Market performance of potato auctions in Bhutan

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Abstract

Market performance with respect to a main horticultural export commodity in Bhutan is the subject of this paper. Imperfections in (market) infrastructure and market structure and conduct may prevent an optimal price for farmers. Market performance is assessed by testing the law of one price for this commodity. This is done by testing three series of auction price data on both long-run and short-run price integration. It is concluded that auction prices were interrelated both in the long and short run with one of the three auctions as the price-leading market. Policy implications are suggested.

JEL Classification: C22, L1, M31, O1, Q13

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1. Introduction

The agricultural sector in Bhutan accounts for a major share of employment in the country. To improve the quality of agricultural products and to attain a higher share of the value added in the supply chain have been major challenges. The role of the export sector of Bhutan is pivotal in commercializing agricultural produce (Swinkels and Sinha, 2001). Bhutan has competitive advantages in horticultural production relative to its main trading partner India, notably during spring and summer when it is too hot in northern India to produce fruits and vegetables. This paper deals with potatoes, a main horticultural export product of Bhutan.

The main export market centers for horticultural products are situated in the south of Bhutan alongside the border with India. Markets may be missing because of various reasons. Direct market access to these export market centers is a serious problem for many farmers, because their farms are located far away from these centers or in remote areas with very limited access to the road system of Bhutan. The roads, often constructed alongside steep slopes, appear to be vulnerable to bad weather conditions and land slides. It happened in the recent past quite often during the rainy season that roads were blocked for several days or weeks disconnecting farmers and traders from their major outlets.

Farmers and traders in Bhutan can benefit from price discovery taking place at major export market centers. The paper is devoted to a performance aspect of the three major export market centers for

vegetables in Bhutan. The degree of price integration among these markets will be tested for potatoes, the main horticultural crop in Bhutan.

The structure of this paper is as follows. The market situation for horticultural crops in Bhutan is discussed in section 2. In section 3, the law of one price is tested for the major horticultural commodity by testing series of monthly price data on both long-run and short-run price integration. It is also tested whether one of the three auctions can be considered to be the price-leading market. In the concluding section, the results of the analysis are discussed and policy implications are suggested.

2. Potato production and marketing in Bhutan

Major strengths of the agricultural sector in Bhutan have been the good taste and organic characteristics of Bhutanese agricultural products and the high demand for off-season vegetables and fruits. Major weaknesses of the agricultural sector have been little vertical integration in marketing supply channels, insufficient knowledge about export markets, absence of group marketing among farmers, insufficient improvements and investments in both harvest and post-harvest operations including presentation and labeling of products, and relatively high transaction costs because of the weak infrastructure to evacuate farm products to national and export markets. A market study recommends to exploit opportunities for vertical co-operation in the supply chain and to exploit off-season markets for premium horticultural products (Van Tilburg, 2001).

Agriculture in Bhutan is mainly located in three valleys in the Eastern, Central and Western district, respectively. Crop production takes predominantly place in these valleys during spring and summer. These valleys stretch from north to south and the main roads in each of these valleys are connecting farming households to main border towns in the south, e.g., Phuentsholing in the Western district, Gelephu in the Central district and Samdrup Jongkhar in the Eastern district. Major flows of horticultural crops cultivated in Bhutan follow these north-south routes because of export opportunities in India. Permanent auctions for horticultural crops in Bhutan have been located in each these three border towns. These towns are spaced at a distance of about 120 km from each other.

Farmers can sell their products directly to consumers at the farmgate, to a collecting trader, directly to consumers at a retail market, or at one of the auctions. The main domestic spot markets for agricultural products in Bhutan are auctions and weekend retail markets.

The Food Corporation of Bhutan (FCB, 2001) has been operating an auction system with permanent auctions in the three border towns with India and, dependent on the quantity of supply, seasonal auctions in the rural areas during harvest time. The main export commodities that have been auctioned are potatoes and orchard crops, predominantly apples and mandarin oranges. Buyers at the permanent auctions tend to be Indian traders. The major buyers purchase in bulk at the auction and are selling their products in major market towns in northern India, for example, Siliguri, Cooch Behar and Calcutta. The petty buyers at these auctions sell their products mainly locally or in neighbouring Indian towns (Penjore and Tshering, 1998). The number of buyers at each auction has been subject of concern because of oligopsonic power. For example, there were about seven major buyers and about 15 to 20 petty buyers active at the Phuentsholing auction in 1998.

The weekend markets are located in or near the larger towns in Bhutan and permanent, seasonal or mobile auctions are mainly operating during the harvest season. Vegetables and fruits offered at these weekend retail markets have been mainly imported from India during the winter season and mainly locally produced during the spring and summer season.

A survey to learn more about market conditions of horticultural farmers was conducted in one of the major horticultural valleys of Bhutan, the Punakha-Wangdue Valley (Wangdi et al., 2000). The result of this survey, based on 55 respondents, showed that main market outlets for potatoes consisted of the weekend retail markets in the towns in either the same valley (about 60% of the volume), or in a neighbouring valley (about 30%), or the wholesale auction market in Phuentsholing at the Indian border (about 10%).

The interest in neighbouring countries for potatoes produced in Bhutan can be illustrated with the following citation derived from an interview with a potato exporter in Phuentsholing (Van Tilburg, 2001): *"The trader is one of the four large-scale potato exporters in Phuentsholing. He buys and sells about 5000 metric tons potatoes yearly. There is a ready market for these potatoes in India. The trader buys mainly at the permanent auction in Phuentsholing, but he also purchased by telephone about 500*

tons of potatoes at the permanent auction of Samdrup Jonkhar. He sets a maximum purchase price for buying in Samdrup Jonkhar by deducting transport and other transaction costs from the ruling auction price in Phuentsholing. Phuentsholing is, according to the trader, the leading market for price discovery in the potato market. He argues that he can easily sell twice the quantity of potatoes as soon as sufficient supply is available at the permanent auctions. The trader sorts the potatoes into various grades with actual market demand in mind. He sells, for example, big potatoes, the "bolders", to the potato chip processing industry in Calcutta and Kathmandu. The small-sized potatoes are usually sold as seed potatoes in the Indian market."

3. Testing on price integration and price leadership

The three permanent auctions, discussed above, are considered with respect to the trade in a homogeneous commodity: potatoes. Each of these auctions is located in another district capital town near the border with India. These auctions are Phuentsholing Center in the west, Gelephu Center in the middle, about 120 km to the east of Phuentsholing, and in the east, about 120 km to the east of Gelephu, we find Samdrup Jongkhar Centre.

The supply of potatoes to these auctions follows a seasonal pattern. There is no supply in January through May. Most of the supply is concentrated in the harvest period September to November. Phuntsholing is by far the largest auction with an average annual supply of 13,000 tonnes according to our sample of monthly data over the period January 1996 - December 2000. In contrast, the average annual supply at the Gelephu auction is 145 tonnes (only 1.1% of the supply in Phuentsholing) and at the Samdrup Jongkhar auction average annual supply is 5,000 tonnes (38% of the supply in Phuentsholing).

In addition to the quantities supplied, our sample also contains the value of the monthly supply as established at each of the three auctions. Consequently, average prices are then simply obtained by value over quantity. In contrast to the quantities, the prices do not show any seasonality. If we compare the September, October and November prices of Phuentsholing with each other for each year in our sample of five years, then we observe that none of the three prices is always lower or higher

than the other two. This is also true for the prices in Gelephu and Samdrup Jongkhar. Consequently, the monthly prices do not follow a seasonal pattern.

Similarly, if we compare the Phuentsholing, Gelephu and Samdrup Jongkhar prices of September with each other for each year in our sample of five years, then we also observe that none of the three prices is always lower or higher than the other two. This is also true for October and November and complies with the "Law of One Price" (LOP).

The graphical evidence of the LOP is confirmed by the selected structural vector error-correction model for the prices of the three markets. Let p_{pt}, p_{gt} and p_{st} be the prices of Phuentsholing, Gelephu and Samdrup Jongkhar, respectively, at time t. A linear model embedding a wide range of dynamic relationships among these prices is the well-know Vector Auto-Regression (VAR) model. A VAR model of order k ($k = 1, 2, ...$), denoted as VAR(k), implies the following system of equations for our three prices:

$$p_{pt} = d_{pt} + \sum_{i=1}^{k} \pi_{p1i}\, p_{p,t-i} + \sum_{i=1}^{k} \pi_{p2i}\, p_{g,t-i} + \sum_{i=1}^{k} \pi_{p3i}\, p_{s,t-i} + \varepsilon_{pt} \tag{1a}$$

$$p_{gt} = d_{gt} + \sum_{i=1}^{k} \pi_{g1i}\, p_{p,t-i} + \sum_{i=1}^{k} \pi_{g2i}\, p_{g,t-i} + \sum_{i=1}^{k} \pi_{g3i}\, p_{s,t-i} + \varepsilon_{gt} \tag{1b}$$

$$p_{st} = d_{st} + \sum_{i=1}^{k} \pi_{s1i}\, p_{p,t-i} + \sum_{i=1}^{k} \pi_{s2i}\, p_{g,t-i} + \sum_{i=1}^{k} \pi_{s3i}\, p_{s,t-i} + \varepsilon_{st} \tag{1c}$$

where the d's contain the deterministic terms like a constant, the π's are parameters and the ε's are multivariate Gaussian white noise residual terms with covariance matrix Ω. For convenience, let us consider a VAR(1) without deterministic terms. Rewriting this model into a reduced-form Vector Error-Correction Model (VECM) gives:

$$\Delta p_{pt} = \alpha_{p1}(p_{g,t-1} - \beta_g p_{p,t-1}) + \alpha_{p2}(p_{s,t-1} - \beta_s p_{p,t-1}) + \varepsilon_{pt} \tag{2a}$$
$$\Delta p_{gt} = \alpha_{g1}(p_{g,t-1} - \beta_g p_{p,t-1}) + \alpha_{g2}(p_{s,t-1} - \beta_s p_{p,t-1}) + \varepsilon_{gt} \tag{2b}$$
$$\Delta p_{st} = \alpha_{s1}(p_{g,t-1} - \beta_g p_{p,t-1}) + \alpha_{s2}(p_{s,t-1} - \beta_s p_{p,t-1}) + \varepsilon_{st} \tag{2c}$$

where $\Delta p_t = p_t - p_{t-1}$ and the α's and β's are parameters. Suppose that all three prices contain a common stochastic trend. Then, the price differences Δp_{pt}, Δp_{gt} and Δp_{st} are stationary and the residuals e_{gt} and e_{st} of the two linear combinations $p_{gt} - \beta_g p_{pt} = e_{gt}$ and $p_{st} - \beta_s p_{pt} = e_{st}$ are stationary as well. Given that the α parameters have the appropriate values, the model can be shown to display error-correction through the error-correction terms $(p_{g,t-1} - \beta_g p_{p,t-1})$ and $(p_{s,t-1} - \beta_s p_{p,t-1})$. The error-correction keeps the residuals e_{gt} and e_{st} stationary. Moreover, if the LOP holds, then $\beta_g = \beta_s = 1$.

Given error-correction and the LOP, the markets are said to be price-integrated in the long-run, because their prices will never diverge. Consequently, testing for price-integration among spatially dispersed markets requires one to test for cointegration as well as the LOP.

In addition to testing for price-integration, it is of interest to learn more about which price responds to which price. The VECM in (2a) - (2c) is a reduced-form model as it allows for contemporaneous correlation among the residuals ε_{pt}, ε_{gt} and ε_{st}. Hence, if we give a shock to one of these residuals, we may not ignore the immediate response by the other residuals if we want to compute the impulse responses of the market prices as a consequence of the shock. Pesaran et al. (1998) deal with this problem by computing so-called "generalized" impulse response functions. The generalized impulse response functions by a shock in ε_{pt} are computed by performing a regression of ε_{gt} on ε_{pt} and of ε_{st} on ε_{pt} that are used to estimate the immediate response of ε_{gt} and ε_{st}, respectively, to the ε_{pt} shock. Similarly, ε_{pt} and ε_{st} are regressed on ε_{gt}, and ε_{pt} and ε_{gt} are regressed on ε_{st} in order to compute the generalized impulse response functions as a consequence of shocks in ε_{gt} and ε_{st}, respectively. Consequently, the generalized impulse responses are not based on a unique structural model for the contemporaneous relationships among the price changes Δp_{pt}, Δp_{gt} and Δp_{st}. Such a model, however, is required if we really wish to identify the short-run parameters in the structural VECM.

An important indication of how to specify the structural model capturing the contemporaneous correlations among the residuals of the reduced-form VECM, is the outcome of testing for long-run causality. The price of market x drives the price of market y in the long run if the price of market x does not respond to the lagged values of the price of market y nor to the price of any other market whose price does respond to lagged values of the price of market y, whereas the price of market y does respond to lagged values of the price of market x and/or lagged values of prices of markets other than market x but responsive to lagged values of the price of market x (cf. Bruneau and Jondeau, 1999). For the VECM in (2a) - (2c) this implies that p_{pt} drives the other two prices in the long run if p_{pt} is not error-correcting, i.e., if $\alpha_{p1} = \alpha_{p2} = 0$. Note that by the specification of the long-run equilibrium relationships $p_{gt} = \beta_g p_{pt} + e_{gt}$ and $p_{st} = \beta_s p_{pt} + e_{st}$ it already seems as if p_{pt} exerts the role of driving the prices of the other two markets in the long run. This, however, is not true, because the way in which

these long-run relationships are normalized does not have any consequences for the results of the tests on long-run causality nor for the impulse responses, whatever the model for the contemporaneous correlations is. Hence, normalizing by putting p_{pt} on the right-hand-side of both long-run equilibrium relationships is just a matter of arbitrary notation.

Nevertheless, if $\alpha_{p1} = \alpha_{p2} = 0$ and hence, the other two prices should do the error-correction, then this may be seen as a suggestion that contemporanously, we may condition Δp_{gt} and Δp_{st} on Δp_{pt}. This, however, still leaves the question unanswered how the causal relationship should be modelled between Δp_{gt} and Δp_{st}. An indication that suggests the conditioning of Δp_{st} on Δp_{gt} is the nonrejection of the restriction $\alpha_{g2} = 0$, while $\alpha_{s1} = 0$ is rejected. To summarise, if $\alpha_{p1} = \alpha_{p2} = \alpha_{g2} = 0$ and $\alpha_{s1} \neq 0$ in (2a) - (2c) so that long-run causality runs from p_{pt} to p_{gt}, from p_{pt} to p_{st} and from p_{gt} to p_{st}, then the structural model for the contemporaneous correlation among Δp_{pt}, Δp_{gt} and Δp_{st} that complies with the long-run causal structure, conditions Δp_{gt} on Δp_{pt} and conditions Δp_{st} on Δp_{pt} and Δp_{gt}. We will now turn to the empirical data on the three market prices to test for cointegration, the LOP and long-run causality.

First of all, we select the order k of the tri-variate VAR model in (1a) - (1c), where each equation includes a constant as the only deterministic term. Given the small number of observations in each of the five seasonal subsamples that consitute our sample, we fixed the maximum number of lags to 2. Hence, we can choose between $k = 0$ (implying no dynamic price interactions at all), $k = 1$, and $k = 2$ (in which case it might be of interest to set a larger maximum number of lags if possible). All well-known lag-length criteria (FPE, AIC, SC and HQ, see, for example, Lütkepohl, 1991: pp.) selected a VAR(1), see Table 1.

Table 1   VAR order selection

Lag	FPE	AIC	SC	HQ
0	0.69	8.15	8.30	8.17
1	0.08*	5.95*	6.55*	6.04*
2	0.13	6.32	7.36	6.46

Note: * indicates lag order selected by the criterion; FPE: Final Prediction Error; AIC: Akaike Information Criterion; SC: Schwarz Information Criterion; HQ: Hannan-Quinn Information Criterion

Next, we apply the Johansen procedure to test the VAR(1) for cointegration. To guide us through this procedure, it is convenient to use some matrix notation. Let $\mathbf{p}_t = (p_{pt}, p_{gt}, p_{st})'$ be the (3×1) vector of the prices. Then, the VAR(1) can be written as

$$\Delta\mathbf{p}_t = -(\mathbf{I} - \mathbf{\Pi}_1)\mathbf{p}_{t-1} + \mathbf{\varepsilon}_t \tag{3}$$

where $\mathbf{I}$ is a (3×3) identity matrix, $\mathbf{\Pi}_1$ is the matrix with the π parameters, and $\mathbf{\varepsilon}_t = (\varepsilon_{pt}, \varepsilon_{gt}, \varepsilon_{st})'$. If the prices are integrated of order 1, denoted as $I(1)$, then the prices contain a stochastic trend such that by taking first differences, i.e., $\Delta\mathbf{p}_t = \mathbf{p}_t - \mathbf{p}_{t-1}$, the stochastic trend disappears. Because $\Delta\mathbf{p}_t$ does not contain a stochastic trend, it is called stationary or integrated of order zero, denoted as $I(0)$. Another way in which a stochastic trend can be canceled, is by taking a linear combination of stochastic-trending variables in such a way that this linear combination does not exhibit any stochastic trend. In this case it is said that the variables contain a common stochastic trend. Their stationary linear combination is better known as the cointegration relation, which might be interpreted in economic terms as a static or long-run equilibrium relationship. Thus, on the left-hand-side of (3) we have stationary prices differences, $\Delta\mathbf{p}_t$. On the right-hand-side, however, the vector $\mathbf{p}_{t-1}$ contains prices in levels that are $I(1)$. Note that there can never be a meaningful relationship between a stationary and a nonstationary variable. Consequently, the matrix $-(\mathbf{I} - \mathbf{\Pi}_1)$ in (3) is forced to find all the linear combinations among the prices in $\mathbf{p}_{t-1}$ that constitute the residuals of the respective cointegration relationships.

In our application two cointegration relationships can be hypothesised: between p_{pt} and p_{gt} and between p_{pt} and p_{st} (which automatically implies that p_{gt} and p_{st} are also cointegrated, hence, this does not add to the number of cointegration relations). To form these two linear combinations the (3×3) matrix $-(\mathbf{I} - \mathbf{\Pi}_1)$ in (3) must have rank 2. A rank of 3 would imply that all three prices are already stationary before taking first differences (after which they are still stationary) and a rank of 0 would mean that there is no cointegration at all among the three prices. The *trace* statistic of the Johansen procedure tests for the restrictions rank$(-(\mathbf{I} - \mathbf{\Pi}_1)) = 0$, ≤ 1 and ≤ 2. Rejecting only the first one suggests one cointegration relation. Two cointegration relations comply with rejection of the first and

second restriction. And the prices are concluded to be stationary if also the last restriction is rejected. Note, however, that we may also have the situation in which one or two prices are already stationary before taking first differences. In that case the *trace* statistic will reject the first respectively the first and second restriction. So to be sure that the result of the *trace* test really points to a cointegration relation, a next step is to test for the absence of the right-hand-side variable in the cointegration relation. In Table 2 the results of the *trace* test are presented.

Table 2   Trace test on cointegration rank in tri-variate VAR

Rank	Trace statistic	5% critical value
$= 0$	27.73*	24.28
≤ 1	8.08	12.32
≤ 2	1.92	4.13

Note: * denotes rejection of the restriction at the 5% level. The trace statistic is computed according to the small sample correction in Johansen (2002) and the critical values are adopted from MacKinnon et al. (1999), Table II. The number of significant test statistics does not change if constant and linear trend are successively included in the VECM. Hence, the VECM without deterministic terms is selected, see Johansen (1992).

The results in Table 2 indicate one cointegration relation instead of the two we expected. The VECM in which we still allow for two cointegration relations (cf. (2a) - (2c)) appears to be (standard errors in ( ), *t* values in [ ] and *p* values in { }):

$$\Delta p_{pt} = -0.17(p_{g,t-1} - 0.99p_{p,t-1}) + 0.29(p_{s,t-1} - 0.93p_{p,t-1}) + \hat{\varepsilon}_{pt} \qquad (4a)$$
$$ (0.28) \qquad (0.02) \qquad (0.21) \qquad (0.03)$$
$$ [-0.60] \qquad [-49.14] \qquad [1.39] \qquad [-27.06]$$
$$R^2 = 0.09; F(2,20) = 1.08 \; \{0.36\}; \text{Durbin-Watson} = 1.36$$

$$\Delta p_{gt} = -1.12(p_{g,t-1} - 0.99p_{p,t-1}) + 0.08(p_{s,t-1} - 0.93p_{p,t-1}) + \hat{\varepsilon}_{gt} \qquad (4b)$$
$$ (0.36) \qquad (0.02) \qquad (0.27) \qquad (0.03)$$
$$ [-3.08] \qquad [-49.14] \qquad [0.30] \qquad [-27.06]$$
$$R^2 = 0.32; F(2,20) = 4.72 \; \{0.02\}; \text{Durbin-Watson} = 1.26$$

$$\Delta p_{st} = -0.49(p_{g,t-1} - 0.99p_{p,t-1}) - 0.64(p_{s,t-1} - 0.93p_{p,t-1}) + \hat{\varepsilon}_{st} \qquad (4c)$$
$$ (0.41) \qquad (0.02) \qquad (0.30) \qquad (0.03)$$
$$ [-1.20] \qquad [-49.14] \qquad [-2.11] \qquad [-27.06]$$
$$R^2 = 0.26; F(2,20) = 3.53 \; \{0.0488\}; \text{Durbin-Watson} = 2.13$$

where the $F(2,21)$ statistic tests for the absence of both error-correction terms (after including a unrestricted constant term in the equation). First of all, the high absolute *t* values with respect to the coefficients of $p_{p,t-1}$ in the cointegration relations provide clear evidence that none of the prices is

already stationary before taking first differences. Note that this conclusion shows that the Johansen procedure also tests for the order of integration of the variables involved, making it unnecessary to first apply Augmented Dickey-Fuller (ADF) tests for this purpose before using Johansen. Secondly, the "speed-of-adjustment" parameter of the error-correction term $(p_{g,t-1} - 0.99p_{p,t-1})$ in (4b) is quite significant and because it lies in the interval $[-2, 0]$ its estimate complies with error-correction behaviour. The same is true for the parameter of the error-correction term $(p_{s,t-1} - 0.93p_{p,t-1})$ in (4c), although its t value may only be slightly significant when compared to the quantiles of the Student-t distribution and rather insignificant when compared with Dickey-Fuller kind of distribution quantiles that one has to use when testing for the absence of cointegration through testing for the absence of error-correction. Still, we may consider the estimate as showing some glimpse of error-correction and hence, cointegration between p_{st} and p_{pt}.

Table 3   Trace test on cointegration rank in the two bi-variate VARs

Rank	Trace test statistic VAR of p_{pt} and p_{gt}	Trace test statistic VAR of p_{pt} and p_{st}	Five percent critical value
$= 0$	16.84*	13.61*	12.32
≤ 1	1.45	2.90	4.13

Note: * denotes rejection of the restriction at the 5% level. The trace statistic is computed according to the small sample correction in Johansen (2002) and the critical values are adopted from MacKinnon et al. (1999), Table II. The number of significant test statistics does not change if constant and linear trend are successively included in the VECM. Hence, the VECM without deterministic terms is selected, see Johansen (1992).

In addition, the insignificance of the speed-of-adjustment parameters in (4a) together with the insignificance of the parameter of $(p_{s,t-1} - 0.93p_{p,t-1})$ in (4b) and the parameter of $(p_{g,t-1} - 0.99p_{p,t-1})$ in (4c), suggest a structure in which the cointegration among p_{pt}, p_{gt} and p_{st} can also be tested for in two bi-variate VARs consisting of p_{pt} and p_{gt}, and p_{pt} and p_{st}. The lag-length of these two VARs was also selected to be one. Table 3 displays the cointegration test results.

According to Table 3 the Johansen *trace* test now also comes to the conclusion that there are two cointegration relations such that the three prices are cointegrated with each other in the form of linear bivariate price relationships. The associated error-correction models confirm the result in (4a) that p_{pt} does not display any error-correction. Hence, we decide to condition Δp_{gt} and Δp_{st} on Δp_{pt}. Next, it

appears that Δp_{st} does not significantly enter the Δp_{gt} equation and, the other way round, Δp_{gt} does not significantly enter the Δp_{st} equation. Consequently, after including Δp_{pt} on the right-hand-side no correlation is left between the residuals of the equations of Δp_{gt} and Δp_{st}. We can now write these two conditional error-correction equations as

$$\Delta p_{gt} = 1.04\Delta p_{pt} - 1.00(p_{g,t-1} - p_{p,t-1}) - 0.03p_{p,t-1} + \hat{u}_{gt} \qquad (5a)$$
$$\quad\;\; (0.17) \qquad\;\; (0.24) \qquad\qquad\quad (0.07)$$
$$\quad\;\; [6.11] \qquad\;\; [-4.23] \qquad\qquad\quad [-0.43]$$
$$R^2 = 0.78; \; F(3,19) = 22.37 \; \{0.00\}; \text{Durbin-Watson} = 1.37$$

$$\Delta p_{st} = 0.56\Delta p_{pt} - 0.83(p_{s,t-1} - p_{p,t-1}) + 0.04p_{p,t-1} + \hat{u}_{st} \qquad (5b)$$
$$\quad\;\; (0.23) \qquad\;\; (0.25) \qquad\qquad\quad (0.10)$$
$$\quad\;\; [2.43] \qquad\;\; [-3.30] \qquad\qquad\quad [-0.42]$$
$$R^2 = 0.41; \; F(3,23) = 5.24 \; \{0.0066\}; \text{Durbin-Watson} = 2.02$$

Note that in both equations, (5a) and (5b), the coefficient of the last regressor, $p_{p,t-1}$, is highly insignificant. Consequently, we cannot reject the restriction that the parameters on the right-hand-side of the bivariate price cointegration equations are equal to one, leading to the conclusion that the LOP holds in the long run. So the cointegration residuals are simply the price differentials between the markets. After imposing this long-run LOP restriction on (5a) and (5b) we also tested for the hypothesis that the LOP holds in the short run as well. With respect to a shock in p_{pt} this hypothesis imposes the restrictions that the parameter of Δp_{pt} is equal to one and the parameter of the price differential is equal to minus one. The estimates in equation (5a) clearly comply with these restrictions and indeed, we could not reject them (p value = 0.98). In (5b) the parameter estimates differs more from the short-run LOP restrictions than in (5a). Nevertheless, in (5b) they cannot be rejected (p value = 0.20) either. Still, we do not impose the short-run LOP on (5b) yet, but first look for further evidence by applying an impulse response analysis.

Before applying the impulse response analysis, let us first present the full structural VECM we ended up with by the analyses above:

$$\Delta p_{pt} = \varepsilon_{pt} \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad (6a)$$
$$\Delta p_{gt} = \Delta p_{pt} - (p_{g,t-1} - p_{p,t-1}) + u_{gt} \qquad\qquad\quad (6b)$$
$$\Delta p_{st} = 0.58\Delta p_{pt} - 0.85(p_{s,t-1} - p_{p,t-1}) + \hat{u}_{st} \qquad (6c)$$

implying a reduced-form given by

$$\Delta p_{pt} = \varepsilon_{pt} \tag{7a}$$
$$\Delta p_{gt} = -(p_{g,t-1} - p_{p,t-1}) + \varepsilon_{gt} \tag{7b}$$
$$\Delta p_{st} = -0.85(p_{s,t-1} - p_{p,t-1}) + \hat{\varepsilon}_{st} \tag{7c}$$

where $\varepsilon_{gt} = \varepsilon_{pt} + u_{gt}$ and $\hat{\varepsilon}_{st} = 0.58\varepsilon_{pt} + \hat{u}_{st}$. In matrix notation we can rewrite (7a) - (7c) into

$$\Delta \mathbf{p}_t = \boldsymbol{\alpha}\boldsymbol{\beta}'\mathbf{p}_{t-1} + \boldsymbol{\varepsilon}_t \tag{8}$$

cf. (3), where

$$\boldsymbol{\alpha} = \begin{pmatrix} 0 & 0 \\ -1 & 0 \\ 0 & -0.85 \end{pmatrix}$$

is the (3×2) matrix of speed-of-adjustment parameters and

$$\boldsymbol{\beta} = \begin{pmatrix} -1 & -1 \\ 1 & 0 \\ 0 & 1 \end{pmatrix}$$

is the matrix with both cointegrating vectors. For computing the impulse responses and their standard errors it is convenient to rewrite (8) into a model with $\mathbf{p}_t$ as dependent variable and only lags of $\boldsymbol{\varepsilon}_t$ as independent variables, i.e., the Vector Moving Average (MVA) representation of $\mathbf{p}_t$. To do so, we make use of the orthogonal matrices $\boldsymbol{\alpha}_\perp' = (1 \ \ 0 \ \ 0)$ and $\boldsymbol{\beta}_\perp' = (1 \ \ 1 \ \ 1)$ (cf. Johansen, 1995, p. 48) such that $\boldsymbol{\alpha}_\perp'\boldsymbol{\alpha} = (0 \ 0)$ and $\boldsymbol{\beta}_\perp'\boldsymbol{\beta} = (0 \ 0)$, and the relation (Johansen, 1995, p. 39):

$$\mathbf{I} = \boldsymbol{\beta}_\perp(\boldsymbol{\alpha}_\perp'\boldsymbol{\beta}_\perp)^{-1}\boldsymbol{\alpha}_\perp' + \boldsymbol{\alpha}(\boldsymbol{\beta}'\boldsymbol{\alpha})^{-1}\boldsymbol{\beta}' \tag{9}$$

Pre-multiplying (8) by $\boldsymbol{\alpha}_\perp'$ and solving for $\mathbf{p}_t$ gives:

$$\boldsymbol{\alpha}_\perp'\mathbf{p}_t = \boldsymbol{\alpha}_\perp'(\mathbf{p}_0 + \sum_{i=0}^{t} \boldsymbol{\varepsilon}_{t-i}) \tag{10}$$

which shows that $\boldsymbol{\alpha}_\perp'\mathbf{p}_t$ is the common *stochastic* trend in the prices. With our estimation of $\boldsymbol{\alpha}_\perp$ this trend is represented by p_{pt}. Next, pre-multiplying (8) by $\boldsymbol{\beta}'$ and solving for $\mathbf{p}_t$ gives:

$$\boldsymbol{\beta}'\mathbf{p}_t = \sum_{i=0}^{\infty} (\mathbf{I} + \boldsymbol{\beta}'\boldsymbol{\alpha})^i \boldsymbol{\beta}'\boldsymbol{\varepsilon}_{t-i} \tag{11}$$

for t goes to infinity. Since $\boldsymbol{\beta}'\mathbf{p}_t$ is stationary, the roots z of the characteristic equation $|\mathbf{I} - (\mathbf{I} + \boldsymbol{\beta}'\boldsymbol{\alpha})z| = 0$ must lie outside the unit circle. With our estimates for $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ we have one root: $z = 6.67 > 0$. Combining (10) and (11) with the use of (9) gives the VMA representation of $\mathbf{p}_t$:

$$\mathbf{p}_t = \boldsymbol{\beta}_\perp(\boldsymbol{\alpha}_\perp'\boldsymbol{\beta}_\perp)^{-1}\boldsymbol{\alpha}_\perp'(\mathbf{p}_0 + \sum_{i=0}^{t} \boldsymbol{\varepsilon}_{t-i}) + \boldsymbol{\alpha}(\boldsymbol{\beta}'\boldsymbol{\alpha})^{-1}\sum_{i=0}^{\infty}(\mathbf{I} + \boldsymbol{\beta}'\boldsymbol{\alpha})^i\boldsymbol{\beta}'\boldsymbol{\varepsilon}_{t-i} \tag{12}$$

where the former term on the right-hand-side is the permanent component in $\mathbf{p}_t$ and the latter one represents the transitory fluctuations in $\mathbf{p}_t$.

From the structural VECM we know that

$$\boldsymbol{\varepsilon}_t = \mathbf{A}\mathbf{u}_t \tag{13}$$

where

$$\mathbf{A} = \begin{pmatrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ 0.58 & 0 & 1 \end{pmatrix}$$

and $\mathbf{u}_t = (\varepsilon_{pt}, u_{gt}, u_{st})'$, a vector with uncorrelated residual terms. Consquently, a shock in p_{pt}, p_{gt} and p_{st} can be represented by $\mathbf{u}_p = (m_p, 0, 0)'$, $\mathbf{u}_g = (0, m_g, 0)'$ and $\mathbf{u}_s = (0, 0, m_s)'$, respectively, where m_p, m_g and m_s are the maximum absolute values of the ε_{pt}, u_{gt} and u_{st} empirical time series observations, respectively. The impulse responses are computed as ($i = 0, 1, ...$)

$$\mathbf{r}_{pi} = [\boldsymbol{\beta}_\perp(\boldsymbol{\alpha}_\perp'\boldsymbol{\beta}_\perp)^{-1}\boldsymbol{\alpha}_\perp' + \boldsymbol{\alpha}(\boldsymbol{\beta}'\boldsymbol{\alpha})^{-1}(\mathbf{I} + \boldsymbol{\beta}'\boldsymbol{\alpha})^i\boldsymbol{\beta}']\mathbf{A}\mathbf{u}_p \tag{14a}$$
$$\mathbf{r}_{gi} = [\boldsymbol{\beta}_\perp(\boldsymbol{\alpha}_\perp'\boldsymbol{\beta}_\perp)^{-1}\boldsymbol{\alpha}_\perp' + \boldsymbol{\alpha}(\boldsymbol{\beta}'\boldsymbol{\alpha})^{-1}(\mathbf{I} + \boldsymbol{\beta}'\boldsymbol{\alpha})^i\boldsymbol{\beta}']\mathbf{A}\mathbf{u}_g \tag{14b}$$
$$\mathbf{r}_{si} = [\boldsymbol{\beta}_\perp(\boldsymbol{\alpha}_\perp'\boldsymbol{\beta}_\perp)^{-1}\boldsymbol{\alpha}_\perp' + \boldsymbol{\alpha}(\boldsymbol{\beta}'\boldsymbol{\alpha})^{-1}(\mathbf{I} + \boldsymbol{\beta}'\boldsymbol{\alpha})^i\boldsymbol{\beta}']\mathbf{A}\mathbf{u}_s \tag{14c}$$

where $\mathbf{r}_{pi}$, $\mathbf{r}_{gi}$ and $\mathbf{r}_{si}$ are the (3×1) vectors of changes in p_{pt}, p_{gt} and p_{st} as a consequence of the $\mathbf{u}_p$, $\mathbf{u}_g$ and $\mathbf{u}_s$ shocks, respectively. Their variances are given by

$$\mathrm{var}(\mathbf{r}_i) = \sum_{j=0}^{i}[\boldsymbol{\beta}_\perp(\boldsymbol{\alpha}_\perp'\boldsymbol{\beta}_\perp)^{-1}\boldsymbol{\alpha}_\perp' + \boldsymbol{\alpha}(\boldsymbol{\beta}'\boldsymbol{\alpha})^{-1}(\mathbf{I} + \boldsymbol{\beta}'\boldsymbol{\alpha})^j\boldsymbol{\beta}']\boldsymbol{\Omega}$$
$$\times [\boldsymbol{\beta}_\perp(\boldsymbol{\alpha}_\perp'\boldsymbol{\beta}_\perp)^{-1}\boldsymbol{\alpha}_\perp' + \boldsymbol{\alpha}(\boldsymbol{\beta}'\boldsymbol{\alpha})^{-1}(\mathbf{I} + \boldsymbol{\beta}'\boldsymbol{\alpha})^j\boldsymbol{\beta}']' \tag{15}$$

where $\mathbf{r}_i = \mathbf{r}_{pi}$, $\mathbf{r}_{gi}$ or $\mathbf{r}_{si}$. These variances can be used to construct 95% confidence intervals around the impulse responses. From the graphs of the impulse responses and their 95% confidence intervals it appears that only one market shows evidence of lagged adjustment: after a shock in its own price, it takes Samdrup Jongkhar less than a month before its price does not significantly differ from the long-run price level. All other graphs do not reveal any significant responses. This confirms our earlier conclusion that with respect to potatoes not only in the long run, but also in the short run the price interactions between the Phuentsholing, Gelephu and Samdrup Jongkhar auctions comply with the LOP.

4. Discussion and conclusion

The overall conclusion of this study is that the evidence presented above indicates that the degree of price integration among the three permanent auctions in Bhutan was relatively good in the period 1996−2000. This conclusion assumes that there was sufficient market competition to prevent monopsony power in these markets. This is in line with the result of interviews conducted with potato wholesalers who were buying at the Phuentsholing auction. Price interactions between the auctions of Phuentsholing, Gelephu and Samdrup Jongkhar were interrelated not only in the long run, but also in the short run with Phuentsholing acting as the leading market. Nevertheless, short-run integration is in the context of this study a rather limited concept. It implies integration within one month, the basis period for which individual price data were obtained.

As discussed in section 2, this result does not imply that all potato farmers had easy access to these auctions in the border towns and, consequently, could directly benefit from the prices offered. An element for further research is to what extent the farm-gate prices, especially when farms are located in remote areas without good access to the road system, are price-integrated with these auction prices. This can be illustrated by the following citation (Penjore and Tshering, 1998):*"Several constraints were observed in the domain of the market infrastructure, post-harvest operations, lack of farmer's associations, road network and provision of inputs and extension to the numerous small, scattered farms in the country. Supply constraints originate mostly from scattered and inaccessible farms*

producing small volumes. There is a lack of adequate market price information on which farmers can base their production, storage and marketing decisions."

An interesting element of the Penjore and Tshering (1998) study is that wholesalers, after purchasing potatoes at the auction, sorted these into grades with a higher added value than the unsorted lot. This implies that growers leave a considerable part of the added value to the wholesaler. Penjore and Tshering (1998) compared auction prices and prevailing retail prices for selected commodities in Phuentsholing and concluded that marketing margins were relatively high, ranging from about 150% for apple and cabbage, about 75% for green chilli and tomato to about 40% for red potato.

Market access and adding value in post-harvest operations appeared to be major bottlenecks for farmers to reap a higher share of the value added in the potato supply chain in Bhutan in the 1996–2000 period. It is therefore recommended that both farmers and extension services take initiatives to improve post-harvest and marketing operations. This may be facilitated by group marketing or more vertical co-operation within the supply chain. Improvements in infrastructure are essential side conditions.

References

Bruneau, C., Jondeau, E., 1999. Long-run causality, with an application to international links between long-term interest rates. Oxford Bulletin of Economics and Statistics. 61, 545−568.

FCB, 2001. Interviews with staff of the Food Corporation of Bhutan in Thimphu and Phuentsholing. In: Van Tilburg, A., The Bhutan National Agricultural Marketing Plan. Report for the Ministry of Agriculture of Bhutan, developed in co-operation with the Agricultural Marketing Section, Policy and Planning Division of the Ministry of Agriculture and SNV Netherlands Development Organisation, Appendix B.

Johansen, S., 1992. Determination of cointegration rank in the presence of a linear trend. Oxford Bulletin of Economics and Statistics. 54, 383−397.

Johansen, S., 1995. Likelihood-Based Inference in Cointegrated Vector Autoregressive Models. Oxford University Press, Oxford.

Johansen, S., 2002. A small sample correction for the test of cointegrating rank in the vector autoregressive model. Econometrica. 70, 1929−1961.

Lütkepohl, H., 1991. Introduction to Multiple Time Series Analysis. Springer-Verlag, Berlin.

MacKinnon, J.G., Haug, A.A., Michelis, L., 1999. Numerical distribution functions of likelihood ratio tests for cointegration. Journal of Applied Econometrics. 14, 563−577.

Penjore, U., Tshering, C., 1998. Operations at the Phuentsholing Auction Yard and Produce Quality Assessment. IHDP/Ministry of Agriculture of Bhutan.

Pesaran, H.H., Shin, Y., 1998. Generalized impulse response analysis in multivariate models. Economic Letters. 58, 17−29.

Swinkels, R., Sinha, S., 2001. SNV Bhutan's Economic Opportunity Strategy. SNV Bhutan, 83 pp.

Van Tilburg, A., 2001. The Bhutan National Agricultural Marketing Plan. Report for the Ministry of Agriculture of Bhutan, developed in co-operation with the Agricultural Marketing Section, Policy and Planning Division of the Ministry of Agriculture and SNV, Netherlands Development Organisation, 51 pp.

Wangdi K., Maya, T., Beck, J., 2000. Study of the Fruit and Vegetable Marketing Channels in Punakha-Wangdue Valley. Ministery of Agriculture, Royal Government of Bhutan, 49 pp.