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An Econometric Model of Agricultural Wages in Bangladesh

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In recent years, a consensus is emerging in favour of the trickle down hypothesis in traditional agriculture. However, any convincing evidence was still lacking in the Bangladesh context. To fill up this gap, the wage models of Rahman (1993) and Ravallion (1994) have shown that agricultural production affects rural wages positively in the short run, which may be interpreted to constitute evidence in favour of the trickle down hypothesis in the short run, but any long run evidence could not be discerned. However, this seems to suggest that possibly one required only the right sort of model for the purpose. To this end, this paper presents an error correction model of rural wages, which shows that agricultural production has significant favourable impact on rural wages in the long run. This may have obvious implications for designing poverty alleviation policies.

I. INTRODUCTION

Controversy surrounds the question whether prosperity brought about by the New Technology of Green Revolution trickles down to the rural poor. Some tend to think that the New Technology may have been immiserising, which raises the question whether it would be desirable to pursue the same type of agricultural development in future. However, in recent years a consensus is growing in favour of the trickle down hypothesis although dissention continues to persist. In the Bangladesh context, the studies of Rahman (1993) and Ravallion (1994) show that, in the short run, the trickle down hypothesis holds true, i.e. the rural wages are positively affected by agricultural productivity. To extend this finding, it will be shown in the present paper that the same holds true in the long run which, properly speaking, may claim to constitute conclusive evidence in favour of the trickle down hypothesis.

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The trickle down debate has produced a vast amount of literature, some of which are cited in the next section. This debate can only be compared with the earlier debate on the "price responsiveness" hypothesis i.e. the question whether the farmers of traditional agriculture are responsive to crop prices, which was closed conclusively by Schultz (1964). At about this time, the scientists introduced the New Technology of modern high yielding varieties of crop seeds requiring heavy inputs of fertilizer and irrigation, which ushered ultimately the so-called Green Revolution. The New Technology has undoubtedly raised agricultural production bringing obvious prosperity for the landed class, especially the large farmers. But it is apparently not clear whether the other classes, e.g. the small farmers and the landless labourers, have also benefited, which can only come mainly through increased agricultural real wage income and to a lesser extent through derived demand (other than farm employment) from the landed class. If the relatively poor benefits, then one could say that the prosperity brought about by the New Technology does in fact trickle down to the poor, which is the so-called Trickle Down Effect. In this case, one could say unambiguously that the New Technology has favourable impact on the rural welfare, and hence the importance of examining the trickle down hypothesis. However, no such unambiguous inference on overall welfare is possible if the trickle down effect does not obtain, notwithstanding the conceptual problem of aggregation of divergent group welfare except through controversial subjective value judgement. However, the evidences so far obtained are rather mixed being both in favour of and against the trickle down effect, and the debate, has not yet been settled conclusively.

In order to establish the trickle down effect, it is often examined whether agricultural productivity has positive effect on agricultural wage because of the absence of more direct data on agricultural income or employment. One may note that the hypothesis of positive wage-productivity relationship is closely related to but apparently not identical with the hypothesis of trickle down effect of New Technology, but the former is necessary for establishing the latter that is a much broader one. The link between the two hypotheses, although they are close, is a bit complex. The wage-productivity hypothesis itself appears somewhat self-evident from the fact that even simple economic reasoning of the usual labour demand function tells one that the employment concomitant on productivity should affect wages positively. Generally, higher production or productivity means lower agricultural prices as well as higher employment, which in turn means higher wage. Thus, higher production causes three effects e.g. higher employment, higher nominal wage and lower agricultural prices, each of which has positive effect on real wage income, and thus finally production must have positive effect on the welfare of labourers. This assertion, which seems rather self evident and even somewhat tautological in the final analysis, is exactly what the trickle down hypothesis would predict, and it might seem at the end, but ironically not at the start, that we may be merely trying to prove an obvious proposition. According to the foregoing formulation of the problem, the existence of the trickle down effect is not to be questioned, but rather finding a reliable estimate of it appears to be the only task ahead of the practitioners. However, surprisingly such an obvious relation has not been found easy to be established convincingly even through econometrics, as it is evidenced by recent studies in the Bangladesh context, because the positive impacts of agricultural production appears to be shrouded by strong negative impact of ever rising population coupled with increasing inequality and/or pauperization leading to even faster growth of labour supply than what simply population growth alone would imply, and this is further frustrated by endemic econometric problems. In principle, econometric techniques should be of help to this end, because the most important feature of the regression technique is its ability to sort out the separate contributions of the independent variables even when they have opposite effects like that of production and population, etc. If a wage model cannot detect the effect of a variable amidst of opposing forces of other variables, it would most often mean inadequacy of the model (or, in some rare cases, inadequate data). For this reason, the often-heard argument, that the effect of production is masked by opposing factors, may not seem justifiable for an insignificant regression coefficient for production. Rahman (1993) and Ravallion (1994) have shown that agricultural production affects wages positively in the short run, which may be interpreted to constitute evidence in favour of the trickle down hypothesis in the short run. This evidence seems to suggest additionally that possibly the trickle down hypothesis could also hold true in the long run. To provide proper evidence in favour of the trickle down hypothesis, it is shown in the present paper that agricultural production indeed affects rural wages positively also in the long run.

II. SOME NOTES ON LITERATURE

During the initial years of advent of the new technology of the green revolution, many thought that while the new technology might accelerate overall growth, the benefits will accrue to only the rich farmers and will not reach the poor farmers and labourers who may even lose. Among those who have discussed adverse effects of green revolution on the poor, special mention can be made of Byers (1980), Griffin (1974), and Pearse (1980). Now after successful adoption of the new technology in many regions of the world, the initial fears of immiserisation appear to have faded away largely. It appears that the poor has benefited in regions where the new technology has been successful, but not where it has failed. For a strong support of this view, reference can be made to Osmani (1993).

Most enquiries on the trickle down effects are basically of the non-econometric type, however with some exceptions. Apart from elsewhere in the world, it has been debated most extensively in the Indian context, which has more relevance for Bangladesh because of geographical proximity implying similarity in agrarian structure and socio-economic setting. Mention must be made of Deepak Lal (1984) which obtained some mild support for the trickle down hypothesis for India through an econometric model based on neo-classical demand-supply framework of wage determination with a reference period of a century ending at 1980. Incidentally, at about the same time, the first regression type of study on Bangladesh was carried out by Khan (1984) who reported results in favour of the trickle down effects, that is, positive effects of production per acre and agricultural terms of trade on real wages. This result has been, however, questioned by Boyce & Ravallion (1991), because of neglect of autocorrelation leading to unreliable model estimates, which will be presented later on. Khan (1984) draws his conclusions from the following model of real wages estimated from yearly aggregate data over the period 1949 to 1979/80:

$$(W/CPI) = -2.5 + 1.0\ Q + 1.8\ ATT - 0.20\ T \qquad (1)$$

where W, CPI, Q, ATT and T are respectively agricultural wage, consumer price index, agricultural production per acre, agricultural terms of trade and time trend. This model has R^2=0.77, DW=1.53 and all the explanatory variables are significant. It may be noted that population or any other variable representing supply of labour is absent in this model. However, T may claim to represent the effect of population besides other trend variables, but in that interpretation, the linear nature of T may not so well represent the exponential growth of population.

Because of imposing space economy, we can only present a summary of what appears to us to be the main points of the trickle down debate raised by the subsequent studies of Boyce & Ravallion (1991), Rahman (1993), Palmer-Jones (1993), Ravallion (1994) and Palmer-Jones (1994), although it might possibly endanger correct representation of the works. The differences among the above studies are too numerous and the reasonings argued are too intricate as well as contentious. Hence, any sort of summary description such as the present one may not adequately capture the true picture, for which the readers must be referred to the original studies, which are also very rich source for knowledge of the many facets of the real wage question as well as related issues including estimation problems. We shall not address here another related debate of the above studies on the trend of real wages over time except making some passing remarks, because this somewhat complicated issue might take us beyond the scope of this paper. For the present purpose, we may note the following.

The correctness of Khan's procedure was questioned by the paper of Boyce & Ravallion (1991) which is a revised version of their earlier study e.g. B&R (1989). B&R (1991) try to show that when neglected autocorrelation is taken into proper consideration, the effect of agricultural terms of trade is no longer significant in Khan's model. They also suspect significant biases in the official production data used by Khan, and report that using Boyce's (1985, Table 10) revised estimates of yields, agricultural production is no longer significant in Khan's model. The study of B&R (1991), starting from a general model which includes agricultural production besides other relevant variables, has the following final model, excluding insignificant variables, estimated over the period 1949-80 for Bangladesh data:

$$\Delta w = 0.045 + 0.22(p\text{-}h) + 0.47(m\text{-}w_{-1}) - 0.32(m_{-1}\text{-}h) - 0.00037(T^2) \quad (2)$$

where the model has $\bar{R}^2$=0.83, and the symbols Δ, T, w, p, m, and h denote respectively the first difference operator, time, log of agricultural wage, log of rice price, log of manufacturing wage, log of cotton cloth price. However, the time trend variable is somewhat problematic (Appendix-1), which has also been voiced by Palmer-Jones (1993) that will be presented later on. Although agricultural production was included in the initial general model, subsequently it turned out to be statistically insignificant so that it did not appear in the final model. Still they appear not to dismiss the possibility of the existence of the positive wage-production relationship, because they opine, "there are likely to be unidentified mitigating factors such as steady growth in agricultural labour supply". They also maintain that the real wages show an alarming downward trend over the years 1949-80, and that the real wages have not shown any observable effect of the rising agricultural productivity due to Green Revolution which, in their opinion, did happen because of adverse effects of population growth, etc.

A statistically significant positive effect of agricultural growth rate on wages was obtained for the first time in Rahman (1993), which is in fact the precursor of the present paper, from the following model estimated over the period 1949-89 using Palmer-Jones' data series:

$$\Delta w = 0.03 - 0.39\,(w\text{-}p)_{-1} + 0.31\Delta p - 0.15\Delta p_{-1} + 0.38\Delta v + 0.52(\text{error})_{-1} \quad (3)$$

where v denotes agricultural productivity per capita, 'error' is the prediction error, and the model has R^2 =0.66, and $\bar{R}^2$=0.61, and all variables are significant. Hereafter productivity will always mean agricultural productivity per capita if not mentioned otherwise. (This model could be improved further in respect of better explanatory power by introducing the second order autoregressive error process which is also statistically significant, and then it would have R^2=0.75 and $\bar{R}^2$=0.70). The most remarkable feature of this model is that productivity is significant in the short run, which is reflected by the fact that Δv shows the same type of short run dynamics as Δp or Δp_{-1}. This result may be interpreted to constitute evidence in favour of the trickle down hypothesis in the short run. Similar evidence has also been obtained by an elaborate model of Ravallion (1994) to be presented later on, which uses Δq for its purpose, and we have verified that if Δv were used instead of Δq, the results would still be similar. The findings of the two authors seem to suggest that the trickle down hypothesis could possibly be true even in the long run, and to prove it, probably one requires only the right sort of model. Such a model will be presented in this paper later on.

Palmer-Jones (1993) has contested both the contentions of B&R, e.g. lack of evidence of positive wage-productivity relationship and declining real wages. He also finds some other problems with the model of B&R, particularly noteworthy are the so-called prediction failure during the 1980s and the problematic time-trend variable. While his own investigation finds the opposite of the second contention of B&R regarding the trend of real wages, unfortunately he could not provide any direct evidence against the first contention of B&R regarding wage-productivity relationship, which will be evident from his model cited below. Palmer-Jones has the following final model of wages estimated over the period 1949-89 (updating the data series of B&R to 1989):

$$\Delta w = -0.25 - 0.48w_{-1} + 0.22p + 0.09p_{-1} + 0.26w_{-1} + 0.17(D724) + 0.0055(T4964) \quad (4)$$

where the model has R^2=0.85 and $\bar{R}^2$=0.82, and the dummy variable D724 takes the value 1 in the years 1972 to 1974 and zero elsewhere, and the dummy variable T4964 is a discontinuous time trend taking the values 1 in 1949, 2 in 1950, and so on up to 1964, and zero from then on. In fact, Palmer-Jones' final wage model does not contain any production term either, like the B&R study, because of statistical insignificance. However, he does not place much emphasis on this result, but conjectures with the help of other evidences that there could indeed exist a positive wage-productivity relationship, but the evidences cited are rather weak.

The paper of Ravallion (1994) comments back in reply to Palmer-Jones (1993) by pointing out a number of problems with the model of Palmer-Jones (simply, P-J hereafter), among which special mention should be made of the prediction failure of P-J's model during the 1980s as well like the B&R (1991) model. Admitting some shortcomings in the original model of B&R (1991), Ravallion (1994) comes up with the following completely new wage model estimated using the same data series over the period 1949-89 as in P-J (1993), which he says does not show the 1980s drift in wage prediction:

$$\Delta w = -0.100 - 0.217(w-p)_{-1} - 0.353(w-p)_{-2} + 0.199(m-p)_{-2} + 0.059(j-p)_{-1} + 0.075(h-p)_{-1} + 0.224(\Delta p) + 0.250(\Delta m) + 0.107(\Delta h) + 0.312(\Delta q) \quad (5)$$

where j and q denote respectively log of jute price and log of production per acre, and the model has R^2=0.82 and $\bar{R}^2$=0.77. One interesting finding of this model is that, unlike either the original model of B&R (1991) or P-J (1993), agricultural growth rate (Δq) is now significant. This confirms the earlier finding of Rahman (1993) that agricultural production affects rural wages positively in the short run. Ravallion's interesting interpretation of this result can be read from the lines "However, note that this is the growth rate, not the level; what we appear to be seeing here is the short-term effect of output shocks, rather than an effect of technical progress" (refer to his note 10). In respect of trend of real wages, Ravallion (1994) maintains essentially the same position as in B&R (1991). Note that this new model has only a weak resemblance in structure with that of B&R (1991), and in particular, there is no term representing labour supply effects on wages either through the use of either population or any proxy variable like the time trend as employed earlier, and this may appear to be a weakness of the model. The long-run effect terms, which are all expressed in terms of rice price, possess such composition that is obviously superior to that of the previous paper e.g. B&R (1991). However, it says that the model is offered for illustrative purposes.

The reply of Palmer-Jones (1994) admits only some of the criticisms, but it does not offer any new wage model instead. It maintains that, like his own wage model's prediction failure, the new wage model of Ravallion (1994) also suffers from prediction failure, i.e. the 1980s wage prediction drift, however using the wage data that P-J (1994) believes now to be appropriate for 1984-89. It observes that both their models seem to be unable in predictions to cope with the apparent rise in real weal wages in the 1980s. However, its chief concern appears to be centered on the time trend of real wages, and it particularly wants to understand the real ultimate cause behind the fall in real wages during the mid-1960s and a rise in the early 1980s, on which it is rather unsure though some proximate causes are listed. In our opinion, the real cause is the fall and rise of agricultural productivity per capita during the two periods respectively, for which we refer to the section on the wage-productivity relationship to be presented later on.

Summarising, one can unmistakably notice that all the econometric studies mentioned above believe in the trickle down hypothesis, although there appears to remain substantial disagreement over whether the data provides convincing evidence. It is apparent from both traditional and econometric type of studies that a consensus is growing in favour of the trickle down hypothesis, that is, about positive effects of production on poverty, but the problem is to find convincing evidence of its existence and providing reliable estimates. Econometric technique can be of special help in this regard because of its unique ability to separate out opposing effects e.g. effects of productivity and population on wages, but it requires the right sort of model specification that can closely represent reality. For the same reasons, econometric technique alone can provide evidence with such confidence level, which non-econometric enquiries cannot. However, some of the econometric studies could not produce any significant result, while two of them provided evidence in favour of the trickle down hypothesis in the short-run only, but could not discern any effect in the long run. However, this seems to suggest that possibly one required only the right sort of model for the purpose. To this end, this paper presents an error correction model of rural wages, which shows that the trickle down hypothesis holds indeed true in the long run.

III. DERIVATION OF THE WAGE MODEL

We would develop here an Infinite Distributed Error Correction Model by extending the standard Sargan-type error correction model to accommodate "infinite distributed lagged" response of wage to rice prices, which is an observed fact of the economy. The worthiness of our effort is most obvious to see in its ability to successfully prove the existence of the Trickle Down Effects and provide reliable estimates of them. The model of agricultural wages is developed in the following steps. (i) One may start by noting that agricultural wages depend obviously on the demand and the supply of labour. The demand of labour is directly influenced by the total agricultural production (Q_t), and the supply of labour by the total population (N_t).[1] (ii) We postulate that the current agricultural wage (W_t) depends on lagged wage (W_{t-1}) which, as we shall see later on, after proper price deflation will provide an error correction mechanism in the final model. (iii) The prices of non-agricultural goods, which are important in the consumption bundle of the labour affecting any real wage estimation (and for that same reason, any estimation of rice-wage i.e. rice equivalent of nominal wage), here represented by the price of cotton cloth (H_t), also enter as explanatory variable. The prices of non-rice agricultural goods, because of their absence in

[1] Clearly, here we are abstracting away from other factors on the demand and supply sides of labour, e.g. rural population density, dependency ratio, incidence of tenancy, incidence of landlessness, level of technology, proportion of irrigated land, intensity of cultivation, extent of urbanisation, terms of trade of agriculture with industry, uncertainty of production (along with uncertainty of weather conditions, input requirements, input prices and output prices), and also from a host of other such factors which have been postulated to affect wages in various empirical studies.

the model, are being represented through default also by the cotton cloth price. In this interpretation, the cotton cloth assumes more importance by representing all non-rice goods in the consumption bundle.)[2] (iv) We also introduce (P_t, P_{t-1}, ... , $P_{-\infty}$) as explanatory variables where P denotes appropriate price deflator which is taken here to be the price of rice. Here the model is assumed to have, not a short memory of only two or a few lagged price terms, but rather a very long memory of infinite time in the past. Therefore, we have the following model where the current time is denoted by the suffix t,

$$W_t = f(W_{t-1}, P_t, P_{t-1}, ... , P_{-\infty}, Q_t, N_t, H_t) \quad (6)$$

Taking log-linear approximation of this equation and denoting the natural logarithm of the variables by their corresponding lower case letters, and omitting the time suffix t, we obtain the following equation,[3]

$$w = g + g_0 w_{-1} + (g_1 p + g_2 p_{-1} + g_3 p_{-2} + g_4 p_{-3} + ...) + (k_1 q + k_2 n + k_3 h) \quad (7)$$

where the p-terms extend backwards to infinity in time, which is equivalent to saying that the rice prices have "infinite distributed lag" effects on wage. Henceforth, all variables will be meant to be in log-form if not mentioned otherwise. Starting from this equation, express q and n as a single (q-n) term where a remainder "n" term appears, then subtract p from h to get the term (h-p), then add the coefficient of (h-p) to the relevant p term which will result for p in a coefficient of (g_1+k_3). Now subtract w_{-1} from both sides to get Δw as the dependent variable where Δ denotes the first difference. Thus the following equation is obtained,

$$\Delta w = g + (g_o - 1) w_{-1} + (g_1 + k_3) p + (g_2 p_{-1} + g_3 p_{-2} + g_4 p_{-3} + ...) + k_1 (q-n) + k_3 (h-p) + (k_1 + k_2) n \quad (8)$$

[2] We refrain from introducing manufacturing wage because of two reasons. Firstly, the hypothesis of migration of labour between agriculture and industry seems to us not so much appealing due to its quantitative unimportance, and secondly, the price of cotton cloth is very highly correlated (R^2=0.94) with the manufacturing wage where manufacturing sector includes cotton cloth as well. Therefore, this would amount to an attempt to capture prices of non-agricultural goods by two different but highly collinear variables. In addition, we are not in favour of inclusion of the jute price because of a number of reasons. The argument of their unimportance is supported by the fact that their exclusion does not affect model performance of the present paper.

[3] However it is admissible to write equation (7) as the primitive after deciding on its structure and identifying the relevant variables. Notably other routes to equation (7) are also possible.

Note particularly that we have, on the right hand side, the following explanatory variables: (i) q and n are jointly expressed as a single term e.g. (q-n) measuring per capita agricultural productivity or simply, productivity,[4] which may be interpreted much meaningfully as the "excess demand for labour". The remaining part of n has a coefficient of (k_1+k_2). (ii) h has been deflated by p to form another single term, e.g. (h-p), which may be called real cloth price. Now in the above equation, deflate w_{-1} by p_{-1} to get lagged "real wage in rice terms" or simply the lagged "rice wage" which provides an error correction mechanism, and add suitable expression to the p_{-1} term which will now have a changed coefficient, and we obtain,

$$\Delta w=g+(g_o-1)(w-p)_{-1}+[(g_1+k_3)p+(g_o+g_2-1)p_{-1}+g_3p_{-2}+...]+k_1(q-n)+k_3(h-p)+(k_1+k_2)n \quad (9)$$

Further, all the p-terms may be expressed in difference form (e.g. Δp-terms), and the Appendix-2 presents the required derivation which is lengthy and apparently not so obvious involving limits of infinite series. This last feature is a departure from the usual practice of starting with a basic model containing only one lagged p-term that has very little a priori justification, and so ending up with a final model having the last price term in level e.g. p_{-1}. Thus, we obtain the following equation that follows the ECM format pioneered by Sargan (1964), with a modification of the usual model specification in that the rice price terms are now all in differences which implies a very convenient property of homogeneity of degree zero (Appendix-3). Therefore, one has the following Infinite Distributed Error Correction Model (as derived in Appendix-2),

$$\Delta w=a+a_o(w-p)_{-1}+(b_o\Delta p+b_1\Delta p_{-1}+b_2\Delta p_{-2}+\ldots\ldots)+k_1(q-n)+k_3(h-p)+(k_1+k_2)n \quad (10)$$

where the lagged Δp terms extend backwards to infinity in time and the coefficients are defined in Appendix-2. Here the level terms provide the long-run relationship while the Δp-terms describe the short-run effects. This is our conceptual model of wages.

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[4] The term "productivity" was used by Khan (1984) to mean production per acre and by the other studies (e.g. Boyce & Ravallion 1991 and Palmer-Jones 1993) to mean "production index". However we shall reserve the term "productivity" to mean only "production per capita" in order to avoid confusion. These shall be understood to have been expressed always in logarithm in accordance with the earlier convention of defining all variables in natural logarithm.

IV. ESTIMATION, INTERPRETATION AND IMPLICATIONS

Estimation of the Model

All the above studies on Bangladesh use the wage data from the series "Monthly average daily wage rate of agricultural labourers without food," published by the Bangladesh Bureau of Statistics. This has unfortunately a gap of missing values during 1990-93 when it was not published, although other related data series have no such problem.[5]

Although estimation with missing data is possible through the procedure of Savin and White (1978) by Shazam computer package, it must be noted that it is a large sample procedure as they say "If….the sample size is large, ML estimates of the parameters of the autoregressive model can be obtained by correcting the likelihood function for missing observations," and the ML method needs the assumption of normality of residuals. In contrast, if estimation is done with only pre-missing years' data as has been done by others mentioned above, one can use GLS method that is valid for any sample size and the residuals need not be normal, and this meets the stringent criteria of leaving no room for doubt when our prime objective is to test a controversial proposition like the trickle down hypothesis. Apart from comparability with earlier studies, this option has given us model estimates with such high significance, as we shall see later on, that some extra d.f. with recent data cannot make any practical difference. Moreover, use of the most recent data is neither a necessity while testing for a time-invariant hypothesis like the present Trickle Down Hypothesis (or for that matter, the Price Responsiveness Hypothesis of Schultz).[6] Since a time-invariant hypothesis must hold for any time period, it suffices to be tested using data for the earlier period with no missing data when the robust exact procedure of GLS can be adopted for estimation. While an up to date exercise with inclusion of the missing period using ML procedure may amount to re-examining the trickle down hypothesis for the recent times, which we intend to do in a future paper.

Since we have found it more worthwhile to limit the study period to the pre-missing years, the required data can be taken from Palmer-Jones (1993) who extended the last two years to the compiled data of B&R (1991), where all yearly

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[5] Though the Bureau has another data series of rural wages that comes along with wages in other sectors of the economy, the possibility of its substitution for the missing values in this study was ruled out for the reason that the latter rural wage series does not have the comprehensive data coverage as the former so that they are not perfect substitutes having the same statistical properties.

[6] In comparison, the most recent data may be needed for a time-specific enquiry about the present poverty situation.

data are expressed as indices taking 1949 as the base year, and the basic source of data is the Bangladesh Bureau of Statistics.[7]

We have followed the single-stage procedure of estimating the full error correction model as preferred in Harvey (1993, p.295-6), (Appendix-4). An examination of residuals of the estimate of the wage model (10) showed signs of autocorrelation, and therefore estimation was done assuming that the errors followed autoregressive structure of suitable order. Although the series of Δp-terms in the model (10) extend backwards to infinity in time, actually one need not go that far back. We shall need only a few of the Δp-terms, because we found that the price difference terms beyond Δp_{-1} turn out to be statistically insignificant. One can also drop the last term involving only population, which proved statistically insignificant presumably because of being uncorrelated with wage increments Δw. Thus, the preferred parsimonious model of wages can be written, adding an error term (e), as follows,

$$\Delta w = a + a_o(w\text{-}p)_{-1} + b_o\Delta p + b_1\Delta p_{-1} + k_1(q\text{-}n) + k_3(h\text{-}p) + e \qquad (11)$$

We found that the error term is not one of simple first-order process, but higher order autoregressive processes of up to fourth order showed significance.[8]

The fourth order and second order autoregressive error processes were found to be most suitable which have been reported here, while third order autoregressive process is only marginally satisfactory which is not reported. The third order autoregressive error process would need a liberal view on the third order error term, i.e. $\rho 3$ (which is significant at 10.1 per cent level), the model performance is otherwise excellent. It is found that with fourth order autoregressive error process, one has the best results. In comparison, the second order autoregressive error model's performance is quite satisfactory, but then one has to take slightly liberal view on certain issues e.g. about the significance level of productivity and ρ_2 i.e. the second order error term. Here only the estimates of

[7] Some problems with the data of the later years in the series were felt by Palmer-Jones (1994). However, Ravallion (1994) finds only minor changes in the final estimates of his econometric model due to this data problem. Therefore, we shall also ignore it and continue to use the same data series of Palmer-Jones.

[8] Some interesting interpretation can be made for the multiplicity of the autoregressive orders which show suitability as possible candidates. The multiplicity shows that the model is robust in respect of order of autoregressive errors and that the model's significance does not depend on the assumption of any particular autoregressive order since so many possible aliases exist. In comparison to our findings, Lal (1984) found AR2 process to be appropriate for his models although even AR3 showed possibility in one of his models.

the second and the fourth order autoregressive models are presented in Table I.

TABLE I
REGRESSION RESULTS OF THE WAGE MODEL

Dependent variable: Δw

Model estimates		First estimate			Second estimate		
Explanatory Variables:	Coeff	Two-tail			Two-tail		
		Coeff	t-ratio	Prob(t)	Coeff	t-ratio	Prob(t)
constant	a	0.1335	2.7653	0.011	0.1048	2.0689	0.048
$(w-p)_{-1}$	a_o	–0.6098	5.6999	0.000	–0.5004	4.7076	0.000
Δp	b_o	0.4532	12.2372	0.000	0.3937	8.2419	0.000
Δp_{-1}	b_1	–0.1629	4.7166	0.000	–0.1292	2.9195	0.000
$(q-n)$	k_1	0.4289	4.4638	0.000	0.2833	1.9566	0.060
$(h-p)$	k_3	0.3300	6.5810	0.000	0.2302	4.0147	0.000
AR1	ρ_1	1.4075	7.0931	0.000	1.0417	5.6443	0.000
AR2	ρ_2	–1.0225	3.9118	0.001	–0.3453	1.9484	0.061
AR3	ρ_3	0.7328	2.9772	0.006	–	–	–
AR4	ρ_4	–0.3427	2.1984	0.037	–	–	–
R^2	–	0.8434	–	–	0.7741	–	–
$\bar{R}^2$	–	0.7871	–	–	0.7196	–	–
SER	–	0.0451	–	–	0.0541	–	–
F	–	14.9659	–	–	14.1977	–	–

Notes: Coeff=Coefficient, Prob(t)=Probability of exceeding the t-ratio, SER=Standard error of regression.

On Some Aspects of the Wage Models

The attractiveness of our model lies in its parsimony, easy conceptualisation, ready economic interpretation, and good performance. The parsimony is reflected by the fact that it employs fewer basic variables in comparison with earlier studies, namely, it need not use manufacturing wages, jute price, time trend and dummy variables, and the reasons have been given earlier in footnote 2. The model employs few long-run and short-run effect terms, which can be postulated from simple reasoning with immediate economic interpretation, and yet the model performance is highly satisfactory.

Both the estimated wage models have very good fit with the observed wage data as shown by R^2 and $\bar{R}^2$ (Table I). Both the models satisfactorily passed various diagnostic tests, for example, test for model misspecification and tests for randomness, homoscedasticity and normality of residuals. However, the normality test for the first model required exclusion of a single outlier-residual (e.g. the year 1984) from the calculation of the normality test statistic only, but it need not be excluded from the model estimate itself or from elsewhere.

Comparison of the first and the second estimates of the wage model

The first estimate of the wage equation has fourth order of autocorrelation in the error term that should not be surprising, since it appears to reflect merely the observed complex cyclical behaviour of the underlying data series where the cycles are typically several years long. Behind the cyclical behaviour, there could be a host of factors, some of which can themselves be cyclical, namely, weather conditions, various government policy regimes, etc. In contrast to ours, the models of Lal (1984) have second order error process (though he says that one of his models could possibly fit with third order error process), and Azam (1993) finds a moving average error process to be appropriate. All the coefficients of the first estimated model are highly significant, and the overall fit of the model as reflected in the value of F-statistic is very good. The model explains 84.34 per cent of the total variation, and the $\bar{R}^2$ is 78.71.

However if one prefers, it is possible to simplify the error process to the second order which is provided by the second estimate of the model in the above table. Note that there the t-values of two coefficients, e.g. (q-n) and AR2, are significant at 6 per cent and 6.1 per cent level respectively. Acceptance of the second model can be justified on two grounds. Firstly, since there can be no universally acceptable level of significance at 5 per cent (or 1 per cent), the observed level which is just above the customary 5 per cent level may be considered fair enough. Note that in similar context, slightly higher levels of significance seem to have been employed by others, [Appendix-5]. Secondly, it may be legitimately argued that the appropriate test for the effect productivity on wages should be a right-hand-sided one-tail test and not the two-tail test that has been employed in Table I, which is unnecessarily restrictive or even inappropriate.[9]

Notwithstanding our preference, we have reported the results of the two-sided tests in Table I in keeping with the usual practice. According to the right-hand-

[9] What may be the appropriate procedure for testing the effect of productivity on wages? In this case, it may be legitimately argued that the usual two-tail test is not only unnecessarily restrictive but it is actually even inappropriate. Since the trickle down hypothesis implies that the productivity effect is positive, it may appear pointless to test whether the productivity effect is zero as it is done in the customary two-tail test. Therefore, properly speaking, the appropriate test for trickle down hypothesis should test the null hypothesis of positive effect against the alternative of zero or negative effect, which is precisely provided by the right-hand-sided one-tail test. For one-sided tests, one may consult any statistical text book on hypothesis testing.

sided one- tail test, the observed t-value of 1.9566 for the coefficient of (q-n) will now have a right-sided p-value of 0.030 (which is equal to exactly half the p-value of the customary two-tail test e.g. 0.060). This means that the right-hand-sided one-tail test statistic (i.e. t-ratio) would be significant at 3 per cent level. The changed one-sided test does not at all alter the basic structure of the model except that the error process simplifies now to the second order, and the overall conclusions remain the same except that the second order autoregressive error term would still require a slightly liberal view for its significance at 6.1 per cent level. The second model estimate has slightly lower explanatory power e.g. by 0.07, and the coefficient estimates are generally also slightly lower than in the first model estimate, which appears to be due to the absence of the third and the fourth order autoregressive errors.

Since the second model is nested within the first model, a test for whether the second model can be maintained against the first model is equivalent to testing the restriction that in the autoregressive error process of the first model, the 3rd and 4th terms are both zero. Such a test is provided by the likelihood ratio (LR) test, so that denoting the likelihood function by LF, the statistic

$$LR = -2[\log LF(\text{Second model}) - \log LF(\text{First model})] \qquad (12)$$

is asymptotically distributed as χ^2 (chi-square) under the maintained (or null) model with 2 degrees of freedom, (since 2 is the number of restrictions needed to define the null hypothesis). The calculated value is LR=9.6466, which has a corresponding p-value of 0.0084, showing that the second model may be rejected in favour of the first model at less than 1 per cent i.e. 0.84 per cent level of significance. Thus it appears that the likelihood ratio test would favour the adoption of the first estimate of the model. However, informally speaking, if one feels more comfortable to work with a model having simpler error process such as the second estimate of the model, then one would need to have a slightly liberal view for significance of the second term of the second order autoregressive error process even when one adopts one-sided test for productivity. In view of the said feeling, both models are reported here, although the first model is clearly superior.

In short, it appears that the most favourite is the first model whose estimate meets the strictest criteria, while the second model has the chief advantage of a simpler error process. However, only the favoured first model will be considered while presenting the relevant graphs (graphs 1.A, 2.A and 3.A) of the observed versus the predicted Δw, w and "rice wage" which are given at the end of the text showing very close agreement between the observed and the predicted values. It should be noted here that some initial observations have been taken up by the estimation of auto-regressive error process for providing lags.

The Long Run Equilibrium Model of Wages

The steady state solution of the wage model of equation (11) is given by only the level terms there dropping the lag and error terms. Thus, the long-run equilibrium relationship is given by

$$(w\text{-}p) = (-a/a_0) + (-k_1/a_0)(q\text{-}n) + (-k_3/a_0)(h\text{-}p) \qquad (13)$$

where $(-k_1/a_0)$ and $(-k_3/a_0)$ are the long-run elasticities of rice-wage with respect to per capita productivity and deflated cloth price respectively. From Table I, the long-run equilibrium wage relationship for rural Bangladesh is estimated to be as follows:

First model: $(w\text{-}p) = 0.2189 + 0.7034(q\text{-}n) + 0.5412(h\text{-}p)$ (14)

Second model: $(w\text{-}p) = 0.2094 + 0.5661(q\text{-}n) + 0.4600(h\text{-}p)$ (15)

In general, the first model has higher elasticities than the second model, which happens because of the fact that ρ_3 and ρ_4 are significant in the former, while they are absent in the latter. However, the first model is the favoured model because earlier we have found that the likelihood ratio test strongly favours the first model over the second model. This point needs to be always borne in mind although the findings from both models will be presented.

The Wage Productivity Relationship

It is found that the current nominal wages are positively affected by changes in productivity having regression coefficients as high as 0.4289 and 0.2833 in the first and the second estimates of the wage model, which are respectively significant at less than 0.05 per cent level (by even the two-sided test) and at 3 per cent level (by right-sided one-tail test). Specially remarkable is the high significance of the productivity term in the first model, because the significance level for two-sided test is not only less than the usual strict level of 1 per cent but actually less than 0.05 per cent i.e. (1/20)-th of 1 per cent. And if one adopts the more appropriate right-sided one-tail test for testing the trickle down hypothesis, the significance level would be less than 0.025 per cent level i.e. less than (1/40)-th of 1 per cent. Such high significance shows beyond doubt that the trickle down effect is certainly positive. Further, the quantitative importance of the trickle down effect is shown by the high value of the coefficient of productivity and the related elasticities. The short-term (within year) elasticities of nominal wage with respect to productivity in the first and the second models are respectively 42.89 per cent and 28.33 per cent, while the respective long-term elasticities are much higher at 70.34 per cent and 56.61 per cent. Note that for obvious reasons, the elasticities of both rice-wage and real wage are exactly the same as the elasticity of nominal wage, both in the short run and the long run.

These findings assure that increase in agricultural productivity does indeed lead to increase in nominal wages and of course also in rice-wages as well as in real wages in the long run. Obviously, this lends strong support to the trickle down hypothesis. In particular, the downward plunge of rice wages (and of real wages) during the period from the early-1960s to the early-1980s appears to have been caused by a fall in per capita productivity, and likewise the increase in rice wages (and real wages) during the mid-1980s by a rise in per capita productivity. These upward and downward trends in real wages have been noted by B&R, Ravallion and P-J, but their models have very little to offer in the way of explaining them. For example, the position of P-J (1994) is rather agnostic, while B&R (1991) and Ravallion (1994) think that factors like rapid population growth outstripping agricultural growth would have a depressing effect on real wages, although neither population nor agricultural production nor any other “real variable” is significant in their models. Thus, the effort of trying to explain or predict the trend of real wage (or rice wage) from models containing only wage-price variables, which can represent at best only wage-price dynamics, is operationally deficient in the absence of “real variables”. The model of the present paper confirms the fact that the effect of agricultural production on wages is positive, while that of population is negative. Note that in the present paper, population is incorporated as a deflator in the per capita productivity term, and the residual effect of population as a separate term is not significant.

The Effect of Rice Price on Wages

Rice has 53.8 per cent weight in the consumption bundle during 1965-66 as quoted in Bose (1968). This weight, which is derived from a survey, must have contained some estimation error even at that time, and moreover the “correct” weight itself may have changed over the years due to economic factors, changes in nutritional knowledge, tastes, habits, etc. For example, according to B&R (1991, footnote 13), the likely weight of cereals is about 50 per cent in the total expenditure of the poorest 50 per cent of rural households. Of course, other authors may have different weights. However, it is true that if the elasticity of wage with respect to rice price is exactly equal to the weight of rice in the consumption bundle, then any change in rice price will not change the “real wage” defined in terms of representative consumption bundle. This fact makes it possible to draw some observations about the effect on real wage from the model of rice-wage as estimated here.

From Table I, it is calculated that the short-term (i.e. within year) elasticity of nominal wage with respect to current rice price (assuming past rice prices given) of the first and the second models are respectively 12.32 per cent and 16.35 per cent, and in comparison, this elasticity is estimated to be higher at around 22 per cent in the studies of B&R (1991), P-J (1993) and Ravallion (1994). This means that although a price increase leads to higher nominal wage, it leads to somewhat lower rice wage (and lower real wage), because the loss due to increased price is not fully offset by the implied increase in wage. Of course, this would mean temporary hardship for the labouring class. Likewise, a fall in rice price would slightly boost the rice-wage as well as the real wage in the short run. The long run elasticity of nominal wage to rice price in the two models are respectively 45.88 per cent and 54.00 per cent, which are close to the "likely" weight of rice in the consumption bundle, and this implies that rice price would have almost no effect on long-run real wage. This feature is also confirmed from the findings of B&R (1991), P-J (1993) and Ravallion (1994), which have long run elasticities of 47 per cent, 46 per cent and 48 per cent respectively (Ravallion 1994, p.341).

The variable Δp_{-1}, which measures increase of rice price during the previous year, is essentially a term in the distributed lag structure for the delayed effect of rice prices, and the effect is negative and it is about one-third in absolute value of that of Δp. All other rice price difference terms of higher order turn out to be insignificant, which does not however imply that they are actually non-existent or unimportant, but it could well turn out that a longer series of data might reveal their true relevance.

The Effect of Cloth Price on Wages

We have earlier noticed that the wage model, because of the absence of non-rice agricultural goods prices in it, has placed on cloth price the role of representing prices of all non-rice goods (including industrial goods) which have 46.2 per cent weight in the consumption bundle during 1965-66 as quoted in Bose (1968). This weight, as we have argued in the foregoing subsection, should be taken as the likely figure but not as the "correct" one. This imposed importance is also reflected in the model estimates. The real cloth price (i.e. cloth price deflated by rice price) has a positive effect on nominal wage (of current year). The short-term elasticities of nominal wage to cloth price are 33.00 per cent and 23.02 per cent respectively in the first and the second model estimates. The long run elasticities of nominal wage with respect to cloth price are respectively 54.12 per cent and 46.00 per cent. This is in accordance with expectation because the cloth price, which represents here all non-rice goods, should have strong positive impact on wages. As per definition, both the short-term and the long-term elasticities of rice-wage are exactly equal to those of nominal wage. Since the long run elasticities are close to the likely weight of non-rice goods in the consumption bundle, remarkably then, any changes in non-rice prices are nearly offset by a corresponding change in nominal wage in the long run, so that the long run real wage would be rather unaffected. However, in the short run, any increase in non-rice prices causes the nominal wage to increase by only as much to compensate nearly half the loss in real wage, and likewise by the same reason, when non-rice prices decrease, the labourers would enjoy a windfall gain in real wage.

The above picture, in respect of effect on real wage due to changes in non-rice prices, appears to be just like the situation with rice price. However, in the case of non-rice goods, there is an important difference in respect of the effect on rice-wage. Here the rice-wage will continue to show, both in the short run and the long run, the *full* effect as implied by the relevant elasticity, because now the change in non-rice goods prices do not enter the denominator of rice-wage (like the case of rice when the change in rice price enters the denominator of rice-wage thereby creating an opposite effect). Thus an apparently curious thing may happen due to (say) 10 per cent increase in non-rice goods prices, when the long run real wage will be rather unaffected due to reasons given earlier, but the long run rice-wage will increase by 5.412 per cent or by 4.600 per cent according to whether the first or the second model is applied, and the same is exactly true for short run rice-wage increase.

Comparison of the Effects of Rice Price, Non-Rice Prices and Productivity

Apart from the differences mentioned above, it is to be noted that both rice price and non-rice prices have several similar effects on wages, both in the short run and long run, except that past prices of rice are also additionally relevant in the short run. Specially remarkable are the facts that the short run effects of rice or non-rice goods on nominal wage are less than the weight of the relevant commodity in the consumption bundle, while the long run effects are broadly equal to the relevant weights in the consumption bundle (which itself may change over the years in response to economic factors, changes in nutritional knowledge, tastes, habits, etc.). This would mean that the full effect is not instant or contemporaneous but needs quite some time for realisation. As a result, it may seem that the response of agricultural wages to prices is sluggish, or in other words, the agricultural wages are sticky. It is important to note here that this feature is not unexpected because the crop production needs some time to be completed. The wage stickiness is often cited for being responsible for various features of agricultural economy, but it needs to be reminded that wage stickiness is not a special peculiarity of agriculture, because it is also observed in many other sectors including the manufacturing and service sectors. Probably the "spread-over" response, which is implied by stickiness, is only peculiarly more visible for the case of price of labour (i.e. wage) than for other prices irrespective of the sector considered. Finally, one may want to know what would be the effect of introducing the prices of other consumption items into the present wage model that has only two items, namely, rice and cloth. Fortunately, from the above finding that both rice and cloth (representing all non-rice items in the present model) have quite similar effect on real wages, one may hope that any other consumption item would also share the same. This result assures one that introducing more consumption items into the wage model will not alter the basic nature of the model estimates or its implications.

Finally, one must note the most important property of the productivity term, namely, the elasticity of real wage is the same as that of nominal wage or rice-wage with respect to productivity — both in the short run and the long run. This property of the effect of productivity is not possessed by either the effect of rice price or non-rice prices. Therefore, whereas the long run real wage is rather unaffected by either rice price or non-rice prices, the productivity term shows the full effect on real wage in the long run as implied by the relevant elasticity. Especially this property of productivity provides hopefully a channel for raising the long run real wage, and it cannot be accomplished by other variables in the model.

V. CONCLUDING REMARKS

It is possible to infer some important conclusions from the present study. First, it shows that it is quite possible to implement the formulation and estimation of econometric models that can successfully test for the trickle down hypothesis. Secondly, the paper proves convincingly the validity of the trickle down hypothesis in Bangladesh agriculture, and shows that the trickle down effects of agricultural production are quantitatively important. Thirdly, per capita agricultural productivity proves to be the single most important channel for raising the long run real wage, which cannot be accomplished by any other variable in the model. In fact, the real wage can thus be raised in a sustained manner by raising per capita productivity, and the highest limit of real wage is bounded only by the highest attainable production implied by the technology and the relevant population. Fourthly, it is important to remember that, in order to raise per capita productivity, agricultural production needs to be increased at a *compound* rate higher than that of population, and if this does not happen, real wage will deteriorate. Fifthly, agricultural growth that raises demand for labour may be able to raise rural real wages and alleviate rural poverty even within the existing agrarian structure despite all its peculiarities. To the extent that higher productivity can alleviate poverty, it may appear that maintenance of harmony rather than alienation in the rural society is going to be in the best interests of the labouring class. Sixthly, anti-poverty policies should target rising prices, which have substantial unfavourable impact on welfare of labourers in the short run, but fortunately little or no such effect in the long run. This has been evidenced by the recent speculation-led food price inflation, which showed once more how critical the demand-supply balance of rice is and that Bangladesh is still a Rice Economy with rice as the prime price setter. Seventhly, this study lends support to the agricultural wage and other related data series, which has been the subject of much criticism in recent years, because of their successful role in the present econometric model. Finally, it may suggest the validity of the trickle down hypothesis for elsewhere in the world.

The wage models presented here show that per capita agricultural productivity has quite significant positive effect on both nominal and rice wages. The first and the second wage models estimate that the short term (within year) elasticity of nominal wage with respect to productivity are 42.89 per cent and 28.33 per cent respectively, while the long run elasticities are 70.34 per cent and 56.61 per cent. We have shown earlier that higher productivity should also generally mean higher employment and lower rice price. So higher productivity should lead to higher wage income, thus establishing both the existence as well as the importance of the trickle down effect, to which one should also add the effect of derived demand due to increased production. Therefore, the findings are that agricultural productivity has strong positive effects on all of the following: current nominal wage, long run real wage, real wage income, and total real income from all sources. This shows that the contribution of production on poverty is certainly positive.

As for the effect of prices, it may be noted that the commodity prices e.g. the rice price and the cloth price (representing all non-rice consumption goods) do not appear to affect the real wages appreciably in the long run. However, in the short run, they have substantial positive effect on the nominal wage, when the effect is somewhat less than proportional to the weight of the relevant commodity in the consumption bundle. This means, in the short run, that any increase in commodity prices leads to a fall in real wage, while any decrease brings the blessing of a windfall gain in real wage. It appears unlikely that introducing prices of other consumption items into the wage model would change the basic nature of the model estimates or the implications.

One may hope that the present findings would contribute significantly towards settling the debate on the trickle down effect, which had so far eluded its existence producing much controversy. The finding that the trickle down effect is quite strong, may have indeed very far reaching implications for agricultural policy, because now one can say with confidence that the New Technology of Green Revolution has not been immiserising as doubted by many. In addition, one may assert further that the New Technology can certainly be, as has been in the past, a very important instrument for rural poverty alleviation. However, agricultural productivity cannot be raised indefinitely because of certain technological limits that may not even be achieved due to various constraints. This points to the fact that increasing productivity alone, although helpful for poverty alleviation, would not be sufficient for poverty eradication which would necessitate other additional measures such as improving the agricultural terms of trade, creation of non-farm employment opportunities, encouraging industrial activities near rural areas, improvement of communication network, spread of education and health facilities, etc. In the end, it should be noted here that the trickle down hypothesis says nothing about the peasant class who might feel distressed despite increased production as has been documented in the Indian case of indebtedness related incidents caused by crop failure in the recent years. The above findings have obvious important bearing on the formulation of national policy for long term planning and short-term management of the economy.

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APPENDICES:

Appendix-1

The time trend was intended "to pick up any time-dependent omitted variables, such as population size" (B&R 1991, p.365), and the origin of time is taken to be "at about the mid-point of the data series, namely 1964/65 (so that t and t^2 are approximately orthogonal)" (p.366). They find that t drops out being statistically insignificant, so that the time trend finally consists of only ($-t^2$), whence they note, "the time trend is found to be concave quadratic" (p.369). Several observations can be made on these results. Our calculation shows that the quantitative contribution of the time trend variable is often comparable to that of any other variable. The effect of time trend declines from the year 1949 until about 1965 when it attains the minimum value zero and thereafter it has rising trend. In such a sort of time trend, the dominant factor must have been factors other than population, because population is expected to have monotonic effect, but the list of other dominant factors has not been explored. By relegating population to an "all catching" time-trend variable which is residual by nature, a known variable e.g. population has been unnecessarily mixed up with other unknown variables. It is apparent that the 'concave quadratic' nature has been imparted on the time trend by B&R's special choice of origin of time - particularly when the linear effect of time, i.e. t, is dropped because of statistical insignificance. This can be seen easily by taking the origin of time at the beginning of data series, when the time trend would become monotonous. This points to the problem with the idea of making t and t^2 orthogonal. There also seems to be a problem with the procedure through which t has been dropped from the model, where t and t^2 have been tested as if they were separate independent variables which they should not probably be regarded as far as the notion of a time trend term is entertained, because a linear time trend is actually nested within a quadratic time trend (which can still contain linear effect of t).

Appendix-2

Derivation of the equation (10) from equation (9) of the main text is as follows. The equation (9) of the main text is

$$\Delta w = g + (g_0 - 1)(w - p)_{-1} + (g_1 + k_3)p + (g_0 + g_2 - 1)p_{-1} + g_3 p_{-2} + g_4 p_{-3} + g_5 p_{-4} + \dots\dots\dots + k_1(q-n) + k_3(h-p) + (k_1 + k_2)n \quad (9)$$

Let the last three terms of the equation (9) be denoted by c to get

$$\Delta w = c + g + (g_0 - 1)(w - p)_{-1} + (g_1 + k_3)p + (g_0 + g_2 - 1)p_{-1} + g_3 p_{-2} + \dots\dots\dots \quad (16)$$

where the lagged p-terms extend backwards to infinity in time. Now all the p-terms on the right-hand-side can be put in difference form by subtracting suitable expression from the "target" p-term and adding the same to the next term. This process needs to be repeated on successive terms one by one. Thus proceeding from the above equation, one has finally the following equation expressed in differences up to the s-th lagged difference term of p, (i.e. up to Δp_{-s}):

$$\Delta w = c + g + (g_0 - 1)(w - p)_{-1} + (g_1 + k_3)\Delta p + b_1 \Delta p_{-1} + b_2 \Delta p_{-2} + \dots\dots\dots + b_s \Delta p_{-s} + Z_s \quad (17)$$

where $b_j = \sum_{0}^{s+1} g_i + k_3 - 1,$ for (j = 1,2,.....,s) (18)

and, $Z_s = (\sum_{0}^{s+2} g_i + k_3 - 1)p_{-(s+1)} + \sum_{s+3}^{\infty} g_i p_{-(i-1)}$ (19)

is the remainder term representing the sum of the remaining terms. Some properties and relationships that must hold for the above equation can be derived from the earlier equation (7) in the main text, which is now written as follows:

$w = c + g + g_0 w_{-1} + g_1 p + g_2 p_{-1} + g_3 p_{-2} + g_4 p_{-3} + ...$ (20)

For this equation, it will be generally true that w will be more closely related to (that is, explained by, or correlated with) the recent p_{-i} 's than the remote p_{-i} 's, (and note that this statement about the relationship has been empirically verified to hold true in the present case, which will be henceforth expressed by simply the word "Verified" on other similar occasions). This means that the absolute g_i 's will tend to decline progressively to zero, i.e. $\underset{i \to \infty}{Lt} |g_i| = 0,$ (Verified). Note further that equation (7) or (20) should also hold at stationary equilibrium, that is, when ($w = w_{-1} = \overline{w}$) and ($p = p_{-1} = p_{-2} = ... = p_{-\infty} = \overline{p}$) obtain, (where $\overline{w}$ and $\overline{p}$ denote the equilibrium values), so that equation (17) then reduces to the following relation at equilibrium:

$(1 - g_0)(\overline{w} - \overline{p}) = c + g + \overline{p}(\sum_{0}^{\infty} g_i + k_3 - 1)$ (21)

which gives the following expression:

$(\overline{w} - \overline{p}) = \{(c + g)/(1 - g_0)\} + \overline{p}\left\{\left(\sum_{0}^{\infty} g_i + k_3 - 1\right)/(1 - g_0)\right\}$ (22)

where c continues to denote its equilibrium value. Now if the equilibrium rice-wage is to be independent of the level of equilibrium rice price, the coefficient of $\overline{p}$ must be zero in the above expression of equilibrium rice wage, that is,

$\sum_{0}^{\alpha} g_i + k_3 - 1 = 0$ (23)

and, the long-run equilibrium rice-wage is given by

$(\overline{w} - \overline{p}) = (c + g)/(1 - g_0)$ (24)

The result of equation (23) ensures that the coefficients b_j's [as defined by equation (18)] of the equation (17) will generally tend to decline to zero as s tends to infinity, that is, $\underset{j\to\infty}{Lt}\, b_j = 0$, (Verified), and also that, for the equation (20), one will have $\sum_0^{\infty} g_i = (1- k_3)$ (Verified). These results will be used to find the limit of the remainder term Z_s. Next write $p_{-i} = (\bar{p} + e_{-i})$, where e_{-i} is the error term having usual properties. So the remainder term Z_s can be evaluated, in the limit, as follows:

$$\underset{s\to\infty}{Lt}\, Z_s = \underset{s\to\infty}{Lt}\, (\sum_0^{s+2} g_i + k_3 - 1)p_{-(s+1)} + \underset{s\to\infty}{Lt} \sum_{s+3}^{\infty} g_i p_{-(i-1)} \tag{25}$$

$$\text{or, } \underset{s\to\infty}{Lt}\, Z_s = \underset{s\to\infty}{Lt}\, (\sum_0^{s+2} g_i + k_3 - 1)p_{-(s+1)} + \underset{s\to\infty}{Lt} \sum_{s+3}^{\infty} g_i (\bar{p} + e_{-(i-1)}) \tag{26}$$

$$\text{or, } \underset{s\to\infty}{Lt}\, Z_s = \underset{s\to\infty}{Lt}\, (\sum_0^{s+2} g_i + k_3 - 1)p_{-(s+1)} + \bar{p}\, \underset{s\to\infty}{Lt} \sum_{s+3}^{\infty} g_i + \underset{s\to\infty}{Lt} \sum_{s+3}^{\infty} g_i e_{-(i-1)} \tag{27}$$

Here the first two terms are zero by virtue of results on the g_i's obtained earlier, and the third term is a sum of "zero-order multiples" of errors. By virtue of being weighted sum of errors, and further by virtue of the g_i's tending towards zero and finally vanishing to zero as *s* approaches to infinity, (where one should note that in the infinite series Z_s, one is letting even the lower limit tend to infinity), we know that Z_s will indeed approach towards 'insignificance', that is, tend to zero, (Verified). But formally speaking, this may not quite ensure exact limit to zero. To accomplish this, take "statistical expectation" of $(\underset{s\to\infty}{Lt}\, Z_s)$. Informally speaking, this procedure looks like 'shooting a dying animal', and thereby hastening the process of and ensuring death. Therefore, the expected value of $(\underset{s\to\infty}{Lt} \sum_{s+3}^{\infty} g_i e_{-(i-1)})$ is now equal to zero, because the expected value of each term in its further expansion is zero. So we have

$$E(\underset{s\to\infty}{Lt}\, Z_s) = \underset{s\to\infty}{Lt}\, E(Z_s) = 0 \tag{28}$$

That is, $(\underset{s\to\infty}{Lt}\, Z_s)$ is zero in the probability limit. Note that, at a less formal level, one might want to write $(\underset{s\to\infty}{Lt}\, Z_s = 0)$ empirically as an approximation even without taking expectation, but it would have been much less rigorous as compared to the derivation presented above, and moreover it would have been open to a host of questions. Therefore, the equation (17) above gives rise, in the limit, to the following equation:

$$\Delta w = c + g + (g_0 - 1)(w - p)_{-1} + (g_1 + k_3)\Delta p + b_1\Delta p_{-1} + b_2\Delta p_{-2} + ... + b_s\Delta p_{-s} + ... \quad (29)$$

Putting back the value of c and redefining the next two coefficients, one gets

$$\Delta w = a + a_0 (w - p)_{-1} + (b_0\Delta p + b_1\Delta p_{-1} + b_2\Delta p_{-2} + ...) + k_1 (q-n) + k_3 (h-p) + (k_1 + k_2)n \quad (30)$$

where the lagged Δp terms, (i.e.Δp_{-j}) terms, extend backwards to infinity in time. This is the equation (10) of the main text.

Appendix-3

The standard ECM is written in the following form:

$$\Delta w = g + (g_0 - 1)(w\text{-}p)_{-1} + g_1\Delta p + (g_0 + g_1 + g_2 - 1)p_{-1}$$

which contains a level term in p_{-1} on RHS that could be helpful in certain situations but prove problematic in others. We wanted to avoid it for a number of reasons. In the above standard ECM, one may note that Δw_t, $(w\text{-}p)_{-1}$ and Δp will be hopefully I(0), but p_{-1} will certainly be I(1). Thus while the LHS of the ECM is hopefully I(0), the RHS is I(1) because of p_{-1}. From the point of view of cointegration econometrics, this situation may be particularly dangerous which everyone might want to avoid. To see the problems from estimation point of view, consider a real life inflationary economy as in Bangladesh where prices have increased by nearly seventeen times over the present study period. Obviously, the coefficient of p_{-1} will not be stable in the sense that its estimates, if estimated separately for each subperiod, will vary over the subperiods within the study period. In particular, this may affect model predictability because of different price regime in the prediction period. For these reasons, our derivation of an ECM e.g. equation (10) has only Δp's and no p_{-1} on RHS.

Appendix-4

The two-stage modelling strategy has evidently more conceptual appeal than the single-stage modelling strategy for the full ECM. However, Harvey (1993, pp.295-6) gives the opposite suggestion from the estimation point of view. After some discussion, he writes the following:

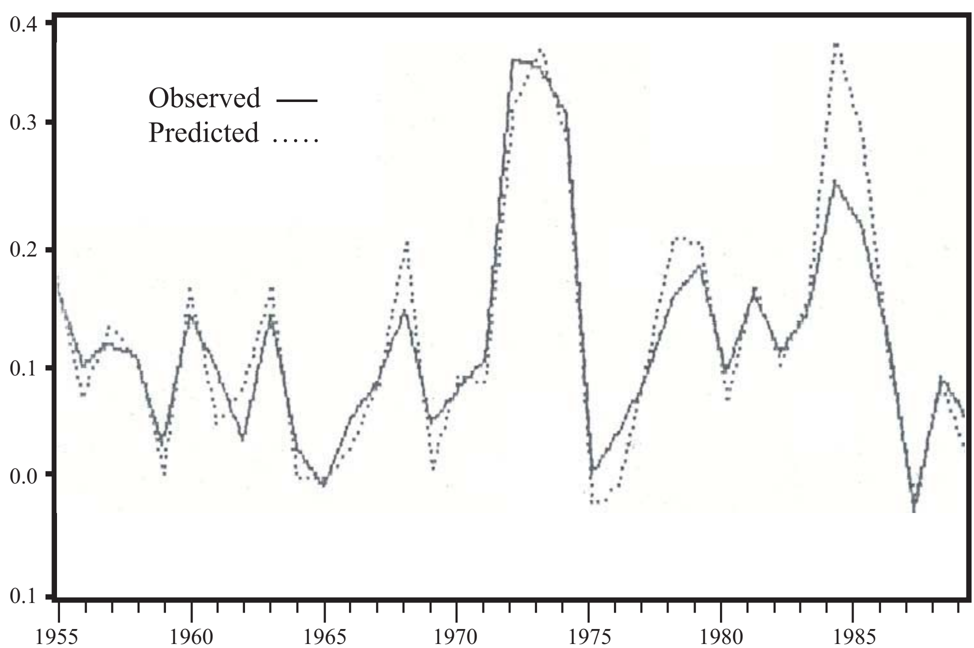
"The above results suggest a two-stage-modelling strategy which may be formalized as follows. Stage One: estimate the long-run parameters by running a static regression in levels; test the null hypothesis of no co-integration by a Dicky-Fuller test for a unit root in the residuals, or by one of the other methods described in Engle and Granger (1987, p.268); hence find a set of explanatory variables which form a co-integrating relationship with the dependent variable. *Stage Two*: use the error correction term, $\hat{z}_t$, that is the residuals from the static regression, as explanatory variable and estimate the short-run dynamics; test down to find a parsimonious dynamic structure. Applications of this strategy can be found in Engle and Granger (1987) and Hall (1986).

Unfortunately the two-stage procedure is not without its drawbacks. Although the OLS estimators in what is sometimes termed as the co-integrating regression converge very rapidly to their limiting distributions, these distributions are not normal and they depend strongly on the other parameters in the full model. Furthermore, the evidence presented in Stock (1987) and Banarjee et. al. (1986) shows that the bias in the estimators can be substantial, particularly in small samples. Thus inferences may be very misleading, and erroneous decisions can be made regarding variables to be included or restrictions to be imposed. At the second stage the bias in the estimators carries over to the error correction term and may adversely affect the small-sample properties of the short-run parameters. The conclusion is that the two-stage procedure is perhaps best viewed as an initial data exploratory tool, rather than as a formal modelling procedure."

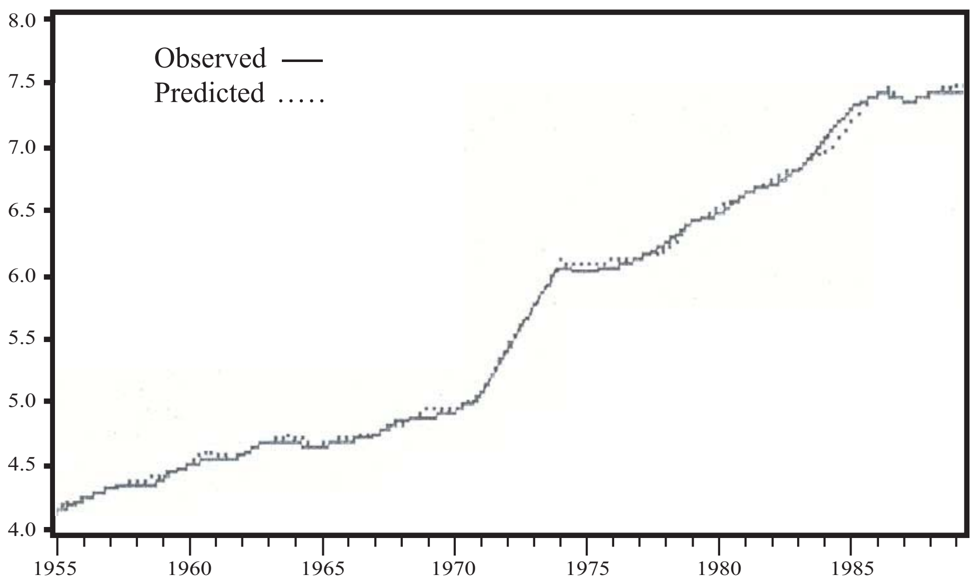
Appendix-5

Slightly higher levels of significance appear to have been employed in the present context by other authors, namely, Ravallion (1994) for the coefficients of two explanatory variables, namely, "lagged log price of cloth/rice" and "change in log manufacturing wage." Although his estimated values of the relevant coefficients appear to be correct, our calculation shows that for the above mentioned first variable, the t-ratio should actually be 1.93 (more exactly 1.9281) instead of 1.98 as shown in Table I of Ravallion (1994), and this would have a critical probability level i.e. p-value of 0.064. Surprisingly, we are unable to reproduce Ravallion's t-ratio of 1.98 (which would have a p-value less than the usual 5 per cent level), and this seems to be a reporting error arising from optical illusion by reading 8 for 3 in the last digit of the t-ratio, that means, reading 1.98 in place of 1.93. For the second explanatory variable mentioned above, the shown t-ratio is 1.96, which is correct but has a p-value of 0.059 that exceeds the customary p-value 0.05. Moreover, one cannot avoid using higher-than-5 per cent level in his model, because if the above mentioned first variable is dropped from the model, the performance of other variables worsens in the new model. However if only the above mentioned second variable is dropped, the performance of all variables (including the first mentioned variable) improves significantly, in the sense that all coefficients would be now significant at less than 5% level. It is interesting to note that if per capita agricultural productivity is employed instead of agricultural production in the model of Ravallion (1994) or in the new models as suggested in this note, the model performance remains almost similar, but thereby an added conceptual advantage might have been gained, because the supply of labour concomitant on population is captured by per capita productivity but not by production.

Graph 1.A: Observed and Predicted $\triangle w$ from Model 1



Graph 2.A: Observed and Predicted w from Model 1



Graph 3.A: Observed and Predicted (w-p) from Model 1