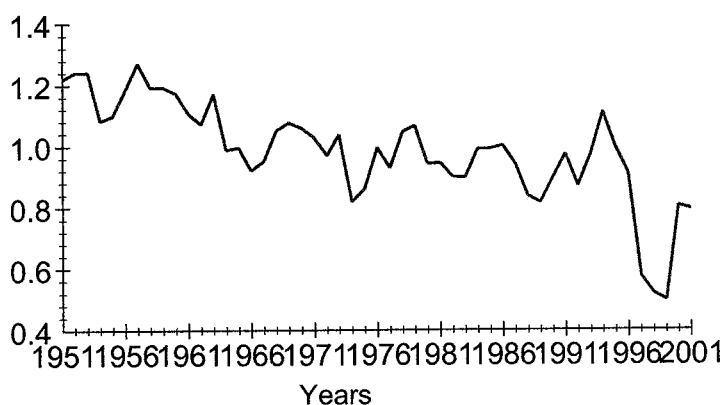
There are two implications of this important finding. It can be expected that either the future values of Rural Head Count Poverty will not continue the relatively fast decline experienced in the 1980s and 1990s (as shown in Table 3b; excluding 1991-92) or the long run equilibrium relationship is changing during these decades. This second important possibility will now be explored.

Exclude the following?

Tables 9 and 10 report re-estimates of the long run cointegrating vector and the error correction mechanism with dummy variables include for the period 1991-2000. Because the estimation procedure searches all possible combinations of the ARDL specification for the maximum possible lags of two means that 3^k regressions need to be estimated when there are k explanatory variables.²¹ It was therefore necessary to limit k to a maximum of ten. Dummy variables were included for the variables which appeared to undergo trend changes in the last decade of the sample.

Figure 7

Issue Price of Rice/CPI for Agricultural Labourers



²⁰ Development Expenditure per Rural Person/CPI for Agricultural Labourers is also important according to the long run estimates for the SBC specification.

²¹ The optimum specification of lags for the ARDL is selected according to the AIC and SBC measures.

The Rural Labour Force/Rural Population variable did not show any trend change in the 1990s and a dummy variable was therefore not included. As shown in Figure 7 the Issue Price of Rice/CPI for Agricultural Labourers exhibited increased variation in the 1990s, although there was no apparent change in trend. A dummy variable was also not included for this variable.

Table 9
Long Run Elasticity Estimates¹

| <i>Dependent variable: Rural head count poverty</i> <i>All variables are in Naperian logs</i> | AIC² | | SBS² | |
|--|------------------------|--------------------|------------------------|--------------------|
| | $\hat{\gamma}$ | $t_{\hat{\gamma}}$ | $\hat{\gamma}$ | $t_{\hat{\gamma}}$ |
| Food grain production/ rural labour force | -1.527 | -2.75** | -0.948 | -2.37** |
| DUM Food grain production/ rural labour force ³ | -7.561 | -2.29** | -6.440 | -2.41** |
| Producer price of rice/ CPI for agric. labourers | -0.156 | -0.46 | -0.109 | -0.33 |
| DUM Producer price of rice/ CPI for agric. labourers ³ | 0.628 | 2.67** | 0.619 | 2.81*** |
| Issue price of rice/ CPI for agric. labourers | -0.170 | -0.64 | -0.039 | -0.15 |
| Public distribution per capita | -0.028 | -0.36 | 0.085 | 1.03 |
| Development expenditure per rural person/ CPI for agricultural labourers | -0.176 | -2.02** | -0.313 | -4.38*** |
| DUM Development expenditure per rural person/ CPI for agricultural labourers ³ | 1.247 | 2.74** | 1.297 | 2.87*** |
| Rural labour force/ Rural population | -2.377 | -2.98*** | -1.687 | -2.82*** |
| Constant | 0.087 | 0.05 | 1.853 | 1.14 |

Sample is 1953 to 2000 (n = 48)

Notes:

¹ The AIC and SBC criteria were used to select the optimum values of the ARDL regressions which were used to calculate the long run elasticities.

² *** represents significant at the 1% level; ** represents significant at the 5% level; * represents significant at the 10% level.

³ The term DUM denotes a dummy variable taking values of the related variable for the years 1991-2000 and zeroes elsewhere.

Table 10
Short Run Error Correction Elasticity Estimates ¹

| <i>Dependent variable: ΔRural head count poverty</i> <i>All log variables are differenced: ³</i> | AIC ² | | SBS ² | |
|--|-------------------------|------------------------|-------------------------|------------------------|
| | $\hat{\beta}_{i0}$ | $t_{\hat{\beta}_{i0}}$ | $\hat{\beta}_{i0}$ | $t_{\hat{\beta}_{i0}}$ |
| Δ Food grain production/ rural labour force | -0.363 | -3.16*** | -0.346 | -3.01*** |
| Δ^2 Food grain production/ rural labour force ⁴ | 0.172 | 1.43 | | |
| Δ DUM Food grain production/ rural labour force ⁵ | -1.163 | -1.73* | -0.607 | -1.23 |
| Δ Producer price of rice/ CPI for agric. labourers | 0.147 | 0.91 | -0.040 | -0.33 |
| Δ DUM Producer price of rice/ CPI for agric. labourers ⁵ | 0.052 | 0.65 | 0.163 | 2.81*** |
| Δ^2 DUM Producer price of rice/ CPI for agric. labourers ^{4,5} | -0.069 | -1.58 | | |
| Δ Issue price of rice/ CPI for agric. labourers | -0.258 | -2.45** | -0.147 | -1.82* |
| Δ^2 Issue price of rice/ CPI for agric. labourers ⁴ | 0.252 | 2.51** | 0.191 | 2.04** |
| Δ Public distribution per capita | -0.087 | -1.85* | -0.054 | -1.34 |
| Δ Development expenditure per rural person/ CPI for agricultural labourers | -0.178 | -4.33*** | -0.196 | -5.20*** |
| Δ^2 Development expenditure per rural person/ CPI for agricultural labourers ⁴ | 0.090 | 2.28** | 0.123 | 3.51*** |
| Δ^2 DUM Development expenditure per rural person/ CPI for agricultural labourers ^{4,5} | 0.144 | 0.63 | 0.474 | 3.10*** |
| Δ Rural labour force/ Rural population | -1.049 | -2.98*** | -0.616 | -2.92*** |
| Constant | 0.038 | 0.05 | 0.677 | 1.05 |
| ecm_{t-1} | -0.441 | -5.09*** | -0.365 | -4.61*** |
| <i>Sample is 1953 to 2000 (n = 48)</i> | $\bar{R}^2 = 0.711$ | | $\bar{R}^2 = 0.691$ | |
| | $F_{14,33} = 9.812$ | | $F_{12,35} = 10.193$ | |

Notes:

¹ The AIC and SBC criteria were used to select the optimum values of the ARDL regressions which were used to calculate the short run error correction elasticities.

² *** represents significant at the 1% level; ** represents significant at the 5% level; * represents significant at the 10% level.

³ The first differences of the logged variables are defined as $\Delta x_{it} = x_{it} - x_{it-1}$.

⁴ The second differenced variables are defined as $\Delta^2 x_{it} = x_{it} - x_{it-1} - x_{it-2}$. The formula used to

calculate the coefficients of these variables is $\sum_{j=1}^{i-1} \hat{\beta}_{ij}^*$.

⁵ The term DUM denotes a dummy variable taking values of the related variable for the years 1991-2000 and zeroes elsewhere.

The estimated elasticities for the short run dynamic specification in Table 10 show that Food Grain Production/Rural Labour Force also increases in importance in the 1990s, consistent with the long run results. The behaviour of the real producer and issue prices are much more complex here with the Producer Price of Rice/CPI for Agricultural Labourers continuing its positive influence according to the SBC specification only. The Issue Price of Rice/CPI for Agricultural Labourers has offsetting effects on changes to rural poverty. Public Distribution per Capita has mild effects whilst Development Expenditure per Rural Person/CPI for Agricultural Labourers continues the complicated cyclical effects with positive effect in the 1990s. The supply side Rural Labour Force/Rural Population remains an important determinant of rural poverty in the short run.

In summary, the productivity and supply side proxies are important short run and long run determinants of rural poverty. Whilst this finding agrees with the previous results reported in Tables 6 and 7, the productivity effect increases dramatically in importance in the 1990s. The real development expenditure per rural person variable continues its complicated cyclical behaviour in the short and long run. Interestingly the role of real prices becomes clouded and real producer and issue prices demonstrate complex behaviour in the short and long run. This appears to be due to the inclusion of the special effects in the 1990s. These findings about the relative price effects reinforce our previous statements that the authorities need to be very careful when manipulating them in discretionary fashion to achieve policy objectives. The timing, direction and magnitude of these effects are unclear.

Given that the effects of the 1990s are important, does this invalidate the previous forecast increase in Rural Head Count Poverty of between 5% to over 15% in 2001? Remember that this prediction could be the result of either the current rural poverty rate declining faster than that dictated by long run fundamentals (which implies rural poverty will increase in the future) or the long run cointegrating relationship has changed in the 1990s and forecasts based on this will therefore be invalid. We used the AIC and SBC error correction models, which include dummy variables to capture the changing effects in the 1990s, to forecast changes in Rural Head Count Poverty in 2001. The models predict Rural Head Count Poverty to increase by 28.40% for the AIC and 19.45% for the SBC specifications in 2001. These predictions are larger than those from the simpler models reported in Tables 5 to 8.

Conclusions and Policy Implications

We have attempted to analyse the rural food sector of the Indian Republic in an intertemporal growth context, with standard assumptions and optimization conditions. The formal model elaborated in the second section of this paper is a major abstraction from the complex diversity of India. However it does capture the essence of the food production system that has operated over the last five decades in India. The paper introduces three innovations in the modelling of the rural food sector.

1. The explicit inclusion of the government sector and its interaction with the food production system, including its resource constraints and the need to balance the short term needs of poverty reduction and long term development objectives. The government's limited capacity to tax and consequent budget constraint necessarily creates conflict between its short term poverty reducing attempts through public distribution of food and subsidized issue price of food on the one hand and its long term developmental goals.
2. The relative issue price of publicly distributed foodgrains (mainly wheat and rice) to the consumer's price index for agricultural labourers is explicitly incorporated in the model. This is in line with widely reported empirical studies confirming the wisdom of senior Indian policymakers.
3. The household labour supply and its implications for the dependency ratios and the dynamic implications of the changing demographic pressures are explicitly incorporated in the model.

The major variables used in the estimation of the model, based on data for the period 1953-2000, were subjected to stationarity tests. The results of Augmented Dicky-Fuller tests were presented in Table 1 and summarised in Table 2. The demographic and labour supply variables were found to be $I(2)$ while rural head count poverty, inputs in the food production system and development expenditure per rural person were first difference stationary, $I(1)$. All other variables were stationary in levels, $I(0)$.

Explorations of the data series for detection of any structural breaks and trend growth rates were then considered. We found important differences in the decadal growth rates of variables with $I(2)$, $I(1)$ and $I(0)$ orders of stationarity. The Brown, Durbin and Evans tests of structural change, summarised in Table 4, show the issue

prices of wheat and rice (relative to the CPI for agricultural labourers) experienced structural change in 1998. The producer price of rice (relative to the CPI for agricultural labourers) saw structural change in the following year, 1999. These results and those of the stationarity tests, imply problematic estimation and inference complications.

We therefore chose to use the autoregressive distributed lag (ARDL) cointegration estimation procedure, which is appropriate for mixed order dynamic processes. The results of the ARDL regressions are summarised in Table 5 with two sets of optimum lags of the VAR, selected according to the Akaike Information criterion (AIC) and the Schwarz Bayesian criterion (SBC). The estimates appear robust when compared across both ARDL regression specifications. They fit the data well by explaining 95% of the variation in the dependent variable, Rural Head Count Poverty. The estimated regressions show a high degree of inertia with 59-64% of the previous year's decrease in Rural Head Count Poverty flowing through to the current year. Despite this, the explanatory variables are also important determinants of rural poverty with the distributed lags ensuring they have enduring effects. The long run elasticity estimates for all variables are shown in Table 6.

These results provide important evidence that the real producer and issue prices significantly affect the level of Rural Head Count Poverty. The inelastic response of Rural Head Count Poverty to the Issue Price of Rice/CPI for Agricultural Labourers ranges from 0.41 to 0.60 for the AIC and SBC lag specifications respectively. The Producer Price of Rice/CPI for Agricultural Labourers was found to have an elasticity of -0.71 . These real price effects dominate the quantity effects of the Public Distribution per Capita which has no significant long run effect on Rural Head Count Poverty. However the other non-price variables are found to be important determinants of rural poverty. Development Expenditure per Rural Person/CPI for Agricultural Labourers has a small inelastic response of -0.21 . The measure of productivity, in the form of Food Grain Production/Rural Labour Force, has a higher elasticity which ranges from -0.90 to -1.25 . The supply side Rural Labour Force/Rural Population has an elastic response ranging between -1.49 and -1.74 in the long run.

The short run (error correction) reactions of Rural Head Count Poverty to divergences from the long run (cointegrating) relationship are shown in Table 7. In contrast to the long run, the real issue and producer prices for rice do not appear to

have important influences on the short run equilibrating adjustments in Rural Head Count Poverty. This means that the authorities should not manipulate real foodgrain issue and producer prices to achieve short term goals. Pricing policies should be designed to achieve desired resource allocation in the long run. Compared to the long run, changes to foodgrain quantities, measured in terms of per capita public distribution, have a small inelastic effect of -0.11 on the short run movement in Rural Head Count Poverty. Real development expenditure (per rural person) has strong short run cyclical effects on rural poverty. The first difference elasticity of -0.16 is countered by the second difference elasticity of 0.09 (consistent with the netted out weaker estimated long run effect). Finally, the productivity measure (Food Grain Production/Rural Labour Force) has an inelastic response of -0.33 , while the supply side proxy (Rural Labour Force/Rural Population) has an inelastic response in the range of -0.54 to -0.71 . These latter short run effects on Rural Head Count Poverty are consistent with the long term findings.

The paper concludes by considering the complicated intertemporal effects of the real prices on rural poverty. The ARDL specifications, selected according to the optimal AIC and SBC criteria, are used to provide forecasts of Rural Head Count Poverty for the year 2001. The SBC model estimates that Rural Head Count Poverty will increase from 27.6% in 2000 to 29.1% in 2001, whilst the AIC model predicts a larger increase to 30.3% in 2001. These projected increases counter the consistent decline experienced in rural poverty since 1992 (with the one-off exception in 1995). They also contrast with our previously discovered high degree of short term inertia in rural poverty in that around 59% to 64% of the previous year's decline in Rural Head Count Poverty will continue into the next year.

These counter findings, plus the worrying projected increases in rural poverty, required further analysis. We disaggregated the SBC and AIC projected increases of 5.3% and 16.2% respectively into two components, which are detailed in Table 8. The first component group comprises the short term (error) correction to the long run (cointegrating) trend. The 2000 level of Rural Head Count Poverty is below the estimated trend value, which implies it will increase in 2001. The SBC specification projects a rise of 5.8% while the AIC specification projects a 7.8% increase. The main contributing factors to these expected increases are the producer price of rice (relative to the CPI for agricultural workers) and the rural labour force (per rural population).

The second component group for the projected increase in rural poverty comprises the dynamic contributions of the explanatory variables to the forecast increases in rural poverty. The effects of this group are more varied across the two specifications which predict -0.5% and 8.4% respectively for the SBC and AIC models. The expected small dynamic decrease in rural poverty for the SBC specification is due to the offsetting effects of productivity improvements which are forecast to decrease rural poverty while development expenditure will increase it.

The relatively large expected increase in rural poverty of 8.4% in the AIC specification is wholly due to the sizeable increase in the issue price of rice (relative to the CPI for agricultural workers). The time series for this variable, shown in Figure 7, clearly details the large reductions in the real price from 1995-97 and to a lesser extent 1998-99. The dynamic AIC specification reported in Table 5 includes a two period lag on this price and the large increase in the price from 1999 to 2000 therefore affects the forecast of rural unemployment for 2001. Indeed almost all of the projected increase from the dynamic variables is due to this very large price increase.

In conclusion we repeat the central messages of these data explorations. First, the significant reductions in Rural Head Count Poverty will not automatically continue. Second, the effects of productivity and demographic supply side improvements are very important determinants of future levels of rural poverty. Third, relative prices, particularly in the form of real issue prices and support prices for the major staples, wheat and rice have important effects on rural poverty. Fourth, the relative price effects are significant long term determinants of the trend in rural poverty and complicated short term determinants. Fifth, the authorities, who have successfully manipulated prices to reduce rural poverty have overused support and issue prices to obtain short term goals. Our findings give the warning that it is inappropriate to actively manipulate real production and issue prices to achieve short run policy objectives.

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Appendix A1

The Hamiltonian: $H = u(c)e^{-\rho t} + \xi \dot{k}$ can be used to maximise household intertemporal utility, $u(c)$ with respect to the household budget constraint. Defining the costate variable, ξ as the net present value of Tobin's q at the current time period, t , that is, $\xi = qe^{-\rho t}$ gives the Hamiltonian:

$$H = u(c)e^{-\rho t} + q\dot{k}e^{-\rho t} \quad (1)$$

and the costate equation $\dot{\xi} = -H_k$ gives the result: $\dot{q} = rq - (\alpha f'_k + d'_k)$ which derives the important solution for q :

$$q = \int_t^{\infty} (\alpha f'_k + d'_k) e^{-r(s-t)} ds \quad (9)$$

In steady state, $q=1$ and $\dot{q}=0$, which when substituted gives the expanded equilibrium condition, $r = \alpha f'_k + d'_k$.

Since q represents the marginal valuation of capital then higher values of q will encourage household investment according to the investment function, $\dot{k} = \Phi(q)$ with $\Phi' > 0$. Substituting for q gives capital formation as a function of the net present values of the marginal product of capital in production and public distribution:

$$\dot{k} = \Phi \left[\int_t^{\infty} (\alpha f'_k + d'_k) e^{-r(s-t)} ds \right] \quad (10)$$

Appendix A2

Define the measure of rural poverty, p as a function of rural household consumption, out of household production, which is below a conventionally accepted minimum, c_{min} :

$$p = -\psi(c_0) \quad c_0 < c_{min} \quad (15)$$

Taking the inverse function $c = -\varphi(p)$ gives the equivalent rate of change in poverty to be inversely related to productivity:

$$\frac{\partial[\varphi(p)]/\partial t}{\varphi(p)} = \theta[\rho - (\alpha f'_k + d'_k)] \quad (16)$$

Rearranging the household budget constraint $c = -\dot{k} + wl_n + rk + d - \alpha_\tau y$, substituting for consumption and integrating from time, t_0 to infinity gives:

$$\begin{aligned} \int_{t_0}^{\infty} \varphi[p(t)] e^{\int_{t_0}^t r(s) ds} dt &= k_{\infty} - \int_{t_0}^{\infty} w(t) l_n(t) e^{\int_{t_0}^t r(s) ds} dt - k_{t_0} e^{\int_{t_0}^{\infty} r(s) ds} \\ &\quad - \int_{t_0}^{\infty} d(t) e^{\int_{t_0}^t r(s) ds} dt + \alpha_\tau \int_{t_0}^{\infty} y(t) e^{\int_{t_0}^t r(s) ds} dt \end{aligned} \quad (17)$$

Discounting to time t_0 by multiplying both sides by $e^{-\int_{t_0}^{\infty} r(s) ds}$ gives the present value of poverty at time t_0 :

$$\therefore \int_{t_0}^{\infty} \varphi[p(t)] e^{-\int_{t_0}^t r(s) ds} dt = -h(t_0) - k(t_0) - d(t_0) + \alpha_\tau y(t_0) \quad (18)$$

where $h(t_0) = \int_{t_0}^{\infty} w(t) l_n(t) e^{-\int_{t_0}^t r(s) ds} dt$, $d(t_0) = \int_{t_0}^{\infty} d(t) e^{-\int_{t_0}^t r(s) ds} dt$ and $y(t_0) = \int_{t_0}^{\infty} y(t) e^{-\int_{t_0}^t r(s) ds} dt$. Now in order to determine the level of poverty at time t_0 , integrate the relationship (16) forward to obtain:

$$\varphi[p(t)] = \varphi[p(t_0)] e^{\int_{t_0}^t \theta[\rho - \alpha f'_k(s) + d'_k(s)] ds} \quad (19)$$

and using (19) to substitute out $\varphi[p(t)]$ in (18) gives the required result:

$$\begin{aligned} \varphi[p(t_0)] \int_{t_0}^{\infty} e^{\int_{t_0}^t \{\theta[\rho - \alpha f'_k(s) + d'_k(s)] - r(s)\} ds} dt &= -h(t_0) - k(t_0) - d(t_0) + \alpha_\tau y(t_0) \\ \therefore p(t_0) &= -\varphi^{-1} \left\{ \pi [h(t_0) + k(t_0) + d(t_0) - \alpha_\tau y(t_0)] \right\} \end{aligned} \quad (20)$$

$$\text{with } \pi = \left\{ \int_{t_0}^{\infty} e^{\int_{t_0}^t \{\theta[\rho - \alpha f'_k(s) + d'_k(s)] - r(s)\} ds} dt \right\}^{-1}.$$

Appendix B

BDE Tests of Structural Change

The Brown, Durbin and Evans (BDE, 1975) annual cumulative sum of the recursive residuals (CUSUM) and the cumulative sum of the squares of the recursive residuals (CUSUMQ) tests on the regression specification $x_t = \beta_0 + \beta_1 t + \varepsilon$ where the variables

are $I(0)$ and on $\Delta x_t = \beta_0 + \sum_{i=1}^p \gamma_i \Delta x_{t-i} + \varepsilon_t$ if the variables are $I(1)$ or $I(2)$.

Figure B1

Net Availability of Food Grains per Capita
Plot of Cumulative Sum of Recursive Residuals

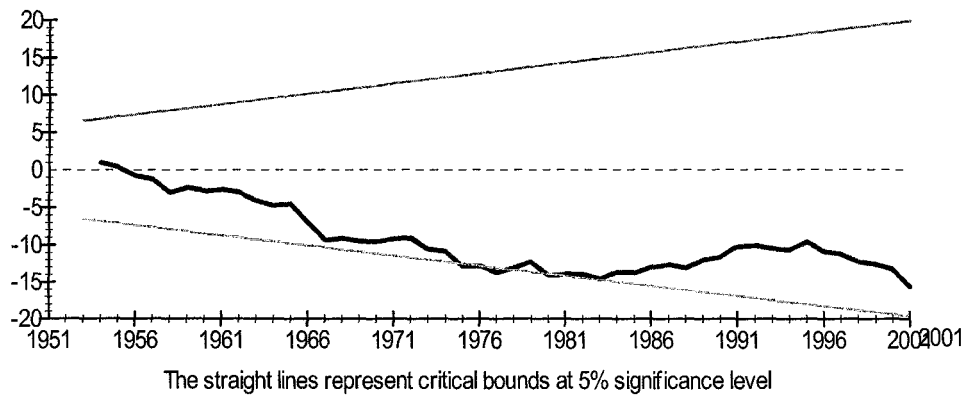


Figure B2

Consumer Price Index (CPI) for Agricultural Labourers
Plot of Cumulative Sum of Recursive Residuals

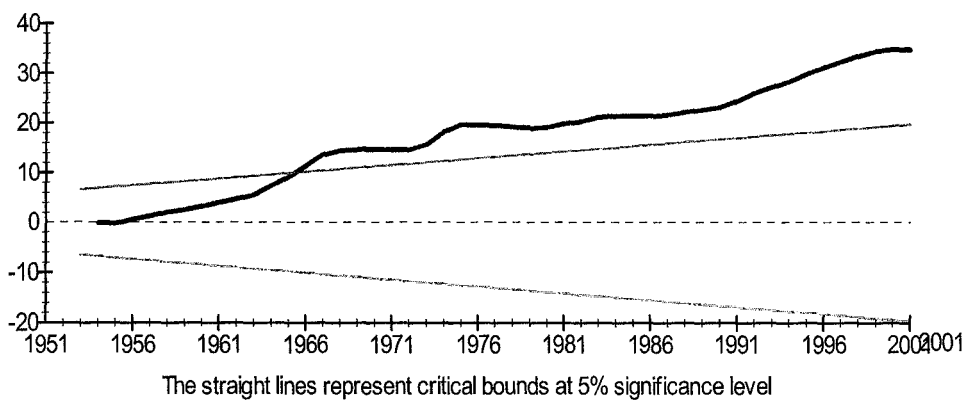


Figure B3
BDE Tests of Structural Change
Producer Price of Rice/ CPI for Agricultural Labourers

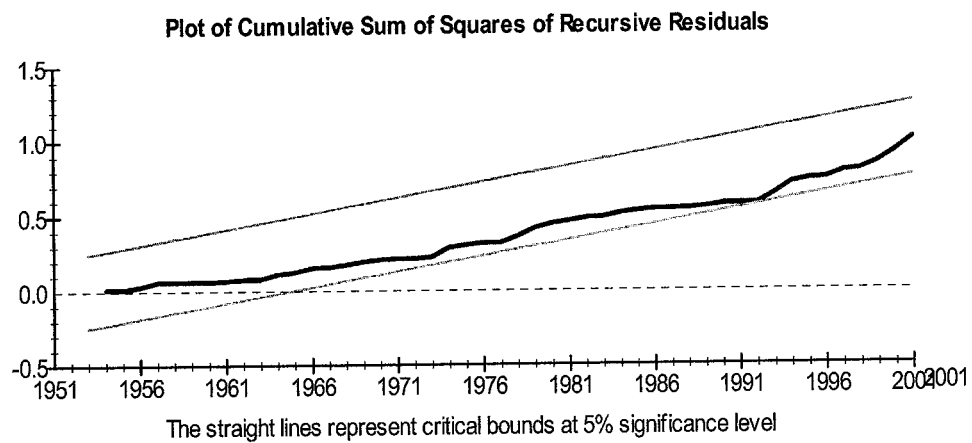
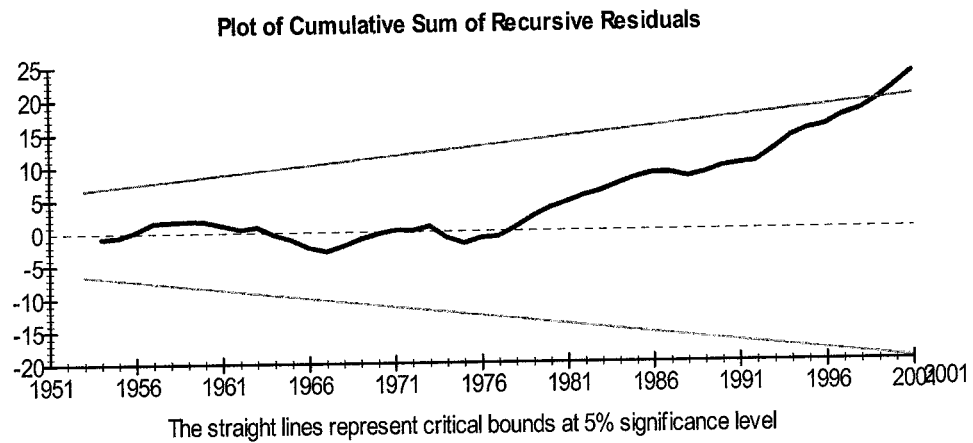


Figure B4
BDE Tests of Structural Change
Issue Price of Rice/ CPI for Agricultural Labourers

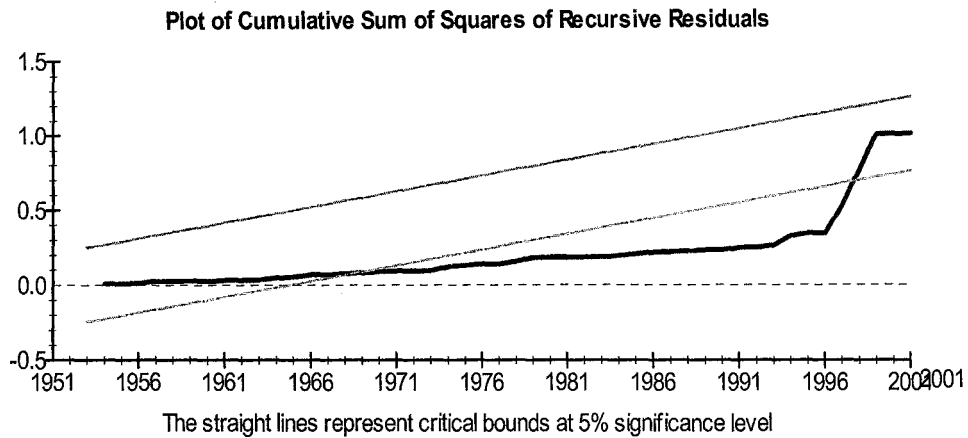


Figure B5
BDE Tests of Structural Change
Issue Price of Wheat/ CPI for Agricultural Labourers

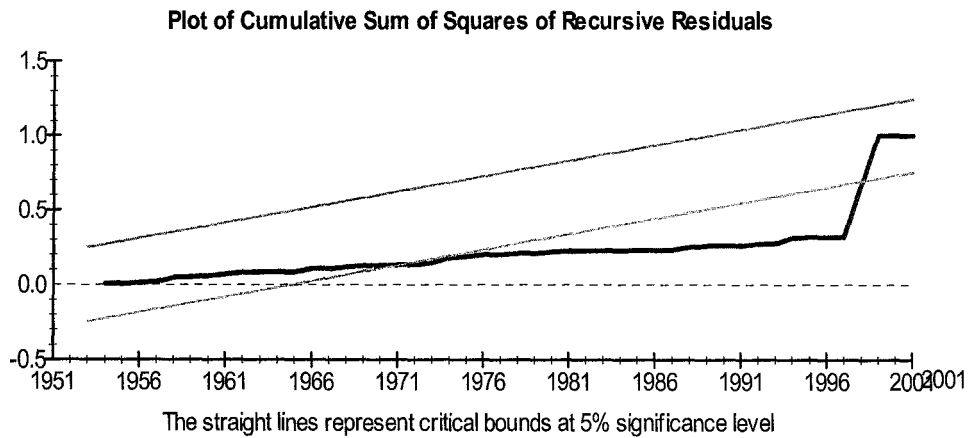


Figure B6
BDE Tests of Structural Change
Literacy Rate

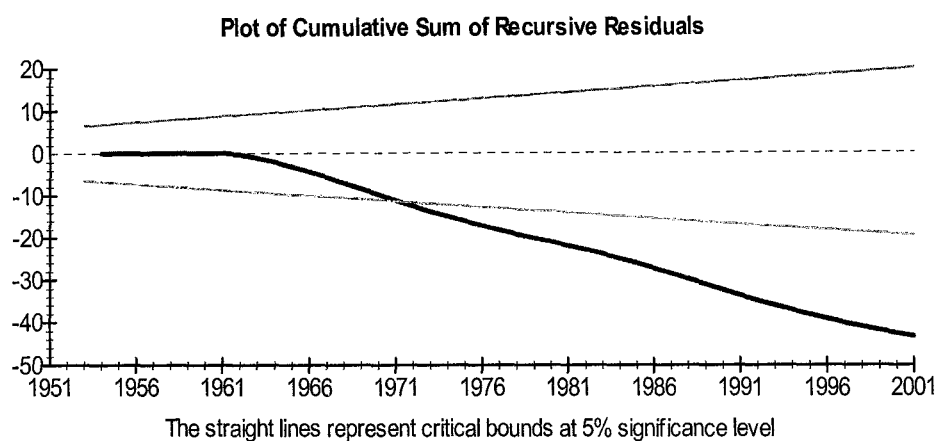


Figure B7
BDE Tests of Structural Change
Rural Head Count Poverty

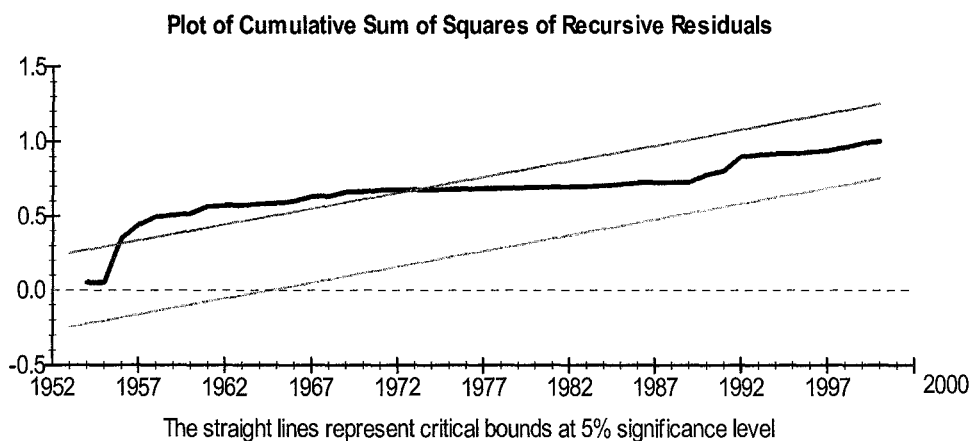


Figure B8
BDE Tests of Structural Change
Public Distribution per Capita

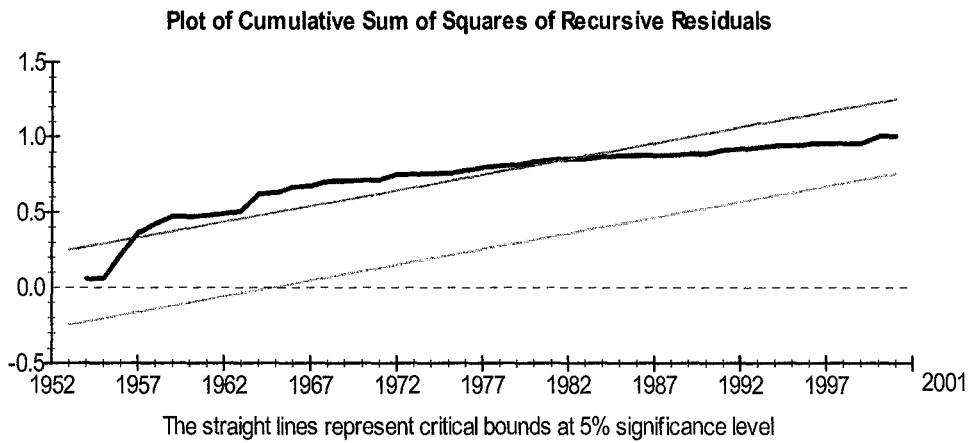
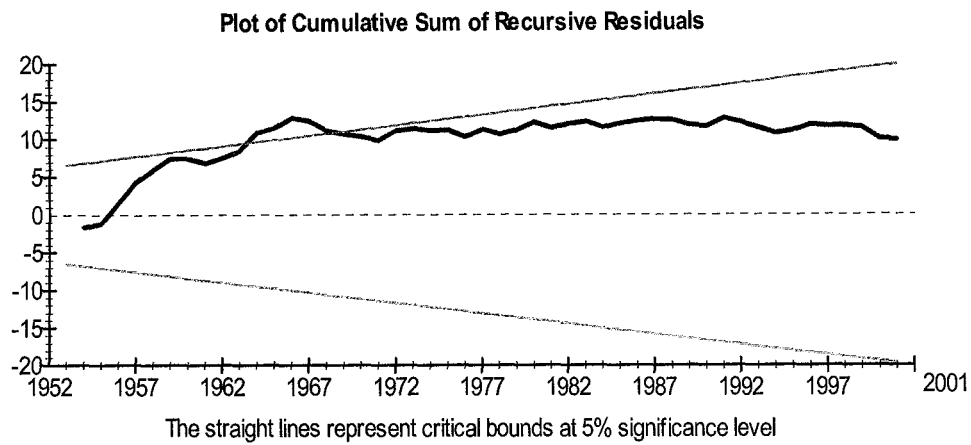


Figure B9
BDE Tests of Structural Change
Producer Price of Wheat/ CPI for Agricultural Labourers

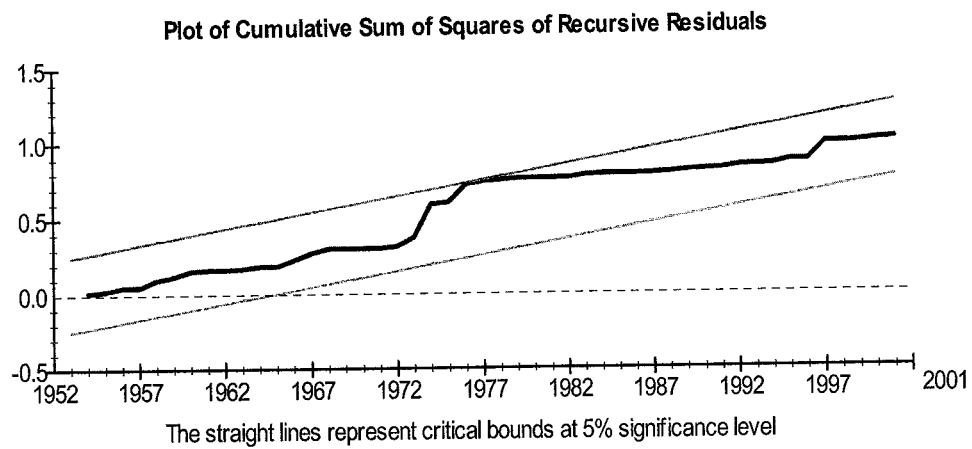


Figure B10
BDE Tests of Structural Change
Proportion of Area Irrigated

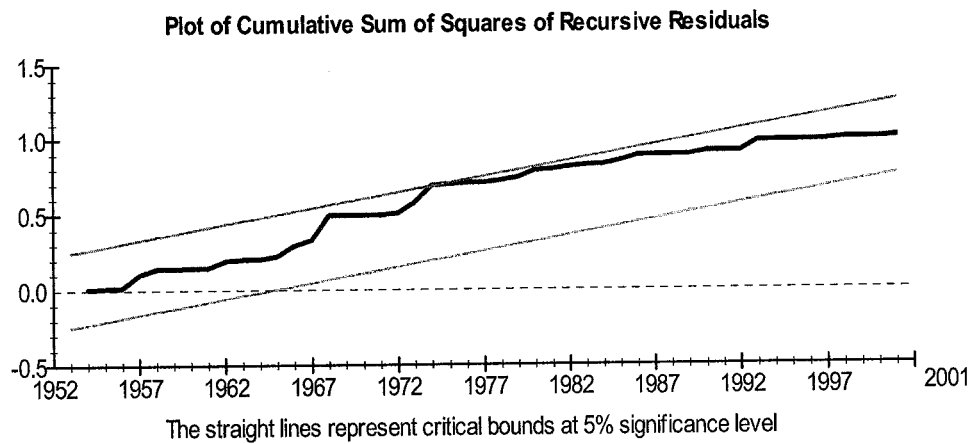


Figure B11
BDE Tests of Structural Change
Rural Population

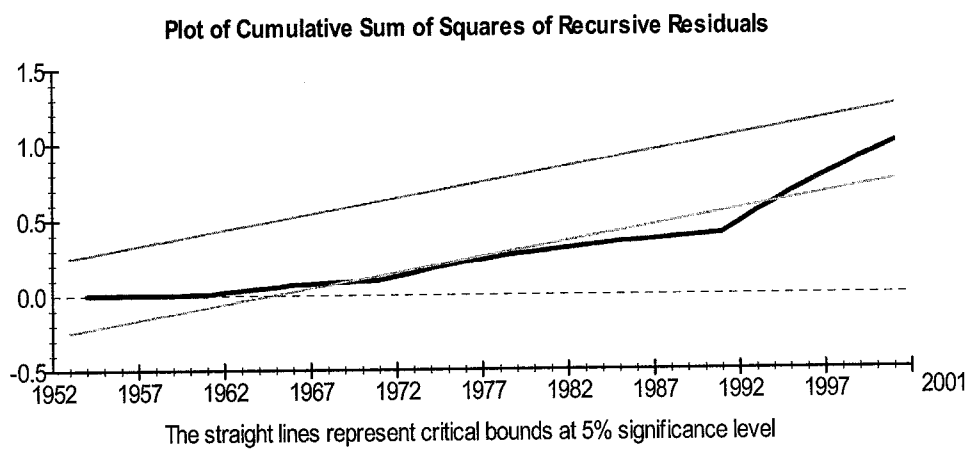
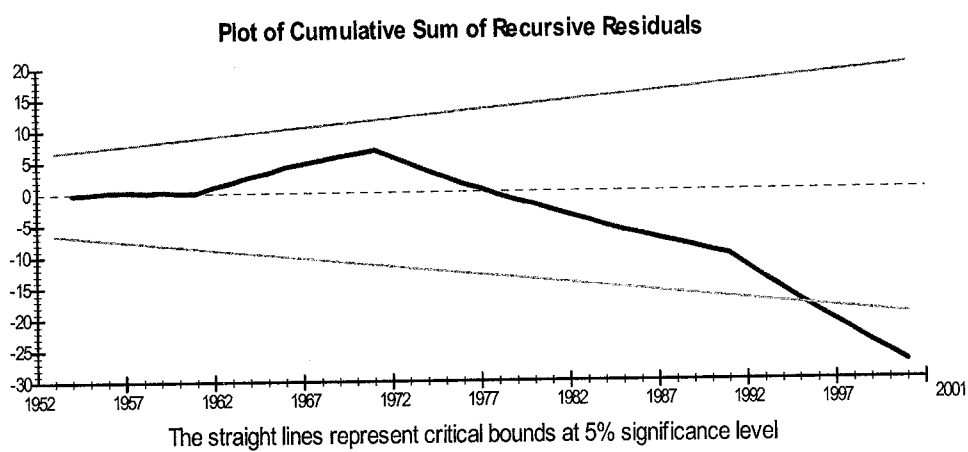


Figure B12
BDE Tests of Structural Change
Rural Labour Force/ Rural Population

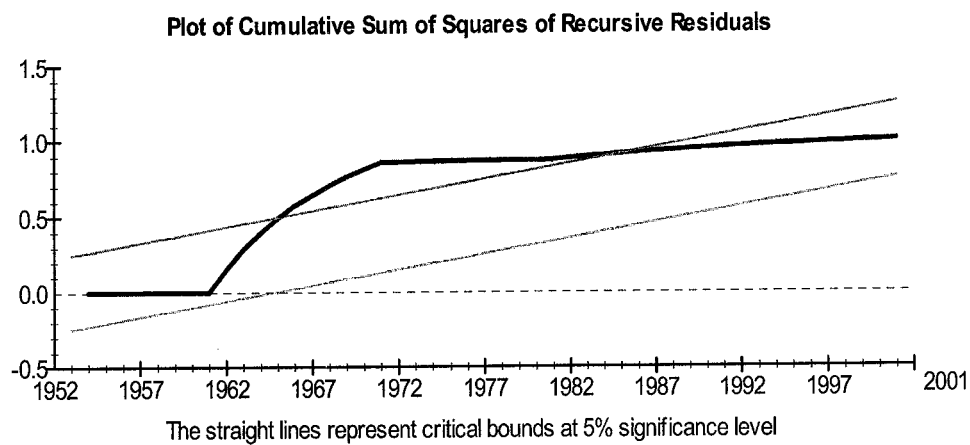
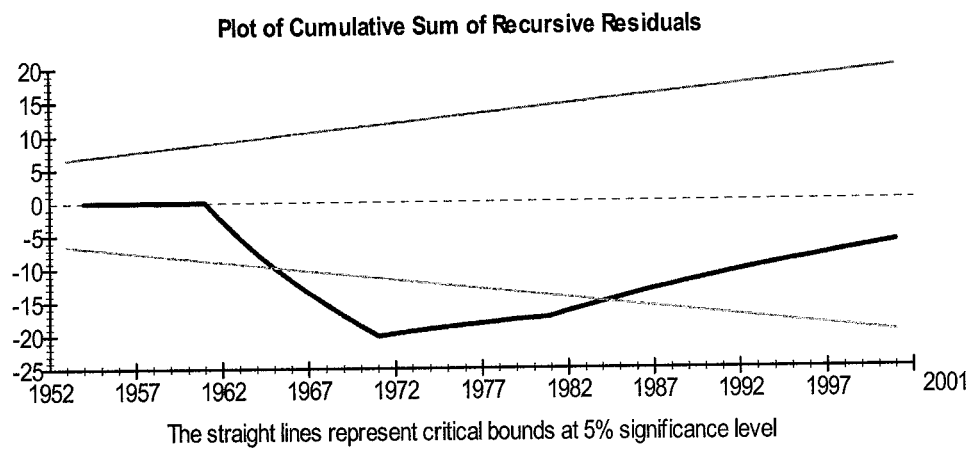


Figure B13
BDE Tests of Structural Change
Children (<15 years old)/ Population

