THE SPATIAL INTEGRATION AND PRICING EFFICIENCY OF THE PRIVATE SECTOR GRAIN TRADE IN BANGLADESH:

Pricing Analysis

JAYANTA DAS
SAJJAD ZOHIR
BOB BAULCH

September 1997

Report Prepared for DFID Project Number: ZB0025
Under RNRSS Crop Post-Harvest Programme

Bangladesh Institute of Development Studies (BIDS)
E-17 Agargaon, Sher-e-Bangla Nagar, Dhaka, Bangladesh
and
Institute of Development Studies (IDS), University of Sussex
Brighton, BN1 9RE, UK

ACKNOWLEDGEMENT

We like to express our sincere thanks to the following people for their participation and contribution to the study which immensely helped us in successfully conducting the research. Ms. Shanaz Begum, Deputy Director of Department of Agricultural Marketing, has helped us with price data and in making initial contacts for surveys. Dr. W.M.H. Jaim, Professor of Bangladesh Agricultural University, and a member of the Research Team has shared his findings on transfer costs and margins. We express our gratitude to Mr. Naser Farid, Assistant Chief of Food Policy Monitoring Unit, D.G. Food, for providing inputs to cleaning of price data and for his constant encouragement to make our exercise policy relevant. The financial support by Department for International Development (formerly ODA) of Britain is also gratefully acknowledged.

The Authors

TABLE OF CONTENTS

SPATIAL INTEGRATION OF FOODGRAIN MARKETS IN BANGLADESH: PRICING ANALYSIS

Section I. INTRODUCTION

Interest in foodgrain markets in Bangladesh has been commonly shared by all active parties; the policy makers, donors and the academia. While the obvious reason for such interest lies in the importance of foodgrain in production as well as in consumption, the subject also provides challenging grounds for innovative quantitative techniques. Moreover, the institutions evolving around the marketing of rice, that involves numerous agents spread throughout the country, has the potential to provide important insights into the problems and prospects of marketing in general. These prospects of exercises on foodgrain market are more alluring when the focus is explicitly on spatial market integration rather than, as has traditionally been the case, on a vertically linked market structure. The present paper however addresses only the issues related to price integration across various foodgrain markets in Bangladesh; and presents findings of the pricing analysis to suggest on the kind of changes that have taken place over the last ten years.[1]

Prices are perceived to be important signals that guide resource allocation in an economy. Within a single market, abstracted from any spatial dimension, a well-functioning market is expected to generate prices that truly reflect the scarcity values of the commodities under consideration. While a market for a commodity may be well functioning at any one place, it may not be well integrated with markets of the same commodity at other locations within a same country. Thus, price distortions are likely to arise at the spatial level, leading to resource misallocation at the national level. While this is true for all commodities, there is an added importance of the spatial integration of foodgrain markets in Bangladesh. It is the staple food in the country; and less integrated markets are more likely to cause localized scarcity even when there are abundant food supplies at the national level. Thus, efficient management of the food distribution system is aided by the presence of an well integrated marketing system. Moreover,

---

[1] The present paper is one of the several outputs of the first phase of a collaborative research between the Bangladesh Institute of Development Studies (Dhaka), Bangladesh Socio-Economic Research Team of the Bangladesh Agricultural University (Mymensingh) and the Institute of Development Studies (Sussex).

how prices are transmitted between markets and identification of important nodal points through which such transmissions take place, are important information for fine tuning policies.

The present exercise has been undertaken within this broader perspective with a view to contextualise the exercise, Section II reviews previous studies on the subject and outlines the policy background. One component of our study analyzed the price data for 14 important rice wholesale markets to verify if they are spatially integrated. The findings of this study are summarized in this paper. The 14 markets were chosen out of about 70 markets in the country wherefrom weekly prices are collected by the Department of Agriculture Marketing (DAM), Ministry of Agriculture. The set was chosen with a view to capture all major actors engaged in long distance trading in rice; and was done upon consultation with the DAM who collects the data, the Food Policy Monitoring Unit, Ministry of Food, who uses the data, and based on interviews with rice traders in a limited number of markets. Since data are not always available in customarized form for immediate processing, the details on their compilation are discussed in Section III.

The focus has been only on coarse variety rice processed from high yielding variety (HYV) paddy. Any further distinction in terms of quality differences within the coarse category, such as between plain and parboiled, could not be made due to the non-availability of such data. Analyses of the weekly price series, presented in Section IV, has a number of distinct, but interrelated focus. The once conventional statistics, such as bivariate correlations, are presented for the purpose of comparison with earlier studies. Since cointegration technique still dominates the literature on market integration, we apply these along with Granger causality tests; and the findings are presented in IV.2 to IV.4. Spurious regressions caused by the presence of non-stationarity in time series data is now well recognized. Thus, every possible available techniques were applied to identify the degree of non-stationarity (if any) in our data so that appropriate model specification could be followed in the exercises that pursued. These methods are however limited by the fact that they fail to account for efficient arbitrage condition; and therefore, analyses were done with the Parity Bound Model (PBM), the results of which are presented in IV.5.

Meticulous data compilation and extensive econometrics exercises underlie the results that are presented in this paper. In spite of our initial intentions, adequate analyses of wheat prices could not be possible since time series on its prices could be compiled only for four markets, and then also for five years. The options were wider for rice, the time series for which were compiled for nine years (1987-96). It was therefore possible to trace changes in rice market conditions over time. One obvious demarcation is in 1992 around when trade in both foodgrain and fertilizer were liberalized. It is our understanding that post-liberalization market prices are yet to stabilize in their long term path. However, a number of interesting results arise out of our exercise which will hopefully enhance our understanding about the dynamics of the market and market integration. These are summarized in Section V, along with their policy implications.

Section II. REVIEW OF STUDIES AND POLICY BACKGROUND

II.1 Review of the Previous Studies

There have been a number of studies on the Bangladesh rice market in the past. Most had focused on vertical marketing issues, primarily estimating marketing margins. A few of the studies however addressed the issue of spatial market integration. They include, Ravallion (1990), Ahmed and Bernard (1989), Chowdhury (1992), and Goletti and Farid (1993). We briefly outline their approach, data coverage and results with a view to setting the background of the current study.

Ravallion (1990) considered a dynamic model of spatial market structure that attempted to test simultaneously alternative hypotheses on "market integration" and "market segmentation". The model assumed a radial market structure where there exists a group of local (rural) markets and a single central (urban) market. Within such frame, trades with the central market dominate local price formation; and the central market price may be posited to be influenced by various local market prices. Ravallion aimed to assess the extent of market integration during the famine of 1973-74; and thus, he considered the period of July, 1972 to June, 1975, for which monthly district level (coarse) rice prices were analyzed. Dhaka was considered as the central market; while five rice surplus districts were considered as "rural hinterland": Mymensingh, Rangpur, Bogra, Dinajpur and Sylhet. The study results rejected the hypothesis of segmented markets, but the test on short-run integration of markets was inconclusive[2]. The latter was read to indicate presence of significant impediments to trade between Dhaka and the main rural supply areas in the north and north-west. Ravallion however noted that observed lack of market integration did not necessarily imply that the markets were non-competitive since government interventions may underlie such outcomes.

Ahmed and Bernard (1989) probed into market integration with a view to verify if adoption of an aggregate approach in modelling the price stabilization programme would be appropriate. Average price spreads across major urban centers were found to be higher during *aus* (18%) compared to *aman* season (15%). A higher marketing margin between any pair of markets did not necessarily lead to trade flows. They also found the proportion of marketing margin to rise with the rise in price levels which was read to suggest that traders tended to reap above-normal profit during such times. Ahmed and Bernard estimated correlation coefficients for 190 pairs of markets. The results indicated that *aus* rice markets were more integrated , only 48 coefficients were not significantly different from zero. Of these, Chittagong accounted for most (20). In contrast, 63 out of 190 coefficients were statistically insignificant in case of *aman* rice. Since the cases of insignificance were mostly found for pairs with Barisal, Patuakhali and Dinajpur, the authors identified concentration of production in " backward agriculture" to be associated with disharmony in price movement. Ahmed and Bernard also estimated the Ravallion model using monthly rice price data for 19 markets covering 1981-85 period. The hypothesis of segmented market was again rejected. It was not same for market integration, the extent of which was found to vary across seasons. The results were similar to those reflected in correlation coefficients; only 36% of the *aus* rice markets had weak intermarket linkages, while 74% of the *aman* markets were poorly linked.

Chowdhury (1992) rerun the Ravallion model with monthly price data for coarse rice in 64 district headquarters for the period July, 1985 to June, 1991. Similar to previous results, the exercise rejected the hypothesis of market segmentation. Inclusion of a seasonal dummy for the monsoon season did not however improve the results on market integration substantially as in the

2 Within the Ravallion model, market segmentation exists when the central market prices do not influence the prices of any one or more of the local markets (Ravallion, 1990).

case of Ahmed and Bernard. Such results were interpreted by Chowdhury to arise due to changes in the geography of the disposal of rice surpluses. While the role of Dhaka as the "central" market may have been true in earlier years, Chowdhury claims that the networks of rice market connections were becoming more diversified.

Goletti and Farid (1993) used various measures of market integration to identify non-price variables that promote or hinder market integration. The four measures of market integration considered were: correlation of price difference, cointegration coefficient, long term multiplier and a composite measure. The latter two were estimated from a dynamic adjustment model. Non-price variables that were included in a regression model to explain variations in the extent of market integration were, distance, paved road density, telephone density, bank branch density, number of strikes and shocks in production, and degree of dissimilarity in production. The study analyzed weekly price of coarse rice in 64 districts for the period July, 1989 to June, 1992. The extent of integration was found to be quite high. Market integration was found to be negatively affected by distance between markets and the number of strikes; and positively affected by the density of paved road, degree of dissimilarity in production, and the number of production shocks. Goletti and Farid had explicitly recognized the limitations of conventional measures of market integration in the presence of significant transportation cost. They attempted to partially reduce this by considering only those markets that are separated by a distance of less than 250 km.

In summing up, the studies on spatial market integration referred to above cover the early 1970's and the whole of 1980's until 1992. In a way, their results reflect changes in the dominant role of Dhaka in the wholesale rice market. All the exercises clearly reject the hypothesis of market segmentation. However, the results suggest of a gradual decline in the type of market integration captured by the Ravallion model. The problem, rightly identified by Chowdhury, lies in the model rather than in the markets. The assumption of a radial market structure with Dhaka as the "central" market is questioned. Such assertion calls for re-examining the relative role of various markets as well as to search for alternative model structure that may meaningfully address the issue of spatial market integration. A second important aspect raised in the literature (Goletti and Farid) is the limitation of conventional measure of market integration in the presence of significant transportation costs. While the procedure of excluding market links that are separated by great distance is one *ad hoc* way to address the problem; there are others which take more explicit account of transfer costs. One such approach, the parity bound model, is used later in this paper.

II.2 Overview of the Changes in Foodgrain Market in Bangladesh

Over the two decades in the 1970's and 1980's, foodgrain production in Bangladesh increased by almost 2.8 percent per annum; and subsequently, there had been impressive increase in the number of millers and traders engaged in processing and arbitraging between the producers and consumers. The changes in the foodgrain market during this period are well documented in the literature, especially by Chowdhury (1992, 1993). At the policy level, there had been gradual phasing out of subsidy in urban rationing, paving the way for increased role for private foodgrain traders. General policies on procurement and distribution continued; and importation of foodgrain remained under government control until the beginning of 1990's. All these years, attaining self-sufficiency in foodgrain production had been the stated policy goal. A two-digit growth rate in crop production during 1989-90 and good harvest in subsequent years led to optimism about the country's prospect of attaining self-sufficiency in rice production. During this period, there were several important policy changes which subsequently affected the domestic foodgrain market in ways that are yet to be fully comprehended. We outline these policy changes along with observations on the changes in the foodgrain market in this section.

Rural ("*Palli*") rationing that once accounted for half the PFDS (Public Food Distribution System) offtake[3], was suspended in December 1991 (and abolished in April 1992) due to alleged leakages ranging between 70% to 100% (Shahabuddin and Zohir, 1994). In the absence of alternative outlets, total PFDS offtake continued to decline throughout 1992 (Figure 1)[4]. The offtakes picked up only since the beginning of 1994, boosted up by increases in market prices as

---

[3] The Directorate of Food is a parastatal body which intervenes in the foodgrain market through procurement and distribution/supply. The latter is conventionally identified as "offtake", which are realized through various channels, such as, statutory rationing, open market sales, food for work program, etc.

[4] Rice offtake as percentage of total rice availability averaged around 3.82 percent during 1978/79 - 1992/93 period; and it was 64.84 percent for wheat. The corresponding figures reached 2.82 and 43.57 percents respectively for rice and wheat during 1992-93 (Shahabuddin and Zohir, 1994).

well as due to widening the coverage under the Food for Education (FFE) programme.[5]

The Bangladesh Government procures foodgrain from food aid sources, and through commercial imports and domestic procurement. Government monopoly over foodgrain import has been relaxed since August 1992. Private import of wheat commenced immediately and virtually led to the suspension of two PFDS channels, namely, the "Flour Mills" and the "Large Employers". The first imports of rice by private traders were in April 1994 when operative tariff rate of 7.5% was eliminated amidst high prices in the domestic market. Import decisions by the government in the past have repeatedly demonstrated lack of far-sightedness. Shahabuddin and Zohir (1994) mention of stock build up due to excessive import during 1987-88 and 1988-89. Public imports shown in Figures 2 and 3 also show that there had been imports of wheat over 300 thousand metric tons during May 1992 and import of rice during October 1992 that may hardly be justified in a situation of declining market prices in the domestic economy.

One important consequence of this was a massive build-up of stock in government food godowns, which reached the level of 1300 thousand mt. tons by July 1992 (Figure 4). While such high stock levels were previously compatible with high levels of procurements, this was no more so in the absence of some important PFDS offtake outlets. Thus, the stock build up subsequently led to sudden withdrawal of rice procurement during 1992 *boro* harvest season (Figure 5). Ignoring the recent sustained increases in procurement since the 1996, substantial declines in government procurement from the domestic foodgrain market since 1992 are visible from Figure 5.

The implications of the aforementioned sequence of government actions for the foodgrain market remain conjectural in the absence of more comprehensive probing. However, two effects may be hypothesized. First, that the pattern of wholesale rice marketing seems likely to have changed following the reforms of 1991-92. Such changes may, in part, have arisen due to changes in the relative roles played by various agents in the market and/or due to significant changes in their behavior with regards to price expectations. It is also widely acknowledged that many traders and millers incurred losses due to sudden withdrawal of procurement during the

[5] Data obtained from the FPMU source shows large offtakes through the Open Market Sales (OMS) channel during November-December, 1993, which essentially reflect the sale of rice from public stock by a Ministerial decision that had been widely criticized in the media.

1992 *boro* harvest. Late importers in 1996 are also said to have incurred losses. Huge losses faced by the latter group of traders and quick earnings by some others during early phase of private import of rice had implications for the relative roles played by agents in different regional markets. In the process, the once perceived central role of the Badamtoli market has been on decline; while trade linkages outside the country may occasionally turn out to be important. Second, wholesale rice prices in the domestic market have exhibited a more cyclical path (with a phase of about four years) since 1992 than in the 1987-1991. Such cyclical swings may be indicative of failure of temporal arbitrage in the rice market.

Section III. DATA SOURCES AND COMPILATION

This section describes the sources of data and the detailed procedure of compilation alongwith the methods that have been followed to interpolate the missing observations. In the first sub-section, the data sources are identified followed by the discussion in III.2 on how two different price series have been merged. Interpolation procedure for missing observations are discussed in the third sub-section.

III.1 Sources of Data

The Department of Agricultural Marketing (DAM), Government of Bangladesh (GOB), collects price information for different varieties of rice and wheat from 70 markets across the country. It collects weekly price information for different varieties (such as local and HYV) of *aman*, *boro*, and *aus* rice and different varieties of domestic and imported wheat. However, DAM does not distinguish between parboiled and non-parboiled rice. The district marketing officers collect the price information from each of these 70 markets every Wednesday.

Fourteen wholesale rice markets and six wholesale wheat markets have been selected for detailed pricing analysis in this study. This study has used the price series on HYV coarse rice, the most commonly consumed variety in Bangladesh, together with the price series for domestic wheat (which is comparable to US soft red winter variety). Each rice price series runs from the first week of December 1987 to the last week of November 1996 giving a total of 470 observations. Each wheat price series runs from March 1989 to March 1995 giving a total of 313 observations. The original price dataset for the fourteen selected rice markets contained no missing observations. However, the Barisal rice price series is not strictly comparable to the other series because it has local *aman* price information in place of HYV *aman* price during the aman season (November to March each year). The original dataset for six selected wheat markets has a large number of missing observations for Chittagong and Jessore. Jessore has 164 missing observations whereas Chittagong has 291 missing observations out of 313. Hence, Jessore and Chittagong had to be dropped from our subsequent pricing analysis. The other four wheat markets have only few missing observations, in 6% to 10% cases, which we have interpolated.

III.2 Procedure Used to Merge Rice Prices into a Single Series

DAM combines the HYV *aman* price series and the HYV *boro/aus* price series into one - using the HYV *aman* rice price from weeks 21 to 44 for the current fiscal year (July- June), and the HYV *boro/aus* price from week 45 to week 20 of the current and next fiscal year. However, such sudden switches from one variety of rice (say, *aman*) to the newly harvested variety (say, *boro/aus*) as practiced by DAM, are likely to result in price discontinuities. In order to smooth out such discontinuities, the *aman* and *boro/aus* price series have been merged using linear weights.

The raw DAM rice price dataset has price information available for both *aman* and *boro/aus* for the "transition weeks" i.e., from weeks 20 to 22 (the weeks when *aman* arrives at the market) and from weeks 43 to 45 (the weeks when *boro* arrives at the market). However, some of the observations on *aman* during the weeks 20 to 22 and some of the observations on *boro* during the weeks 43 to 45 are missing. For these two periods, relative prices of *aman* to *boro* were calculated for the weeks where both the prices were available. The missing relative prices were interpolated to get a complete set of relative prices. The procedure used to interpolate these missing relative prices are explained in the next sub-section. Then the missing *aman* prices were calculated by multiplying the relative price of *aman* to *boro* by the *boro* price. The missing *boro* prices were calculated by multiplying reciprocal of the relative price by the *aman* price.

Using a set of linear weights to the *aman* and *boro/aus* prices over the weeks 20 to 22 and 43 to 45, two price series have been merged into one. The weights are shown in the Table III.1 The basic logic of using this set of weights reflects the availability of the type of rice in the market. In week 19, almost no *aman* rice is available in the market; thus the whole weight goes to *boro* which is available. In week 20, as some *aman* rice arrives in the market, a low

Table III.1 Weights used to merge two price series

WEEK	AMAN WEIGHT	BORO WEIGHT	COMBINED
1-19	0	1.0	BORO
20	0.25	0.75	MERGED
21	0.5	0.5	MERGED
22	0.75	0.25	MERGED
23	1.0	0	AMAN
24 - 42	1.0	0	AMAN
43	0.75	0.25	MERGED
44	0.5	0.5	MERGED
45	0.25	0.75	MERGED
46 - 52	0	1.0	BORO

weight (0.25) is put on *aman* price. In week 21, as even more *aman* rice becomes available, a little more weight (0.5) is put on it. Proceeding this way, in week 23, zero weight is put on *boro* rice as it is no longer available in the market by then. Similar reasoning applies for the transition between *aman* and *boro* in week 43 to week 45.

The Barisal rice price series posed another problem because HYV *aman* rice price is not available for this market. DAM uses the local *aman* price in place of HYV *aman* price for the weeks 21 to 44 to make the series complete. However, since local *aman* is perceived to be superior to HYV *aman* in quality and normally sells at a higher price, it is not strictly comparable to the price of HYV *aman* for other markets. In order to construct a pseudo Barisal HYV *aman* price series from the available local *aman* price series, the price information from an adjacent market, Bhola, have been used. The details of the procedure used can be found in the Appendix-III.1.

III.3 Procedure Used to Interpolate Missing Observations

The original DAM dataset for rice prices for the fourteen selected rice markets has no missing observations. However, the wheat price dataset for the four selected wheat markets have some missing observations. The number of missing observations for Dinajpur were 21, for Bogra 23, for Dhaka 33, and for Narayanganj 23. These missing observations were then interpolated using the average price of the adjacent weeks for a particular week. Interpolating the missing observations are necessary due to the fact that most of the models that are estimated in our study involves some kind of lag structure and hence estimation with missing observations is problematic.

Even if the original DAM rice price series for the fourteen selected markets have no missing observations, some of the transition week prices are missing from their raw data files. Hence, a complete set of relative price of *aman* to *boro* was not available to merge the *aman* and *boro* series into one. Out of total 54 transition weeks (6 weeks per year for 9 years of sample), the following are the number of missing information for the selected markets: 18 for Dinajpur, 5 for Bogra, 38 for Naogaon, 27 for Jessore, 24 for Khulna, 16 for Barisal, 32 for Sherpur, 23 for Dhaka, 18 for Narayanganj, 36 for Sylhet, 12 for Chandpur, 12 for Choumuhani, 25 for Chittagong, and 26 for Bhairab Bajar. To interpolate the missing relative price for a specific week, relative price of an adjacent week from the same market have been used. If there still exist some gaps, the average of the two adjacent weeks' relative price is used to interpolate those gaps.

In this section, the data sources, the compilation procedure, and the methods to interpolate the missing observations have been explained in detail. The final datasets for rice and wheat that will be used for the pricing analysis in the subsequent sections contain 470 observations for fourteen wholesale rice markets and 313 observations for four wholesale wheat markets.

Section IV. THE SPATIAL INTEGRATION OF FOODGRAIN MARKETS

In recent years, there has been a veritable explosion in the literature concerning testing for the integration of agricultural markets in developing countries. Studies in the 1960s and 1970s would have relied on conventional methods of price analysis, such as bivariate correlation coefficients and static tests of the law of one price, have now been swept-up in the rapidly emerging time series literature. The new tests for market integration that have been proposed allow issues such as the influence of common trends, simultaneous price determination, discontinuities in trade flows, and the extent and speed of price adjustment to be assessed. To date, these new test approaches have not been applied to agricultural markets in Bangladesh. The purpose of this section is therefore to apply these new techniques to assess the spatial integration of foodgrain markets in Bangladesh.

IV.1 Correlation Coefficients

Some of the very earlier studies (Farruk 1972) on food market integration used correlation coefficient statistics as a measure of market integration, which is now widely discredited.[6] The critics of this method point at the presence of other synchronous factors such as general price inflation, seasonality, population growth, and public procurement and distribution policy. Blyn (1973), and Harriss (1979) correctly note that bivariate correlation coefficients will be biased upward due to the existence of common trends and seasonality in price data . Thus, measures of correlation coefficients may suggest of high market integration even when there is, in reality, little arbitrage between markets. A reverse situation may arise when the transfer costs between any two markets is high or if there are seasonal reversals in trade flows. Under any such circumstance, the markets may be well integrated spatially, and yet, observed correlation between the two price series could be low. One way to take care of the former criticism is to consider correlation of price differences. The modern econometrics literature has taken this argument further in noting that the regression results are spurious when price series are non-

[6] Correlation coefficients were also used in the early structure-conduct-performance studies of food markets in India and West Africa by Lele (1967) and Jones (1968).

stationary. While the recent techniques for testing market integration are pursued in subsequent sections, results based on bivariate correlations between prices (at both levels and first differences) are discussed in this section.

There are 91 bivariate links across 14 markets; and the correlation coefficients for price levels for rice ranged between 0.68 and 0.93. Except for correlations involving Barisal, most other coefficients were above 0.80. When compared across three different periods, only 32 out of the 91 coefficients were found to be above 0.75 for 1987-90 period, which increased to 77 for 1990-93 period and 87 for the 1993-96 period. Again, if one left aside Barisal, the last two periods do not have any difference. Prolonged deflationary trend during 1992-94 followed by an inflationary trend during 1994-96 may partly explain the increase in price correlation during the last two periods. Significant improvements in road infrastructure during late 1980s and early 1990s may explain the rest.[7]

However, given the earlier mentioned problems associated with the use of bivariate correlations at levels, it is not appropriate to make any inference based on the results reported above. Instead, we discuss the bivariate correlation coefficients of the price series in their first difference. The findings are presented in summary form in the Appendix-IV.1 to reflect whether the coefficients are significantly different from zero. For the 9 years period (1987-96), the value of bivariate coefficients ranged between 0.07 (Narayanganj-Sylhet) and 0.48 (Narayanganj-Chandpur). The associations between first order price differences across all pairs of markets except those involving Barisal were found to be significantly different from zero at 1% level of significance. At 1% level of significance, the sole exception was in case of Sherpur and Chittagong.[8]

Estimation of bivariate correlations for sub-periods reduce the degrees of freedom, and thereby, raises the chance of an estimated coefficient to be statistically insignificant. This is well reflected in our presentation in the Appendix-IV.1. However, since the number of observations

[7] In the case of wheat, price series for four markets were available for the period 1989-94. Bivariate correlation coefficients for nominal wheat prices ranged from 0.65 to 0.82.

[8] As for wheat, the correlation coefficients for price changes ranged between 0.10 and 0.18. Of the four markets considered, Dinajpur price changes were found not to be significantly related with other market prices except Dhaka. In contrast, Narayanganj price changes were significantly associated with price changes in Dhaka and Bogra.

are same for each of the sub-periods, one may compare the statistics estimated. It is found that a larger number of the coefficients are significantly different from zero during the first sub-period than the latter two periods. The only exception is Naogaon, in which case association with price changes in other markets have increasingly become significant. In contrast, Chittagong, Bogra, Sylhet and Narayanganj are some of the markets where such associations have diminished over time. Price changes in Barisal remain to be less significantly linked with price changes in other markets.

Plausible explanation of low association between price changes in Barisal and Chittagong markets with price changes in other markets may lie in specific taste of the population in these areas. We had noted that local aman produced in Barisal remains the dominant staple of the population in that area. And, it is only during shortfalls, HYV coarse rice flows into the area. Chittagong also happens to have a revealed preference for non-parboiled rice, even though this rice may be of coarse variety. Such specificity in taste, and absence of variety-specific price data may be reflected in low association between price changes involving these markets.

Another explanation may lie in the greater frequency of unanticipated price changes during the second two sub-periods as compared to the first one. It is quite possible that expectation formations are yet to stabilize in the post-liberalization period; and thus association between contemporaneous price changes may be less significant. This however does not suggest that markets are less integrated than before. It is quite possible that there have been shifts in important nodal points in the whole rice marketing system, and thus, with price series for a single set of markets, price associations may often be found to decline[9]. More importantly, regulated markets that are poorly integrated may show a greater degree of contemporaneous price association compared to a set of unregulated markets that are well integrated. Such issues may be more adequately addressed upon taking account of lags in price transmission; and this is pursued in later sections.

---

[9] Decline in the relative importance of Dhaka (as the "central") market has already been noted in section II.

IV.2 Stationarity and Cointegration

Testing whether the price series is stationary or non-stationary is important because if the data is non-stationary, then regressions run in levels will lead to spurious results[10]. OLS estimation involving non-stationary data is not valid because of spurious results. For stationary series, standard OLS estimation procedure is valid. If series are non-stationary (i.e., they contain a "unit root"), estimation techniques involve making it stationary first. However, if two or more non-stationary series are also cointegrated, the most appropriate technique for estimation involves an error correction mechanism. Thus, to decide the most appropriate estimation model, knowledge of stationarity or non-stationarity of the series is a prerequisite.

To test the univariate price series for stationarity, two different procedures were used: the Augmented Dickey-Fuller test, and the Kwiatkowski test. The procedure used to test each series together with the results are discussed below.

Augmented Dickey-Fuller (ADF) Test

For serially correlated observations, to test the null hypothesis of non-stationarity, the standard equation for the ADF test takes the following form:

$$\Delta P_t = \mu + (\alpha - 1)P_{t-1} + \sum_{i=1}^{n} \gamma_i \Delta P_{t-i} + u_t \qquad (1)$$

where P_t is the price series to be tested, μ is a constant, and u_t an independent and identically distributed (i.i.d) error term. The t-statistics on $(\alpha - 1)$ is then used to test the null hypothesis that the coefficient is equal to zero, i.e., $\alpha = 1$, which implies that the series, P_t, is non-stationary. In this equation, the number of lag, n, is determined by the Akaike Information Criterion (AIC). The results of the ADF test (without trend) applied to the wholesale rice and wheat price series for selected markets in Bangladesh are shown in the Table IV.1 and IV.2 respectively.

The ADF tests were performed both on the original and first differenced series without a time trend, since time-plots of the weekly series reveal no obvious trend. The ADF tests on the original rice price series are reported in the second column of Table IV.1 show that eight out of

[10] For a non-stationary series, a shock would leave a permanent effect on the level of the series whereas if it is stationary, the effect of any shock would wear off with the passage of time. Estimation procedure also varies for stationary and non-stationary series.

fourteen rice price series are non-stationary at the 5% level and all but one series (Bogra) are non-stationary at the 10% level. Then the ADF tests were performed on the first differenced series, where the null hypothesis is that the original price series are integrated of order 2 or higher (against an alternative that the series are I(1)). These results, shown in column 3 of the Table IV.1, indicate that the null hypothesis could be rejected at the 1% level for all price series. Based on overall findings it can be concluded that most of the fourteen series are non-stationary. The second column of Table IV.2 shows that only two out of four wheat price series are non-stationary at the 5% level. And the null hypothesis of original price series are integrated of order 2 or higher is rejected at the 1% level as can be seen from the third column of Table IV.2.

Table IV.1 Augmented Dickey-Fuller Tests for Rice Price

Null Hypothesis	RICE	
	I(1)	I(2)
Barisal	-2.63*	-9.16***
Bhairab Bazar	-3.64***	-11.43***
Bogra	-2.53	-9.66***
Chandpur	-2.95**	-11.07***
Chittagong	-2.69*	-13.39***
Choumuhani	-2.96**	-12.59***
Dhaka	-3.07**	-12.04***
Dinajpur	-2.83*	-11.20***
Jessore	-2.85*	-13.51***
Khulna	-2.89**	-8.87***
Naogaon	-2.80*	-11.99***
Narayanganj	-2.81*	-9.88***
Sherpur	-3.19**	-9.91***
Sylhet	-2.86*	-13.49***

Note: ADF critical values for sample size 470 observation are: - 2.57 at 10%; - 2.87 at 5%;and - 3.43 at 1% with constant but no trend included. Asterisks indicate the level of statistical significance at which the null hypothesis of unit root can be rejected: *** stars for 1% level; ** for 5% level; and * for 10% level.

Table IV.2 Augmented Dickey-Fuller Tests for Wheat Price

Null Hypothesis	WHEAT	
	I(1)	I(2)
Bogra	-2.62*	-8.15***
Dhaka	-2.28	-8.46***
Dinajpur	-3.12**	-10.32***
Narayanganj	-3.415**	-6.29***

Note: ADF critical values for sample size 470 observation are: - 2.57 at 10%; - 2.87 at 5%; and - 3.43 at 1% with constant but no trend included. Asterisks indicate the level of statistical significance at which the null hypothesis of unit root can be rejected: *** stars for 1% level; ** for 5% level; and * for 10% level.

Kwiatkowski Tests

A number of recent studies (Banerjee et al. 1992) have reported that the standard ADF tests are not very powerful against the relevant alternatives (such as mean-reverting autoregressive processes with roots near unity) and often incorrectly fail to reject the null hypothesis of non-stationarity. So, to double check the results from the ADF tests reported above, the Kwiatkowski tests were performed to check the non-stationarity of the price series. In contrast to the ADF test, this tests a null hypothesis of stationarity against the alternative of non-stationarity. To calculate the test statistic, one regresses the price series on a constant (in the case of level stationarity), or on a constant plus a time trend (in the case of non-stationarity), and calculates the LM statistic from the residuals from that regression. No trend term was included in the test, so the null hypothesis was one of level stationarity.

The results of the Kwiatkowski test for rice price are shown in Appendix-IV.2 for a series of lag truncation parameter. The computed test statistics for each of the 14 rice price series and 4 wheat price series are all higher than the critical value at the 1% level. Hence the null hypothesis of stationarity can be strongly rejected in favor of non-stationarity for all the 14 rice and 4 wheat price series under consideration[11].

Based on the above findings from the ADF and Kwiatkowski tests, all the 14 rice price

11 Also note that the reported test statistics are not very sensitive to the number of lags that are used - all being quickly settled only after first lag.

and 4 wheat price series can be regarded as non-stationary. Hence, standard OLS regression techniques, if applied to the variables in levels, will lead to "spurious regressions" unless the series are also cointegrated. In the next sub-section, cointegration between combination of these series is therefore examined.

Cointegration Tests

If two or more series are individually non-stationary but there exists a linear combination of them which are stationary, then they are said to be cointegrated. Cointegration among a few series imply that there might be some long-term equilibrium relationship among these variables. A long-term equilibrium relationship entails a systematic co-movement among variables which an economic system exemplifies precisely in the long term. Cointegration may be present between just two variables or among more than two variables. Both bivariate and multivariate cointegration results are reported next.

Engle-Granger Bivariate Cointegration Tests

The Engle-Granger cointegration test can be carried out in two steps. The first step involves the OLS regression of one I(1) price series on another I(1) price series plus a constant:

$$P_{i,t} = \alpha + \beta P_{j,t} + u_t \qquad (2)$$

where $P_{i,t}$ = price in market i, $P_{j,t}$ = price in market j. This is known as the "cointegrating regression". Optimum lag length in the cointegrating regression was determined by AIC. The second step involves testing whether the residuals, u_t , from the cointegrating regression are non-stationary using the ADF test described above. If the residuals are stationary, then the two series are said to be cointegrated.

Every possible pairwise combination of markets were tested for cointegration by treating every market as the dependent and independent variable in the cointegrating regression. So, a total of 182 pairs of markets were tested for cointegration[12]. The null hypothesis of no cointegration between rice price series could be rejected for all 182 possible market pairs at the 1% level except for the case where Choumuhani was the independent variable and Chandpur was the dependent variable. In this case, the null could be rejected at the 5% level. For wheat prices, the null hypothesis of no cointegration could also be rejected at the 1% level, except for the case where Bogra is dependent variable and Dinajpur is independent variable. For this case the null could be rejected at the 5% level.

These results show that there is strong evidence that all of the price series (both for rice and wheat) are cointegrated on a pairwise basis indicating a long-run relationship between them. In addition to this, these results also imply that the most appropriate estimating equation to use in test for the Law of One Price (LOP) is an error correction mechanism.

Johansen's Multivariate Cointegration Test

This is a procedure for testing for cointegration in a system of variables. The null hypothesis is the existence of a specific number of cointegrating relations (say, h) among the variables (say n) in the system. The alternative hypothesis is the existence of n cointegrating relations, where h could be less than or equal to n. This approach allows us to test for the number of cointegrating relations in a system of variables. The meaning of having h cointegrating relations is that it is possible for h variables out of maximum of n to jointly determine the long-run evolution of the dependent variable. Put differently, this means there exists h linear combinations of the variables which are stationary.

The Johansen test involves the application of a standard likelihood ratio test in three steps: (i) estimating the unrestricted system (Vector Auto Regression (VAR)) under the null hypothesis (that there are exactly h cointegrating relations in the system); (ii) imposing the

---

[12] There is no reason why price in market i should only be treated as dependent variable. It could also be that price in market j appears on the left hand side of the regression equation. However, the cointegration test results would not be the same for both cases, as we know that the coefficients estimated from a reverse regression is not the reciprocal of the coefficients estimated from forward regression. So, the choice of which market is dependent variable in the cointegrating regression may affect cointegration test results.

restriction that there are n cointegrating relationships among the elements of the system and re-estimating the VAR under this restriction; and (iii) measuring the loss of likelihood resulting from the imposition of the restriction. The loss of likelihood is measured as the fall in the value of the restricted eigenvalues (λ^*_i) relative to their unrestricted value (λ_i). The validity of the restriction is then tested using the likelihood ratio test:

$$2(\mathcal{L}_A - \mathcal{L}_O) = -T\sum_{i=h+1}^{n} \ln\{(1-\lambda_i^*)\backslash(1-\lambda_i)\} \tag{3}$$

where $\mathcal{L}_A$ is the largest value of log-likelihood function in the absence of any constraints, $\mathcal{L}_O$ is the largest value of log-likelihood function under the constraints, and T is the number of observations. The LR test statistics is distributed as χ^2 with r(n - h) degrees of freedom where r is the rank of the unrestricted eigenvector matrix. The optimum number of lags to include can be determined by the Akaike Information Criterion (AIC).

Test statistics for eleven null hypotheses of three (i.e., h = 3) cointegrating relationships to thirteen (i.e., h = 13) cointegrating relationships were calculated using a constant and no time trend for rice-price series. For wheat price series, 3 null hypotheses starting from one (i.e., h = 1) cointegrating relationship to three (i.e., h = 3) cointegrating relationships were also calculated using a constant and no time trend. The results alongwith the appropriate critical values are reported in Table IV.3. According to AIC, the optimum number of lag for rice was 1 whereas that for wheat was 4.

From Table IV.3, 10 out of the 11 null hypotheses for rice could easily be rejected at the 1% level except when h = 12 which could be rejected at the 5% level. For example, the test statistics for the null hypothesis that there are 13 cointegrating relationships in a VAR(1), (H_0 : h = 13) is 6.97. For h = 13, the 1% critical value for Johansen's test is 6.40 (Osterwald-Lenum, 1992). Since our computed test statistics, 6.97, exceeds that critical value, the null hypothesis of 13 cointegrating relationships is rejected at the 1% level in favor of the alternative hypothesis of 14 cointegrating relationships. Similarly for wheat also, 2 out of 3 null hypotheses could be rejected at the 5% level. Only the null hypothesis of one cointegrating relationship (h = 1) can be rejected at the 1% level.

Bivariate Engle-Granger cointegration tests show that the long-run relationship exists between all the possible pairs of markets both for rice and wheat. Multivariate Johansen cointegration tests show that the pairwise cointegrating relationship are consistent with each other indicating that the wholesale rice and wheat markets in Bangladesh are functioning together as a single system and that there is no evidence for independent regional price formation.

Table IV.3 Johansen's Multivariate Cointegration Test

Number of Cointegrating Relationships (h)	LR Test Statistic
RICE	
13	6.97***
12	22.45**
11	46.81***
10	74.04***
9	114.27***
8	159.24***
7	210.29***
6	263.16***
5	330.26***
4	400.43***
3	477.12***
WHEAT	
3	6.23**
2	21.44**
1	41.15***

Note: Asterisks indicate the level of significance at which the null can be rejected- *** for 1% level, ** for 5% level.

IV.3 The Law of One Price (LOP)

The Law of One Price (LOP) is one of the most straightforward tests for market integration. It states that price of a homogenous commodity in one place should differ from the price in another place by only transfer cost if the markets are integrated. This is also known as equilibrium arbitrage condition. If the markets are not integrated, the price differential may be more than the transfer cost. The test is very simple involving a simple linear regression of current price in one market, P_{it}, on a constant term and price in another market, P_{jt}.

$$P_{it} = \alpha + \beta P_{jt} + u_t \tag{4}$$

The test is performed by checking whether the null hypothesis of $\beta = 1$ holds or not via a simple t-test. If the null hypothesis is rejected, the LOP is also rejected[13].

If the price series involved in above regression (2) are each non-stationary but cointegrated, then following the Granger representation theorem, the most efficient way of estimating the LOP identity will be in its error correction form. The restricted error correction form is shown in

$$\Delta P_{it} = \alpha + \beta \Delta P_{jt} + \gamma \hat{u}_{t-1} \tag{5}$$

where $\hat{u}_{t-1}$ is the lagged residuals from cointegrating regression (4), which is known as "the error correction term".

The Law of One Price may be estimated using either the original prices or their natural logarithms. If the original prices are used, absolute marketing margins are assumed as the maintained hypothesis. On the other hand, if natural log prices are used, the maintained hypothesis is one of proportional marketing margins. The LOP was estimated using equation (5) and prices expressed first in original and then natural logs using weekly rice and wheat prices described in section II. The null hypothesis that $\beta = 1$ in equation (5) could be rejected at the 1% level for rice and wheat for all possible market pair for both original and log prices.

This clear rejection of the LOP raises two immediate questions concerning foodgrain

---

13 However, if price transmission is presumed to take few time periods to be completed, one can use lagged version of LOP such as $P_{it} = \alpha + \beta P_{j,t-k}$ where k is the appropriate lag number.

markets in Bangladesh. First, whether the wholesale rice and wheat markets in Bangladesh are far from being integrated, and whether testing procedure are biased against the LOP? Baulch (1994) argues that the null hypothesis of the LOP is an inappropriate test for market integration if the trade flows are discontinuous between markets and when the transport costs between markets are significant. Hence, LOP may not be the most appropriate way to measure market integration.

The LOP as a measure of market integration may also be criticized on several other grounds. First, it cannot account for price transmission between markets. If the information does not flow from one market to another instantaneously, the LOP will be rejected. This discussion indicates that LOP will be satisfied more often if we allow sufficient time (2 to 3 weeks) for price information to flow from one market to another. So, the poor performance of LOP may also be due to the fact that it assumes the trade to be completed instantaneously. Second, expectation of higher future prices in the destination market and the possibility of storage makes the LOP to be less likely to hold between markets across the same period. For example, Williams and Wright (1991, p 229) show that possibility of storage can weaken the LOP.

IV.4 Granger Causality

This section discusses the results of bivariate Granger causality, long-run multipliers, Vector Error Correction Model (VECM), and block exogeneity tests. Unlike the LOP, these tests allow for price transmission between markets to take time and allows one to analyze the issue of how prices are determined. In particular, bivariate Granger causality tests allow one to assess whether foodgrain prices are simultaneously determined or whether certain markets occupy positions of price leadership. Block exogeneity tests allow one to assess whether prices are formed on a regional or national basis.

Bivariate Granger Causality

Granger causality tests measure whether the information on a variable, present or past, can help improve the forecast of another variable. If it does, the former variable is said to Granger cause the latter. In our context, we examine whether the price series in one or more markets Granger cause price series of another or another group of markets thereby indicating whether prices are jointly or independently determined. To test for Granger causality between market i and market j, the following specification were used

$$\Delta P_{i,t} = \alpha_0 + \sum_{k=1}^{n} \alpha_k \Delta P_{i,t-k} + \sum_{l=1}^{m} \gamma_l \Delta P_{j,t-1} + u_t \qquad (6)$$

where the suitable number of lags for two series are determined via Akaike Information criterion (AIC). The null hypothesis of this test is of non-Granger causality (i.e., $\gamma_l = 0$ for all l) while the alternative hypothesis is Granger causality. So, rejection of the null hypothesis indicates that prices in j-th market Granger-cause prices in market i. Two sets of this test for each pair of market is possible taking each market as dependent variable. If prices in market i Granger-cause prices in market j and prices in market j Granger-cause those in market i, this indicates that prices in two markets are simultaneously determined.

Estimation of 182 possible pairs of markets (taking each market as dependent and independent variable) for rice were performed and the results indicate that the null hypothesis of non-Granger causality could be rejected for all possible market pairs at the 5% level. This bidirectional Granger causality provide further evidence that rice prices in the fourteen markets in our study are simultaneously determined. Estimation of 12 possible pairs of markets for wheat were also carried out and the null hypothesis of non-Granger causality were rejected for all pairs at the 5% level. In line with our findings for rice markets, it is found that wheat prices in the four selected markets are also simultaneously determined.

To assess the extent of price integration, long-run multipliers (LRMs) were calculated from the error correction version of equation (6) for all pairs of markets using the Bardsen transform. LRMs indicate the proportion of a price change in one market that is passed on to another market after a given number of lags. For example, a LRM of 0.8 with a lag structure of 5 would indicate that only 80% of the price change in one market is , on average, passed on to the other market after five periods. To be consistent with the Law of One Price (and also the Ravallion's 1986 model), LRMs should be close to one. However, for the 182 pairs of rice markets considered in this analysis, 131 of the LRMs were less than 0.9 and 96 less than 0.85, all with a lag structure of 2 periods. In contrast for the 12 pairs of wheat markets for which data is available with a three period of lag structure all LRMs were in the 0.97 and 0.98 range indicating a high degree of price co-movement. Taken together with the clear rejection of the LOP in section IV.3 above, these LRMs indicate that perfect price co-movement should not be anticipated, either in the short or long-term, in Bangladesh rice markets. For wheat, the evidence is more mixed but it is appropriate to remind readers that the sample of wheat markets considered is, for reasons of data availability, very restricted.

For rice, it has also been possible to estimate LRMs for the two periods: December 1987 to December 1990, and December 1993 to November 1996, which may be thought of as the pre-liberalization and post-liberalization periods. The average long-run multipliers between the 182 pairs of markets under consideration rose from 0.50 in 1987-90 to 0.81 in 1993-96 indicating that price changes have been communicated much more efficiently in the post-liberalization period. The reasons for this improvement in pricing efficiency, which are mirrored by improvements in the overall level of market integration, are discussed in more detail below.

VECM and Block Exogeneity

A multivariate generalization of Granger causality tests is feasible within a VAR (vector autoregressive) environment, whereby, one may test whether the lags of one set of variables enter ("Granger cause") the equations for another set of variables. The general application of this test has been in the empirical macro-economics literature to test for exogeneity of (say) monetary variables from the real variables (Sims 1972). In the agricultural economics literature, these tests have also been used to identify exogenous or dominant markets (Palaskas and Harriss-White 1996). We propose two different concepts to identify blocks of variables in our context. The first is based on a regional configuration of the markets; the second groups the prices according to whether they are of "terminal" or "procurement" markets. The groupings of the markets (and thereby, series of price variables) at these two levels are described in Table IV.4 below. Beside testing multivariate Granger causality within this frame, we have also done separate exercises upon considering Dhaka market as one block, because of the importance the latter market is perceived to have in the national network of rice markets.

The various tests on stationarity and cointegration of the price data for the 14 markets, that have been presented in the earlier sections, had indicated that they are non-stationary and cointegrated. This suggests that a vector error correction model (VECM) is the appropriate way to address block exogeneity. The latter, in our specific context, allows one to test the null hypotheses that prices in a set/block (referred to here as Block 1) of markets are not Granger caused by lagged prices in another block of markets (referred to as Block 2). For each of the

Table IV.4 Grouping of Markets for Block Exogeneity Tests

Regions	Markets	Market	Markets
North-West	Dinajpur, Bogra, Naogaon	Terminal	Dhaka, Khulna, Chittagong
South/S-West	Barisal, Jessore, Khulna		
Central	Dhaka, Narayanganj	Procurement	Dinajpur, Naogaon, Sherpur
North-East	Sherpur, Sylhet, Bhairab Bajar		
South-East	Chandpur, Choumuhani Chittagong		

price variables included in the Block 1, the unrestricted specification under VECM, is given by:

$$\Delta P_{i,t} = \alpha_i + \sum_{i=1}^{x}\sum_{k=1}^{n}\beta_{i,k}\Delta P_{i,t-k} + \sum_{j=1}^{y}\sum_{l=l}^{m}\gamma_{j,l}\Delta P_{j,t-l} + \sum_{i=1}^{x}\Delta P_{i,t-n-1} + \sum_{j=1}^{y}\theta_j\Delta P_{j,t-m-1} + u_{i,t-1} \quad (7)$$

where, Δ is to denote changes (first difference); i denotes the price series in Block 1; k is the lag considered for P_i 's, with the maximum lag considered being n; j denotes the price series in Block 2; l is the corresponding lag that takes a maximum value of m; α, β, γ, δ and θ with the subscripts are parameters.

Since the Akaike information criterion suggests of an optimal lag of 2, we have considered a maximum of a two period (week) lags in testing block exogeneity. As noted previously, Granger causality tests for block exogeneity can be done on both directions. The more interesting cases arise when one block Granger causes the other while the other does not Granger cause it. In our context, such a finding will imply price leadership of one block of markets vis-a-vis the other block. The VAR option under the RATS (Regression Analysis of Time Series) 4.02 version allows one to test for block exogeneity with log likelihood ratio test statistic that has chi-square distribution. The findings are briefly summarized below.

1. Prices in the terminal markets and procurement markets, considered as separate blocks, are found to Granger cause each other. The results hold for the whole period as well as for the three sub-periods considered.

2. Prices in the South and South-west are found to be Granger caused by North-west prices in all periods. While the reverse causality is generally true, for the period 1993-96, the null hypothesis that South-west prices do not Granger cause North-west prices cannot be rejected at the 1% level of significance (even though it is rejected at the 5%).

3. Causality holds in both directions for North-west and South-east prices.

4. The prices in the central markets (Dhaka and Narayanganj) are always found to be Granger caused by north-west prices. But the reverse does not hold for all sub-periods. The prices in the Central markets do not Granger cause North-west prices during 1987-90 period, this being true even at the 10% level of significance. For 1990-93 period, the null hypothesis of non-causality cannot be rejected at the 5% (while it can be rejected at the 1%) level of significance. However, for the last sub-period, the central prices are found to Granger cause north-west prices.

5. While Dhaka prices are found to Granger cause all other subsets of prices considered, reverse causality for all sub-periods holds only in case of other terminal markets (Chittagong and Khulna). For example, Naogaon-Dinajpur prices were found not to be Granger caused by Dhaka prices during 1987-90 and 1990-93 periods. Similarly, Sherpur-Bhairab Bazar prices were not Granger caused by Dhaka prices during 1987-90, and again in 1993-96 periods.

One general conclusion that emerges from the aforementioned findings is that prices are not transmitted from any one or a set of particular markets to another one or a set of markets. We find evidence of uni-directional price transmission with regards to flows from north-west to the center (especially, Dhaka) during the early years, which is no more there during the last period. It is our understanding that during particular seasons of the year, uni-directional causality may still hold, but there is reverse switching during other seasons. Other than the last reported case on Sherpur-Bhairab Bazar, all block exogeneity test carried out suggest that uni-directional causality does not exist between any pair of blocks during 1993-96 period. This suggests of a well integrated marketing system, where aggregate supply and demand become relevant in formation of prices in both ends of the marketing links.

IV.5 The Parity Bounds Model (PBM)

All of the above procedures to measure market integration have used only price information. None of them used any information on transfer costs which are crucial for the long distance trade. Baulch (1994, 1997) has developed a new technique called Parity Bound Model (PBM) to measure market integration which uses both price information as well as the information on transfer costs between two markets. Using additional information on transfer costs between two markets together with price information, the PBM estimates how often it is profitable for the markets to trade. When the price differential is approximately equal to transfer costs, this indicates a situations in which an arbitrage is binding. In our subsequent discussion, we will denote this probability as the regime 1 probability. The PBM also measures the probability of the cases where price differential falls short of or exceeds the transfer costs. The probability of price differential being short of transfer costs is called as regime 2 probability, and the probability of price differential being more than the transfer costs is called the regime 3 probability. The higher the estimated probability for regime 3, the lower is the extent of market integration. The actual procedure of estimation is a combination of a switching regression framework and a stochastic frontier model, the details of which could be found in Baulch (1997).

The PBM was estimated using maximum likelihood estimation for seven selected market pairs for rice and wheat which are known to trade regularly. The model was estimated for all of these seven markets pairs for two subperiods: the pre-liberalization period (i.e., December 1987 to December 1990) and post-liberalization period (i.e., December 1993 to November 1996) . This division allows the extent to which foodgrain markets have become more integrated to be assessed. The estimated regime probabilities are reported in the Table IV.5.

For both rice and wheat, the probabilities for regime 3 are extremely low for most of the market pairs in both the pre-liberalization and post-liberalization periods. This indicates that traders have left very few profitable arbitrage opportunities unexploited[14]. In contrast, regime 2 probabilities for both rice and wheat are substantial indicating that transfer costs frequently

[14] An exception is Chittagong-Naogaon in the pre-liberalization period, in which rice price differentials exceeded transfer costs in about 21% of observations. Note however, that during these period it was relatively rare for Chittagong and Naogaon to trade direct. Instead most rice shipped from the North-west to Chittagong passed through the Badamtali or Babu Bazaar markets in Dhaka.

Table IV.5 Values of Regime Probabilities Estimated by PBM

GRAIN / MARKETS		REGIME PROBABILITIES		
		λ_1	λ_2	λ_3
	RICE			
1a.	Dhaka-Dinajpur (Dec' 1987 - Dec' 1990)	0.763 (12.42)	0.237 (3.87)	0 (0.01)
1b.	Dhaka-Dinajpur (Dec' 1993 - Nov' 1996)	0.812 (11.40)	0.188 (2.64)	0 (0.05)
2a.	Dhaka-Naogaon (Dec' 1987 - Dec' 1990)	0.904 (18.64)	0.096 (2.0)	0 (0.21)
2b.	Dhaka-Naogaon (Dec' 1993 - Nov' 1996)	0.714 (12.40)	0.285 (4.92)	0.001 (0.56)
3a.	Dhaka-Sherpur (Dec' 1987 - Dec' 1990)	0.832 (10.65)	0.168 (2.15)	0 (0.0)
3b.	Dhaka-Sherpur (Dec' 1993 - Nov' 1996)	0.770 (15.57)	0.230 (4.65)	0 (0.02)
4a.	Chittagong-Naogaon (Dec' 1987 - Dec' 1990)	0.540 (0.0)	0.249 (0)	0.211 (0)
4b.	Chittagong-Naogaon (Dec' 1993 - Nov' 1996)	0.968 (10.57)	0.008 (1.73)	0.024 (0.25)
	WHEAT			
1a.	Narayanganj-Dinajpur (Mar' 1989 - Mar' 1992)	0.924 (32.44)	0.076 (2.69)	0.0 (0.06)
1b.	Narayanganj-Dinajpur (Mar' 1993 - Mar' 1995)	0.978 (39.15)	0.022 (0.88)	0.0 (0.02)
2a.	Dhaka-Dinajpur (Mar' 1989 - Mar' 1992)	0.388 (3.26)	0.523 (5.24)	0.089 (0.73)
2b.	Dhaka-Dinajpur (Mar' 1993 - Mar' 1995)	0.940 (25.74)	0.060 (1.66)	0 (0.04)
3a.	Dinajpur-Bogra (Mar' 1989 - Mar' 1992)	0.862 (11.65)	0.075 (2.95)	0.063 (0.88)
3b.	Dinajpur-Bogra (Mar' 1993 - Mar' 1995)	0.931 (6.03)	0.002 (0.42)	0.067 (0.43)

Note: t-statistics (calculated by Gallant-Holly method) in parenthesis exceeds the price differentials. In these periods, it is not profitable for traders to engage in inter-market arbitrage. In the pre-liberalization period, it was, for example, not profitable to trade rice between Dhaka and Dinajpur almost 24% of the time.

By comparing the regime probabilities for two sub-periods for a specific market pair, it is possible to see whether the liberalization policies had any effect on the extent of market integration. The general finding is that except for the Dhaka-Naogaon and Dhaka-Sherpur pairs for rice, wholesale foodgrain markets have become more integrated after the liberalization policies had been initiated. The increase in the percentage of observations in which it is profitable to trade in the post-liberalization period may be linked to two main factors. First, the reduction in DG Food procurement combined with the opening-up of international trade in foodgrains in 1992-93, dramatically widened the scope of the private sectors activities. Second, improvements in transportation infrastructure have reduced unit freight costs on a number of routes. The opening of the Chinese friendship bridge at Mymensingh (on the Dhaka-Sherpur route) in 1991 and the completion of several bridges on the main Dhaka-Chittagong highway (which now involves no ferry crossing) in 1993 are of particular importance to the market pairs considered here. So too is the general improvement of roads throughout the country. By reducing the freight component within transfer costs such improvements in transportation infrastructure lead to a general increase in the percentage of observations in which it is possible to trade between any given market pair.

The main exception to this story are rice in Dhaka-Naogaon and Dhaka-Sherpur pairs. Table IV.5 shows that Dhaka-Naogaon pair has experienced a 19% decline in profitable arbitrage opportunities in the post-liberalization period whereas Dhaka-Sherpur pair has experienced 6% decline in profitable arbitrage opportunities. This phenomenon in Dhaka-Naogaon pair may be attributed to two factors. First, a switch to direct marketing of rice from mills in the North-west to points of consumption may have led to lower volumes of rice being traded via the main Naogaon-Dhaka route. The start of direct shipments from Naogaon to Chittagong from 1993 is specially notable in this regard. Second, increasing congestion and delays on the main Aricha-Nagarbari ghat crossing over the Jamuna river may, by increasing transfer costs, have chocked-off otherwise profitable arbitrage opportunities for Naogaon traders and led to a diversification of procurement sources by traders in Dhaka. For Dhaka-Sherpur pair, similar interpretation may partly apply.

Setting aside these two peculiar cases of Dhaka-Naogaon and Dhaka-Sherpur, the overall picture that emerges from the parity bound model estimation is of an increase in profitable trading opportunities, arbitrage and spatial market integration in the post-liberalization period. This is consistent with the evidence from the Granger causality tests that a unified and simultaneous system of price formation is operating throughout Bangladesh.

To investigate whether market integration in rice differs in rainy (wet) season from dry season, separate estimations of the parity bound models were performed. *Aman*, even though a wet season crop, is marketed during the dry season. The opposite holds in the case of *boro/aus* which is marketed in the rainy season. Hence, the PBM for dry season was estimated using only the *aman* data series whereas the PBM for rainy season was estimated using the combined *boro/aus* data series. The sample covers the period of December 1987 to November 1996. The estimated regime probabilities for four market pairs (three of which include Dhaka) are reported in Appendix IV.3. Estimated regime 1 probabilities for *aman* data series are found to be consistently higher than *boro/aus* data series for all four market pairs. However, other than in the case of Chittagong-Naogaon pair, regime 3 probabilities are all zero for both *aman* and *boro/aus* periods. This suggests that while the reference markets are equally integrated (by considering the sum of regime 1 and regime 2 probabilities) during both the seasons, trade flows between the markets occur more frequently during the *aman* seasons (since regime 1 probability is higher during *aman* season compared to *boro/aus* season). Such results are consistent with our field observation that demand for poor quality rice (which is more prominent in case of *boro/aus* as compared to *aman* rice) has been on decline amongst Dhaka consumers. Our finding significantly differs from that of Ahmed and Bernard (1989) who found *aus* market to be more integrated than *aman* for the period of 1981-85. Given substantial increase in production of coarse variety *aman* since 1988 and due to increase in importance of road transportation replacing river transportation, it is no wonder that *aman* rice markets will be more integrated than *boro/aus*. The case of Chittagong-Naogaon which clearly reveals *aman* market to be more integrated than *boro/aus* may partly be explained by specificity of taste among Chittagong consumers. Since non-parboiled rice are almost exclusively *aman* rice our observation on non-integration during *boro/aus* season (higher regime 3 probability) is quite consistent.

Section V. SUMMARY AND CONCLUSIONS

Pricing analyses, which was the focus of this report, had to undertake a number of preliminary exercises that involved compilation of the time series on prices and numerous tests on stationarity and cointegration for the purpose of model specification. Based on these, three different analytical exercises were performed to assess the spatial integration and pricing efficiency of Bangladesh rice and wheat markets. The exercises included: (i) estimating the Law of One Price and long-run multipliers, to assess the extent to which changes in prices in one market are transmitted to another market; (ii) performing Granger causality tests to assess if lagged prices in one (or, a block of) market(s) influence the prices in another market (or, a block of markets), and thereby to identify the process of price formation across various markets; and (iii) running the parity bound model (PBM) to assess the changes in the degree of market integration upon explicitly incorporating transfer costs. The results from these exercises are summarized here, and their implications are discussed in the light of evolving foodgrain market in Bangladesh.

Our exercise had been constrained by data limitation on wheat prices. For the four markets for which weekly data could be availed for six years (1989-95), the Law of One Price is rejected for all market pairs. However, estimates of long run multipliers show that price changes in one market do get fully transmitted to other markets within a period of three weeks. The PBM exercise shows that integration between the wheat markets (Narayanganj-Dinajpur, Dhaka-Dinajpur, and Dinajpur-Bogra) has significantly improved between 1989-1992 and 1993-1995.

Changes in the wheat marketing environment between these two periods may account for these phenomenon. Public procurement of wheat, calculated on an annual basis, declined by almost a half between 1989-1992 and 1993-95. The two periods may also be distinguished by the presence (during most part of the first period) and absence (during the last period) of rural rationing. Average monthly offtake of wheat from the rationing system was around 40,000 metric tons during the first period, and below 10,000 thousand MTs during the second period analyzed.[15] The second period is also characterized by private import of wheat, which have been permitted since September 1992. From March 1993 to February 1995, private sector wheat imports amounted to 0.53 million MT., which was one-fourth of the total external procurement of wheat during the period.

All these changes in the policy environment have affected the nature and direction of trade flows in the domestic wheat market. Prior to the liberalization of wheat imports, public wheat imports were distributed through rural rationing and food for work programmes. This system gave rise to a domestic network of wheat marketing that passed publicly distributed wheat back to the terminal centers. With the legalization of private imports, the direction of flows has partly reversed. However, it is our understanding that the flows as well as the relations between various wheat markets in the country are yet to stabilize.

Given the limitations with regards to wheat, most of our analyses have centered around the rice markets. As a whole, when the weekly price data for the nine years are considered, all the 14 markets are found to be well integrated. This is borne by all our exercises based on bivariate and multivariate Granger causality tests and by the PBM exercise. There is however one caveat. Market integration, as conventionally perceived within the Law of One Price model, does not appear to hold between any of our markets. This absence of perfect price comovement is also born out by our estimates of long run multipliers, based on an error correction model. These show that in more than half the bivariate links considered, less than 85% of the price changes in one market get transmitted to another market, even after a lapse of two weeks.

One obvious implication of this finding is the invalidity of testing for market integration in Bangladesh using model based on the perfect co-movement of price, such as used by Ravallion (1986). However, rather than taking this finding to imply lack of market integration, we read the failure of LOP to indicate problems with its underlying model of price transmission. Given that rice does not flow throughout the year from one market to another, even when trade flows are uni-directional, they may be discontinuous. In period when markets do not trade, one does not expect price change in one of the markets to be transmitted to the other market. So on

[15] Average annual offtake from the PFDS was 1.59 million MT of wheat during the first period, which declined to 0.98 million MT during the second period.

average, the long run multiplier should be expected to be lower than unity. This is borne out by our estimates of long-run multipliers both for the whole nine years for which we have rice prices, and for the two three year sub-periods before and after market liberalization. However, the fact that the average long-run multiplier for rice prices rose from 0.50 to 0.81 between these two sub-periods indicates an improvement in price transmission following liberalization.

More interesting results emerge from our exercises on multivariate Granger causality and the PBM which attempt to capture the changes in Bangladesh rice markets over the last decade. The period has been characterized by significant increase in rice production as well as in marketed surplus (Haggblade, 1994). There had also been significant changes in the Government policy towards the foodgrain market along with some unanticipated actions that may have affected the rice market. Imports of wheat and rice by the private sector were opened up during 1992, even though the first such import of rice did not commence until April 1994.[16] With the withdrawal of rural rationing in October 1991, the size of public food distribution had diminished significantly.

All these policy changes coincided with a number of interrelated government actions. Due to substantial public imports during the early part of 1992, the public stock of foodgrains built up. As a consequence, the government withdrew its procurement programme in the midst of 1992 *boro* harvest. Since then, the country has experienced cycles of price movements that had not been experienced previously.

Amidst all these changes, there had been winners and losers amongst traders in the rice market. The large traders who had procured during the early *boro* season in 1992 are alleged to have incurred huge losses. The same fate struck late importers of rice in 1995-96. But during the first year of private sector rice imports in 1994-95, there were new entrants into the market who are reported to have earned substantial short-term profits. Since these new entrants' only previous experience was in the indenting business, they fed the rice they imported from India into existing marketing channels. Thus, introduction of private rice imports did not destabilize the domestic rice marketing system, but did lead to changes in the share of existing wholesale

[16] Total private sector imports of rice amounted to 583,000 MT in 1994-95, and 650,000 MT in 1995-96

markets in total trade volume.

Given all these changes during the 1992-96 period, the extent of market integration is likely to be underestimated from the price data. Nonetheless, our period-specific results, based on both Granger causality and the PBM, suggest that rice market are generally more integrated during 1993-96 than before. One important reason for this is the improvement in road infrastructure, especially in the early 1990s. Improvements in telecommunications, especially the coverage of most markets under the Nationwide Dialing (NWD) System, also facilitated transfer of pricing information and orders between markets. A second reason for increased market integration may be due to an increased number of traders and the shift in relative market power away from Dhaka. Routing of rice via Dhaka has declined substantially in recent years, while the volume of direct long distance trade has increased. Such direct marketing along with the emergence of independent markets within Dhaka city (who themselves engage in the long distance trade in rice), is likely to have reduced the relative market power of the Badamtoli traders.[17] This decline in the importance of Dhaka as a rice trading hub together with the emergence of a number of important wholesaling centers in the procurement regions (e.g., Naogaon and Sherpur) is creating a new, more spatially efficient marketing environment for rice in Bangladesh.

[17] The cyclical down turns in market prices during 1992 and 1996 may also have eroded the financial power of these traders.

APPENDIX-III.1 Procedure Followed to Adjust Barisal Price Series

In order to construct a pseudo Barisal HYV *aman* price series from the available local *aman* price series, the price information from Bhola have been used. Bhola is an adjacent district to Barisal where price series on both local and HYV *aman* are available. Using Bhola price series to calculate Barisal HYV *aman* series was deemed to be reasonable since the people in both these areas have very similar taste and other relevant demand characteristics. The correlation coefficient between *aman* price series in Bhola and *aman* price series in Barisal is 0.74. However, there are some missing observations in both the local and HYV *aman* price series for Bhola. Out of 216 observations, 38 are missing for local *aman* and 66 are missing for HYV *aman*. To interpolate those missing observations, the following procedure had been followed.

In the first step, if price information for a week is not available, average price of adjacent two weeks from the same year is used for that week. If this does not work, the price of the same week next year is used. In second step, if there still exists any gap, Bagerhat price series is used for the corresponding weeks and years. Correlation between Bhola local *aman* price and Bagerhat local *aman* price is 0.86 and correlation between Bhola HYV *aman* and Bagerhat HYV *aman* price is 0.86. After interpolating all the missing HYV and local *aman* prices for Bhola (using some information from Bagerhat series), relative price of HYV *aman* to local *aman* is calculated for Bhola from week 21 to week 44 for all nine years. Plotting these relative price series, no systematic or abrupt changes are found for any of the years[18]. In the next step, the HYV *aman* price series for Barisal is calculated by multiplying Barisal local *aman* price by relative price found above. This estimated HYV *aman* price series for Barisal is used to substitute the corresponding local aman price each year that is reported by DAM to make all the price series comparable.

---

[18] The range of these relative prices are 0.15 for 1987-88, 0.14 for 1988-89, 0.11 for 1989-90, 0.13 for 1990-91, 0.11 for 1991-92, 0.19 for 1992-93, 0.41 for 1993-94, 0.69 for 1994-95, and 0.18 for 1995-96.

APPENDIX-IV.1 Degree of Statistical Association between Contemporaneous Prices in First Difference (number of bivariate correlation coefficients that were found to be not significantly different from zero)

Markets	1987-90	1990-93	1993-96	1987-96
Barisal	7	5	8	1
Bhairab Bazar	1	3	2	0
Bogra	1	4	5	0
Chittagong	4	3	8	1
Choumuhoni	2	5	3	0
Chandpur	0	1	1	0
Dhaka	2	4	1	0
Dinajpur	3	5	3	0
Jessore	1	9	5	1
Khulna	1	6	3	0
Naogaon	11	4	2	1
Narayanganj	2	1	6	0
Sherpur	1	1	5	0
Sylhet	1	5	8	0
Aggregate	19	28	30	2

Note: The figures corresponding to various markets are number of cases (out of 13) where the bivariate correlation coefficients are not significantly different from zero at the 5% level. Figures in the bottom row correspond to a total of 91 bivariate links.

APPENDIX-IV.2 Kwiatkowski Tests for Level Stationarity for Weekly Rice Price in Bangladesh

Lag Parameter	0	1	3	6	9
			RICE		
Barisal	8.92***	4.61***	4.61***	4.61***	4.61***
Bhairab Bazar	8.72***	4.45***	4.45***	4.45***	4.45***
Bogra	16.67***	8.40***	8.40***	8.40***	8.40***
Chandpur	12.60***	6.42***	6.42***	6.42***	6.42***
Chittagong	9.05***	4.61***	4.61***	4.61***	4.61***
Choumuhani	10.30***	5.27***	5.27***	5.27***	5.27***
Dhaka	11.26***	5.75***	5.75***	5.75***	5.75***
Dinajpur	7.95***	4.04***	4.04***	4.04***	4.04***
Jessore	7.28***	3.72***	3.72***	3.72***	3.72***
Khulna	9.55***	4.88***	4.88***	4.88***	4.88***
Naogaon	11.90***	6.04***	6.04***	6.04***	6.04***
Narayanganj	10.79***	5.53***	5.53***	5.53***	5.53***
Sherpur	10.42***	5.32***	5.32***	5.32***	5.32***
Sylhet	11.33***	5.78***	5.78***	5.78***	5.78***
			WHEAT		
Bogra	1.93***	0.99***	0.99***	0.99***	0.99***
Dhaka	8.18***	4.27***	4.27***	4.27***	4.27***
Dinajpur	1.90***	0.98***	0.98***	0.98***	0.98***
Narayanganj	3.82***	2.00***	2.00***	2.00***	2.00***

Note: One sided critical values are - 0.347 at 10% level, 0.463 at 5% level, and 0.739 at 1% level. Asterisks indicate the level of statistical significance at which the null hypothesis can be rejected: *** stars for 1% level, ** stars for 5% level, and * star for 10% level.

APPENDIX-IV.3 Values of Regime Probabilities Estimated by PBM

MARKETS	REGIME PROBABILITIES		
	λ_1	λ_2	λ_3
RICE			
1a. Dhaka-Dinajpur (*Aman*)	0.885	0.115	0
	(21.68)	(2.83)	(0.19)
1b. Dhaka-Dinajpur (*Boro/aus*)	0.553	0.447	0
	(11.13)	(9.32)	(0.09)
2a. Dhaka-Naogaon (*Aman*)	0.928	0.072	0
	(31.36)	(2.42)	(0.34)
2b. Dhaka-Naogaon (*Boro*/aus)	0.700	0.288	0.012
	(13.49)	(6.08)	(0.90)
3a. Dhaka-Sherpur (*Aman*)	0.884	0.116	0
	(22.83)	(2.99)	(0.06)
3b. Dhaka-Sherpur (*Boro/aus*)	0.841	0.159	0
	(21.54)	(4.08)	(0.11)
4a. Chittagong-Naogaon (*Aman*)	0.972	0.011	0.017
	(59.79)	(0.84)	(1.45)
4b. Chittagong-Naogaon (*Boro/aus*)	0.508	0.250	0.242
	(13.65)	(13.25)	(13.20)

Note: t-statistics (calculated by Gallant-Holly method) in parenthesis

REFERENCES:

Adam, C. S. *Time Series Econometrics for Africa.* Center for the Study of African Economies, St. Antony's College, Oxford, 1993.

Ahmed, R., and A. Bernard. "Rice Price Fluctuation and an Approach to Price Stabilization in Bangladesh" *International Food Policy Research Institute*, Research Report No. 72, Washington D.C., 1989.

Banerjee, A., J. Dolado, J.W. Galbraith, and D.F. Hendry. *Co-Integration, Error-Correction, and the Econometric Analysis of Non-Stationary Data.* Oxford University Press, 1994.

Barrett, C. "Market Analysis Methods: Are Our Enriched Toolkits Well-suited to Enlivened Markets?" *American Journal of Agricultural Economics,* 1996.

Baulch, B. "Spatial Price Equilibrium and Food Market Integration." *Ph.D. Dissertation*, Food Research Institute, Stanford, 1994.

Baulch, B. "Testing for Food Market Integration Revisited." *The Journal of Development Studies,*.33, 1997.

Blyn, G. "Price Series Correlation as a Measure of Market Integration." *Indian Journal of Agricultural Economics*, 28, 1973.

Chowdhury, N. "Rice Markets in Bangladesh: A Study in Structure, Conduct and Performance." USAID, Dhaka, 1992.

Chowdhury, N. "The Structure, Conduct of Bangladesh's Wheat Markets: Some Emerging Insights." *Bangladesh Food Policy Project, IFPRI*, Dhaka, 1993.

Engle, R.F., and W.J. Granger. "Co-integration and Error Correction: Representation, Estimation, and Testing." *Econometrica*, 55,1987.

Farruk, M.O. *Structure and Performance of the Rice Marketing System in East Pakistan.* Cornell University Press, New York, 1972.

Goletti, F., and N. Farid. "Structural Determinants of Market Integration, the case of Rice Markets in Bangladesh." mimeo, *Bangladesh Food Policy Project*, IFPRI, Dhaka, 1993.

Haggblade, S. "Evolving Foodgrain Markets and Food Policy in Bangladesh." *International Food Policy Research Institute, Bangladesh Food Policy Project*, 1994.

Hamilton, J.D. *Time Series Analysis.* Princeton University Press, Princeton, New Jersey, 1994.

Harriss-White, B. "*A political Economy of Agricultural Markets in South India - masters of the countryside*", Sage Publications, New Delhi, 1996.

Harvey, A.C., *Time Series Models*. Philip Allen, London, 1981.

Hendry, D.F., and J. Richard. "On the Formulation of Empirical Models in Dynamic Econometrics." *Journal of Econometrics* 20, 1982.

Johansen, S., and K. Juselius. "Maximum Likelihood Estimation and Inference on Cointegration-With Applications to the Demand for Money." *Oxford Bulletin of Economics and Statistics*, 52, 1990.

Jones, W.O. "The Structure of Staple Food Marketing in Nigeria as Revealed by Price Analysis." *Food Research Institute Studies*, 8, 1968.

Kwiatkowski, D., P. Phillips, P. Schmidt, and Y. Shin. "Testing the Null Hypothesis of Stationarity against the Alternative of Unit Root." *Journal of econometrics*, 54, 1992.

Lele, U. "Market Integration: A Study of Sorghum Prices in Western India." *Journal of Farm economics*, 49, 1967.

Osterwald-Lenum, M. "A Note with Quantiles of the Asyptotic Distribution of the Maximum Likelihood Cointegration Rank Test Statistics." *Oxford Bulletin of Economics and Statistics*, 54, 1992.

Palaskas, T. and B. Harriss-White. "Testing Market Integration: New Approaches with Case Material from the West Bengal Food Economy." *The Journal of Development Studies*, 30, 1993, pp 5-6.

Ravallion, M. "Testing Market Integration." *American Journal of Agricultural Economics*, 68, 1986.

Ravallion, M. "*Markets and Famines.*" Claredon Press, Oxford, 1987.

Ravallion, M. "*Markets and Famines.*" University Press Limited, Dhaka, 1990.

Sexton, R.J., C.L. Kling, and H.F. Carman. "Market Integration, Efficiency of Arbitrage, and Imperfect Competition: Methodology and Application to U.S. Celery." *American Journal of Agricultural Economics*, 1991.

Shahabuddin, Q., and S. Zahir. "Markets as Conduits of Micro-Macro Transmission", Focus Study No. 1, CIRDAP, Dhaka, 1994.

Sims, C. "Money, Income and Causality." *American Economic Review*, 6, 1972.

Williams, J., and B.D. Wright. "*Storage and Commodity Markets.*" Cambridge University Press, Cambridge, 1991

Figure-1: PFDS Offtake of Cereals and Monthly Coarse Rice Prices
(1987/88 to 1996/97)

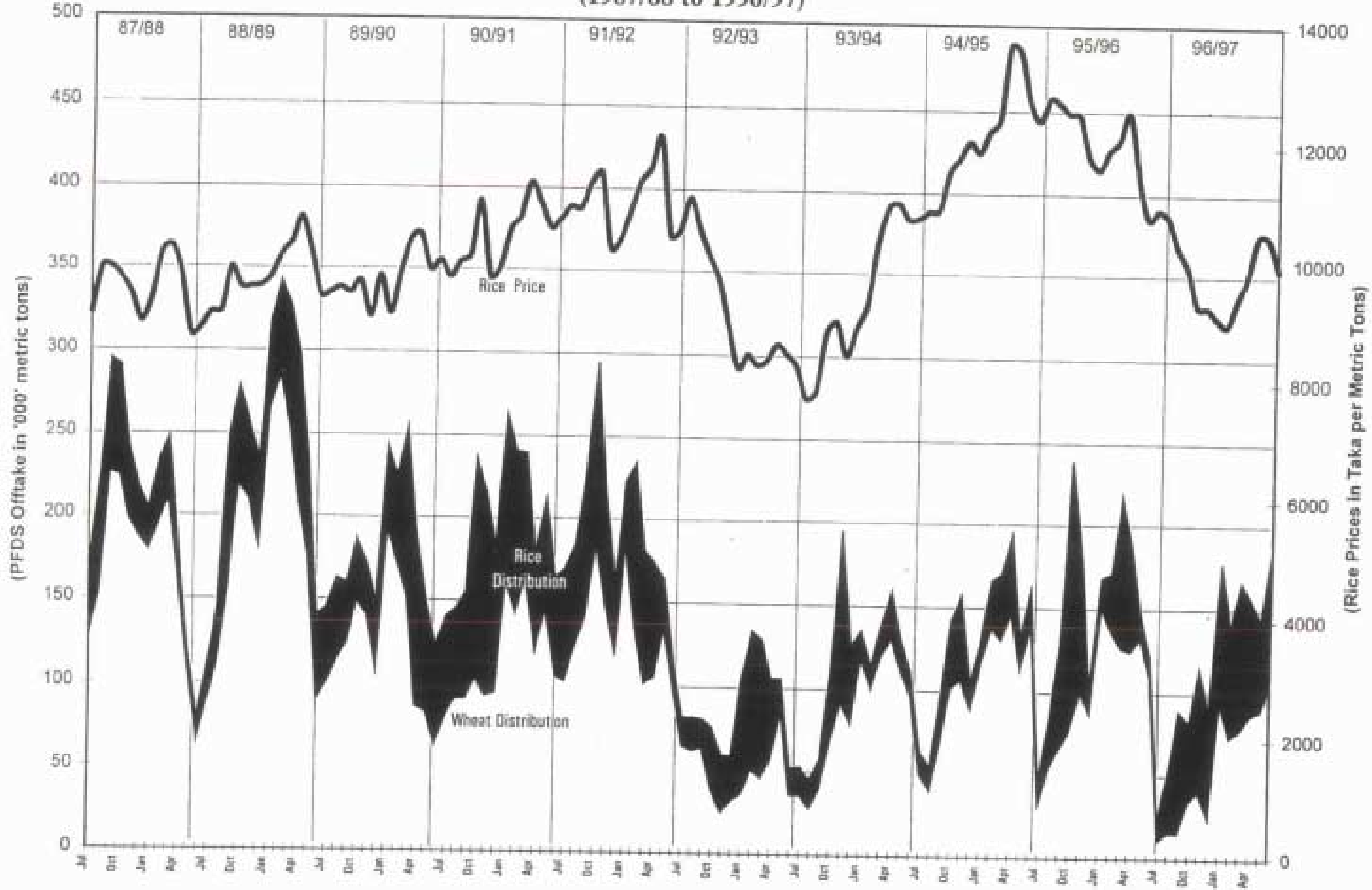

Figure-2 : Public and Private Import of Wheat
(1987/88 to 1996/97)

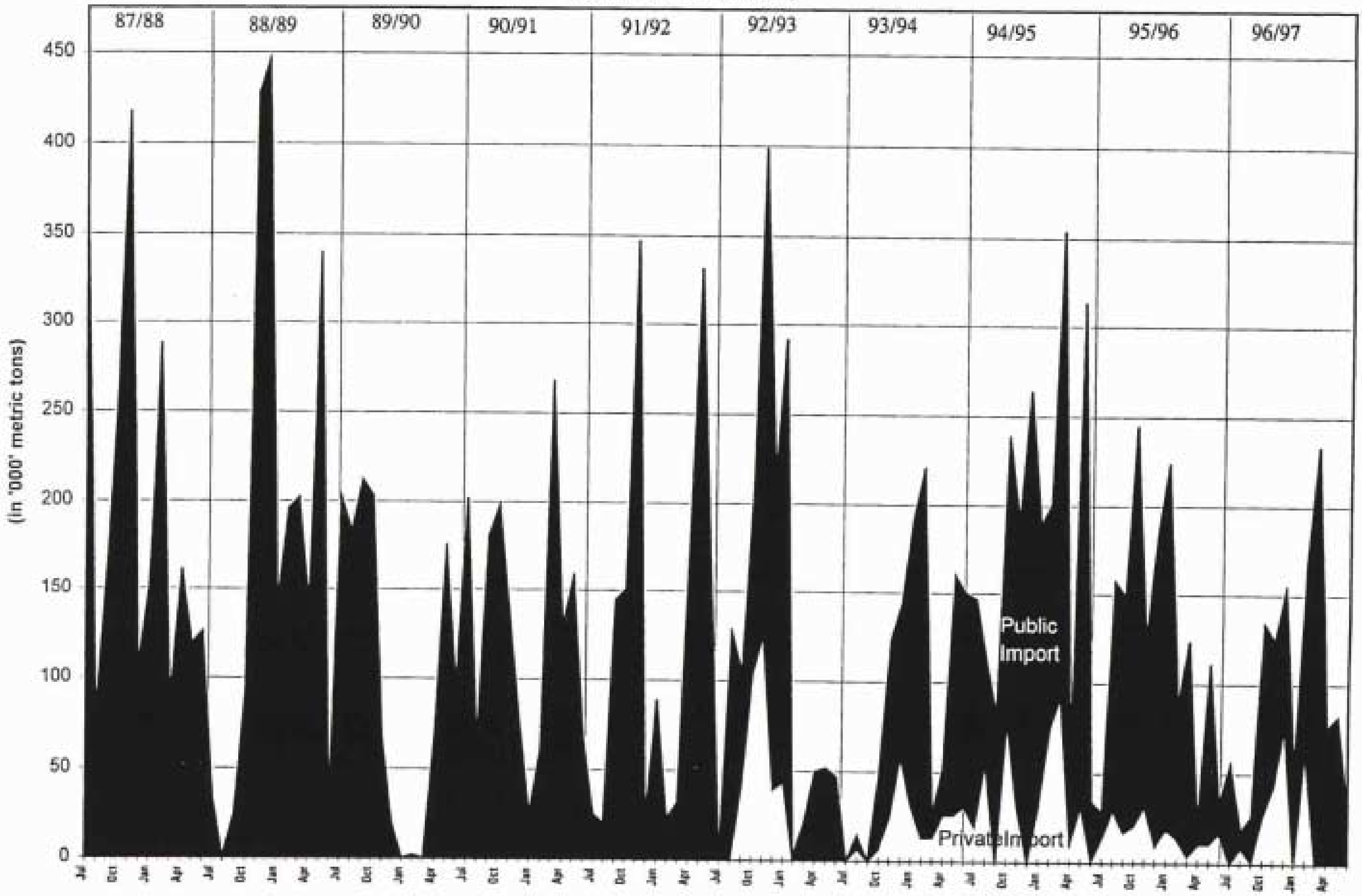

Figure-3 : Public and Private Import of Rice (1987/88 to 1996/97)

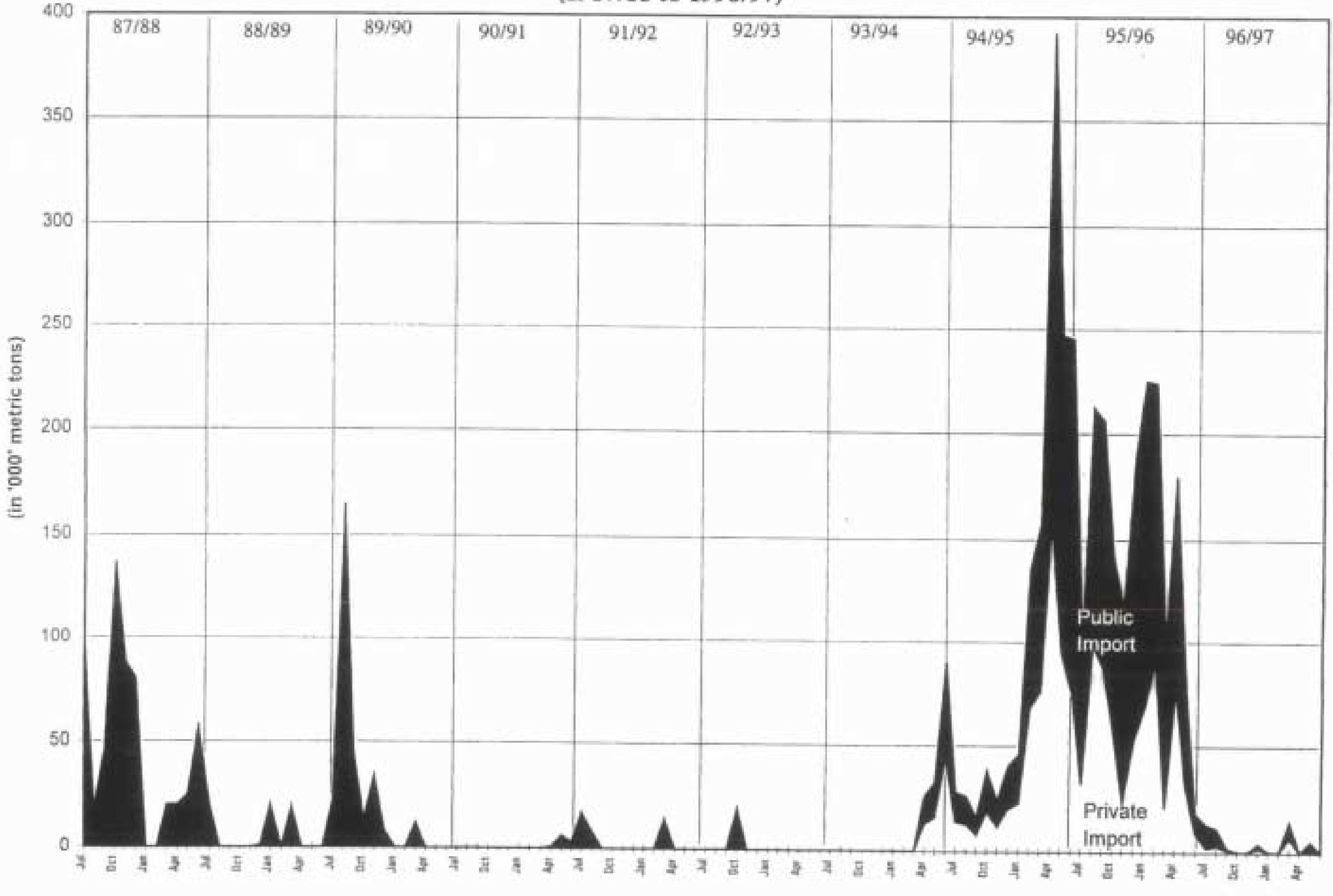

Figure-4 : Public Stock of Wheat and Rice
(1987/88 to 1996/97)

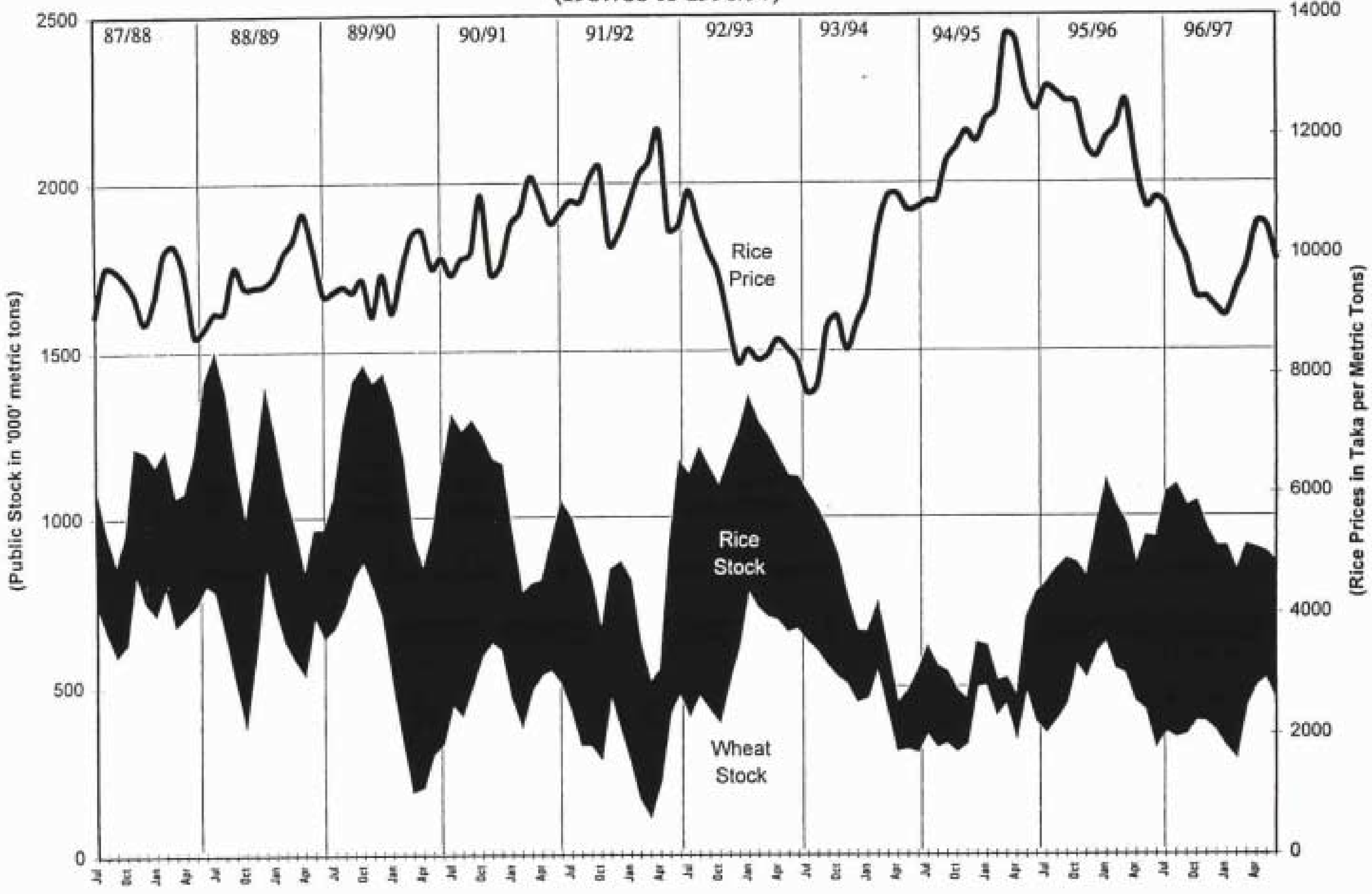

Figure-5 : Quantity and Prices of Public Rice Procurement (1987/88 to 1996/97)