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International market and domestic fragrant rice markets integration in Pakistan: Evidence from quantile cointegration analysis

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Abstract

We study the relationship between export prices and domestic fragrant basmati rice markets in Pakistan over the period 2009 to 2022, combining monthly price data from five locations and six international references rice markets. Unlike previous studies, we use a quantile cointegration model to study market cointegration between the international and domestic rice markets. We find that cointegration is less likely when domestic prices are relatively low. In this, we argue that higher domestic prices will serve to motivate arbitrage thereby making domestic prices sensitive to export prices. Furthermore, we find evidence of inelastic relationship in which domestic prices seem insensitive to export prices. The results further suggest that if cointegration is more likely at the higher quantiles, then there might be an increase in sensivity, though an inelastic relationship remains.

Key words: Rice markets, Cointegration, Quantile regression, Pakistan

1. Introduction

Are local fragrant basmati rice markets in Pakistan integrated with the international market? In this study we provide an answer for Pakistan, a country where rice market has long been subjected to government control and interventions. Rice market interventions, however, have been minimal since 2001 as a result of the move by the government to merge the Rice Export Corporation of Pakistan with the Trading Corporation of Pakistan (Tobias et al., 2012). The imposition of the minimum export prices on four grades of rice (e.g., super basmati rice, basmati, broken white rice and long-grain rice) during the 2007-2008 food price crisis and its eventual withdrawal have highlighted the temporary nature of Bangladeshi rice trade policies and have renewed interest in the international agricultural price transmission.

Particularly for rice, price relations between export and domestic markets have constituted a keen area of research because of its key roles in policy formulation regarding investments in infrastructure for improving food security and reducing poverty (Ahmad and Gjølberg, 2015), and to the association with stabilization pricing policies implemented by governments whose objective is to ensure domestic food supply and deliver price stability (Dawe and Timmer, 2012). In addition, as argued by John (2013), the direction of price transmission between export and domestic rice markets has major policy implications for both rice-exporting and-importing countries.

There exist many recent studies that investigate the dynamic relationship between export and domestic rice prices (see, *inter alia*, Alam et al., 2012; Chulaphan et al., 2013; John, 2013; Ahmad and Gjølberg, 2015; Fiamohe et al., 2015; Chen and Saghaian, 2016; Lee and Valera, 2015; Sirikanchanarak et al., 2016; Barboza et al., 2020). As discussed in the following section, these studies consider cointegration in the context of threshold effects, regime change, and techniques that are intended to improve test power.

The contribution of our paper is to test for rice export-domestic price cointegration within a quantile cointegration framework. In the case of a potentially thick-tailed distribution, a quantile approach can deliver larger efficiency gains and provide more reliable results compared with the conventional least squared-based counterparts. Existing regression analyses of the relationship between different rice price series typically rely on OLS or least absolute deviations methods and so only estimate the marginal effects of the covariates on the conditional mean (median) function of the dependent variable. Such estimates sidestep the potentially heterogeneous patterns of the influence of the covariates in the conditional distribution. Rather than assume a constant speed of error correction, a quantile approach allows for differing speeds of adjustment across the quantiles. We also make further contributions to the understanding of the relations between export and domestic prices of rice. This paper follows Kuriyama's (2016) quantile cointegration approach, which, according to Xiao (2009), is essentially a time-varying approach for the detection and estimation of long-run relationships.

The paper is structured as follows. Section 2 provides an overview of rice trade policy in Pakistan and discusses recent literature on integration of domestic and global rice markets. Section 3 discusses our empirical approach. Section 4 describes the data used. Section 5 reports and discusses the obtained results. Section 6 provides some concluding remarks.

2. Recent literature

Market integration in prices is described as a situation when price trends move in the same direction as they respond similarly to market conditions (OECD, 2018). Market integration also shows the extent to which demand and supply information are communicated between two locations (Ahmad and Gjølberg, 2015). Market integration is associated with the law of one price, which suggests that given a free market, prices of a good would equalize across different locations through arbitrage (Chen and Saghaian, 2016). When a market is

well-integrated market, prices are competitive and the international market assures that domestic markets meet their local demands. As for arbitrage, which refers to the concept of moving products from lower-priced to higher-priced regions (Bierlen et al., 1998), it occurs when the price spread between two markets are exceed the transaction cost (Baulch, 1997). Even with gains from a price spread, however, it is still possible that arbitrage does not occur because of an imperfect market setup where factors such as natural hazards, government controls, imperfect information, and risk aversion are present (Baulch, 1997; Bierlen et al., 1998).

Numerous studies have examined market integration and price transmission in the context of rice prices. In the case of Pakistan, for example, Ahmad and Gjølberg (2015) used Engle-Granger and Johansen cointegration tests and found that Pakistani rice markets are integrated with the international markets based on Thailand and Vietnam reference export prices. However, the authors empahisized that Pakistan's extent of market integration with the international rice market have decreased because of rice export policies. Applying the vector autoregression (VAR) model, John (2013) showed that the Thai rice export shocks are transmitted into its domestic markets. From the perspective of the post-trade liberalization period in Bangladesh, Alam et al. (2012) used a Johansen multivariate cointegration test and an error-correction model and found a long-run and unidirectional relationship between the world reference prices for rice based on Thai 100% B and domestic wholesale prices of rice.

Meanwile, Chen and Saghaian (2016) applied the the Johansen test and threshold vector error correction model and showed that export prices of Thailand, Vietnam and United States cointegrated. Similarly, Chulaphan et al. (2013) found long-run relationships in prices of high and low quality rice among Pakistan, Thailand, Vietnam and the United States. Sirikanchanarak et al. (2016) found that there exist co-movements between the Thai 5% and Vietnam 5% export prices using the time-varying copula-based VAR models.

Lastly, Shively and Thapa (2016), and Hossain and Verbeke (2010) analyzed integration in the domestic rice markets. Using ARCH and GARCH models, they found strong evidence of local price intertemporal carryover and very weak evidence of a very low degree of integration from regional, central, and border markets to local markets. Hossain and Verbeke (2010) looked at the extent of market integration between six regional markets in Bangladesh after the rice market liberalization in the country using cointegration analysis and VECM. They showed that the six regions show no clear market integration in the short run due to either insignificant results or low elasticity. However, they showed that there is cointegration in the long run among regions. They further showed that long run integration tends to be quicker for regions that are geographically closer to each other suggesting a need for investment in transportation infrastructure and networks.

Unlike most of the above mentioned studies on rice market integration, we focus our investigation on the relationship between the domestic prices of fragrant rice in Pakistan and the reference export prices based on Thailand 5% and Vietnam 5% brokens. Analyzing the integration of fragrant rice market to the international market would provide crucial information to the donor agencies and breeders in international research centers and national governments in terms of evidence-base studies in support of decision-making and policies towards the provision and targeting of investment and research support for fragrant rice.

3. Methodology

Our empirical treatment proceeds on the basis of four stages with respect to analyzing the long-run relationships between domestic and export prices. First, we assess the correlation coefficient linking the Pakistan prices to export prices. This enables us to shed light on the nature of market integration with a measure of the direction and strength of correlation or co-movement between the two-price series. Second, we assess the time series properties of the price data using unit root tests. Third, though our focus is on the quantile-based investigation

of cointegration, we initially explore the long-run relationships between the two series using the conventional two-step Engle-Granger (non-)cointegration testing.

Fourth, we employ Kuriyama's (2016) quantile cointegration methodology upon confirmation of the absence of linear cointegration between the two series. The quantile cointegration approach inherits advantages from the conventional Engle and Granger (1987) that performs unit root tests on the residuals from the cointegrating regressions. Specifically, we consider the quantile cointegration model proposed by Kuriyama (2016). This model is an extension of Xiao and Phillips' (2002) fully modified analysis based on a cumulative sum (CUSUM) statistic to the case of conditional quantiles. Following Kuriyama (2016), we used CUSUM statistic to tests the equilibrium relationship between the domestic prices of basmati rice y_t and international reference prices x_t across different quantiles as follows:

$$y_t = \alpha'(\tau)d_t + \beta'(\tau)x_t + u_t(\tau) = \theta'(\tau)z_t + u_t(\tau), t = 1,2,\dots,T \quad (1)$$

where $\theta(\tau) = (\alpha'(\tau), \beta'(\tau))'$, $\tau \varepsilon [0,1]$, and $\hat{u}_t = y_t - \hat{\theta}'(\tau)z_t$. The quantile estimator is obtained by solving the following optimization problem:

$$\min_{\theta} \sum_{t=1}^{T} \rho_\tau(y_t - z_t'\theta(\tau)) \quad (2)$$

where $\rho_\tau(u) = u(\tau - I(u < 0))$ which denotes the asymmetric weights function specified in Koenker & Bassett (1978).

4. Data description

We obtained monthly observations of domestic prices of basmati rice in Pakistan and international reference prices from from the Food and Agriculture Organization' Global Information and Early Warning System on Food and Agriculture (FAO GIEWS) database for a period ranging from January 2009 to May 2022. In particular, we consider retail prices of basmati rice in five locations in Pakistan, namely Karachi, Lahore, Multan, Peshawar and Quetta. These markets are among the eight major domestic rice markets in Pakistan that also

includes Rawalpindi, Sukkur and Hyderabad (Ahmad et al., 2027). However, the choice of the aforementioned five rice markets is dictated by data availability. In addition, not only some of those five rice markets are involed in rice exports but also some of them are situated near the surplus and deficit rice production regions.

We considered monthly data on export prices of Thailand 5% brokens, Thailand 25% brokens, Vietnam 5% brokens and Vietnam 25% brokens as international references prices in line with Jamora and von Cramon-Taubadel (2016, 2017). Other studies that used Thailand and Vietnamese rice prices include Coxhead et al. (2012), and Ahmad and Gjølberg (2015). These broken rice classes are regarded as a coarse rice variety, while basmati rice is a fragrant and long grain rice variety that commands a higher price than non-aromatic rice (Calingacion, 2014).

Figure 1 displays the data for Pakistan domestic prices of basmati rice and prices of Thailand 5% brokens and Vietnam 5% brokens. There appears to be limited evidence of a close positive relationship here. In fact, there appears to be instances where a negative relationship could be present. This might further the case for a quantile-based investigation. The positive or negative direction of correlation should be interpreted with caution. For example, in integrated markets, negative correlation could occur when markets shift to alternative supplies as a result of either prices increases are being transmitted or as prices increase. In this case, non-zero correlations in the first instance may provide an indicative measure of market integration (OECD, 2018).

[Insert Figure 1 here]

To shed light on rice market integration, Table 1 reports pairwise correlations of monthly rice prices. Domestic rice prices in Pakistan exhibit positive correlation with both export prices of Thailand 5% brokens and Vietnam 5% brokens. The positive correlation could be potentially linked to the trade scale of rice of Pakistan, Thailand and Vietnam and

their vital positions in the global rice trade. Those three countries are among the large rice exporters with many export-partner countries (Chen and Zhao, 2023). However, there is relative low correlation between the Pakistani domestic basmati rice prices and the aforementioned international benchmark prices. This can be attributed to the price of basmati rice, which has an aromatic or fragrance feature, not being closely related to the price of coarse rice. As Giraud (2013) pointed out, there has been a split between price trends in fragrant and coarse rice prices starting in the mid-2000s, with coarse rice prices flattening while fragrant rice prices has barely seen any significant decrease from its peak prices in 2008. According to OECD (2018), integrated markes would be associated with higher correlation between the price levels or price changes of rice in two countries. In this case, rice prices move together closely and respond similarly to regional or international events or shocks. In integrated markets, however, prices could go either way. For example, markets may shift to alternative supplies as prices increase or with the transmission of price increases. This would give rise to the presence of negative correlations (OECD, 2018).

[Insert Table 1 here]

5. Empirical results

The results are divided into three parts. In the first part, we provide the unit root test results for the domestic and export price data series. In the second part of our analysis, we estimate a conventional cointegration test aimed at unraveling the long-run relationships between domestic and export prices. In the third part of our analysis, we test whether or not the quantile long-run equilibrium relationship exists between the two price series.

5.1. Univariate unit root tests

Our empirical work begins with data specification. Table 2 reports the unit root test results for the domestic and export price data series. The results indicate that the unit-root null cannot be rejected by the DF-GLS test for most of the price series. These results are

consistent with the findings in the literature such as Ahmad and Gjølberg (2015) and Ghafoor and Aswan (2012). However, the results also suggest that the unit-root null is rejected at the 10% significant level in the cases of export prices of Vietnam 5% and 25% brokens. Overall, the results in Table 2 gives rise to the possibility of cointegrating relationship between the export and domestic price series.

[Insert Table 2 here]

5.2. Two-step cointegration test

As an initial exploration of the long-run relationships between domestic and export prices is conducted using two-step Engle-Granger (non-)cointegration testing. The results reported in Table 3 indicate that the null of non-cointegration is not rejected at the 5% significance level for all the bivariate cases. This is in conformity with the results in Ahmad and Gjølberg (2015) with respect to the relationship between the domestic prices of IRRI rice varieties in Pakistan and international prices using Thailand and Vietnam as bechmarks. Inefficient flow of information and higher marketing margins in one market as compared to other markets could be the main reason for such absence of cointegration. Ahmad and Gjølberg (2015) emphasized that if price signals are not transmitted efficiently from one market to another, decisions among rice producers, consumers, and inventory holders may be non-optimal. In addition, no cointegration may reflect low levels of trade and poor infrastructure. The possible absence of cointegration between those five locations may also reflect the distance between those markets that are located in different provinces. The lack of evidence in support of linear cointegration motivates us to explore the possibility of quantile cointegration.

[Insert Table 3 here]

5.3. Quantile cointegration test results

Table 4 reports the CUSUM cointegration test results for 6 export price-domestic price groups of 4 relationships each across 9 quantiles. This gives rise to 216 quantile cointegration tests. In contrast to the previous Engle-Granger results, there is now evidence of cointegration. While the cointegration null hypothesis is rejected in most cases, there is evidence of quantile cointegration in 13 of the cases or 6% of the sample that we consider. These cases are indicated by shading. Of the 24 relationships that we consider, 9 of the relationships or 38% of our sample is characterized by cointegration in at least one quantile. For Pakistan, domestic basmati rice prices at the national level are cointegrated with three international reference prices, namely Thailand 5% brokens, Thailand 25% brokens and Vietnam 5% brokens. There is evidence of integration between three local basmati rice markets and world market using prices for Thailand 5% brokens. For Peshawar local rice market, there is evidence of integration with two international reference prices (Thailand 5% brokens and Vietnam 25% brokens). The Karachi local market is integrated with Thailand 5% brokens and Vietnam 5% brokens, while Multan is integrated with Vietnam 25% brokens.

The results discussed above can be explained as follows. Peshawar is situated close to the border of Afghanistan, whose rice imports are primarily sourced from Pakistan, India and China. Meanwhile, Karachi is a port city from which rice is shipped to other countries and therefore exposed to the international rice markets. As for Multan, this market is not only situated near the Indian borer, but also located relative close to production or supply areas in Pakistan. Thus, Peshawar, Karachi and Multan domestic rice prices exhibit integration with Thailand and Vietnam prices potentially because the global rice trade networks of these two countries and the exposure of Pakistan to international rice markets through border trade and

port could have facilitated price signals and information to freely flow from the world markets to those three domestic rice markets in Pakistan.

[Insert Table 4 here]

There are three main points emanating from the results contained in Table 4. First, cointegration occurs at the higher quantiles for the majority of 13 cases where there is evidence of cointegration. This point suggests that cointegration is a phenomenon that is more likely when the domestic price series are relatively high in relation to their respective sample means. Another way of describing this result is to say that cointegration is less likely when domestic prices are relatively low.

The way to explain such an asymmetric cointegrating relationship is from the perspective of speculative trading in rice. The attribute of basmati rice is considered to have an aromatic feature that improves with age. For milled basmati rice, previous year's rice may command a higher price than the current fresh season's produce. Generally, it is considered that six to nine months of post-harvest storage improves aroma. Taking into account this factor, one needs to also look at the seasonality effect. A priori, when prices are high, there is a lot of speculative trading in rice and non-sector related investors also jump in to benefit from price plays. With depressed prices, there is a possibility that the speculative trade element is low and hence lower cointegration. Because of lack of access of farmers to storage, it is an annual trade strategy for investors and downstream rice value chain actors to buy paddy at harvest and store for two to six months in order to benefit from the usual expected increase in prices. Based on the foregoing discussion, we argue that higher domestic prices will serve to motivate arbitrage thereby making domestic prices sensitive to export prices.

Our second key point is that in all cases where quantile cointegration is present, the positive slope slope estimator $\hat{\beta}^{+}(\tau)$ that links domestic and export prices is inelastic and less

than 0.5. There are two ways to explain this inelastic relationship where domestic prices of basmati rice seem insensitive to export prices. First, basmati rice is most preferred among all the types of rice available in Pakistan where the vast majority of basmati produce is locally consumed and sold in the domestic markets as highest price rice (Akhter and Haider, 2020). Pakistan only exports small quantities of basmati rice and it is consumed primarily by higher income consumers[1]. Thus international price fluctuations are of less concern for food security resulting in the insensitivity of domestic prices to export prices.

Second, not sensitive to price shocks but rather irrigated area; According to Ahmad and Gjølberg (2015), possible reasons for the inelastic relationship include trade rigidities, and the lack of transportation infrastructure and networks. In the case of the Pakistani fragrant rice market, prices do not respond to the same extent that international coarse rice prices react to market signals (Giraud, 2013).

The third message emerging from our result is that for the three cases where cointegration occurs in more than quantile, there is some evidence that sensitivity to international prices increases with the quantile. For each relationship, there is generally limited variation in the beta estimates across the quantiles. For a given quantile, there is considerable variation in the beta estimates across the relationships. This applies to Lahore local price-Thailand 5% brokens and Multan local price-Vietnam 25% brokens, but the opposite applies to Pakistan domestic price-Thailand 25% brokens. The overall message of the above findings is that if cointegration is more likely at the higher quantiles, then there might be an increase in sensivity, though an inelastic relationship remains.

4. Concluding remarks

Findings from this study indicate that cointegration is less likely when domestic prices are relatively low. Thus, we argue that higher domestic prices will serve to motivate arbitrage

[1] Pakistani basmati rice is mainly exported to Saudi Arabia, EU, Kuwait, Union of Arab Emirates and the US.

thereby making domestic prices sensitive to export prices. We also find that there is inelastic relationship in which domestic prices seem insensitive to export prices. Furthermore, the results suggest that if cointegration is more likely at the higher quantiles, then there might be an increase in sensivity, though an inelastic relationship remains. International and domestic market integration is important for providing unbiased information on prices to Pakistan's basmati rice producers, which will help the government implement policy reforms through price channel.

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Figure 1. Pakistan domestic basmati prices and export prices for Thailan 5% and Vietnam 5% brokens, January 2009-May 2022.

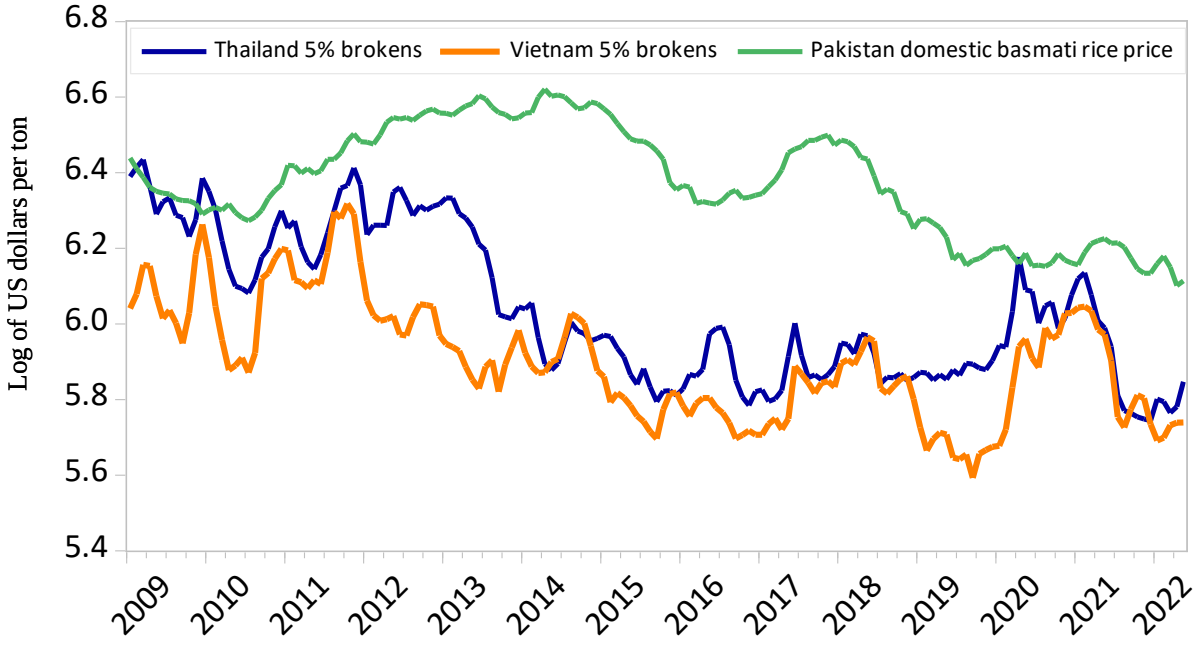

Table 1. Correlation Matrix

	Pakistan domestic price	Thailand 5% brokens	Vietnam 5% brokens
Pakistan domestic price	1.000		
Thailand 5% brokens	0.308	1.000	
Vietnam 5% brokens	0.275	0.817	1.000

Table 2. Elliott-Rothenberg-Stock DF-GLS tests

Series	Level	First Difference
Karachi basmati price	-1.176424	-1.654294 *
Lahore basmati price	-0.876107	-7.294372 ***
Multan basmati price	-0.377712	-6.933032 ***
Peshawar basmati price	-0.146615	-9.646085 ***
Quetta basmati price	-0.881041	-10.12778 ***
Pakistan export price	-0.818130	-8.686456 ***
Thailand 5% brokens	2.129	-5.178 ***

Notes: These are DF-GLS test statistics based on regressions that include a constant, but exclude a deterministic trend. In these regressions, the Schwarz Information Criterion determines the lag length. *** denotes rejection of the non-stationary null at the 1% level.

Table 3. Engle-Granger (Non-)Cointegration Tests

y-x	τ-statistic	p-value
Pakistan average price-Thailand 5% brokens	-0.4195	0.9684
Pakistan average price-Thailand 25% brokens	-0.3709	0.9715
Pakistan average price-Vietnam 5% brokens	-1.0380	0.8947
Pakistan average price-Vietnam 25% brokens	-0.9597	0.9088
Karachi local price-Thailand 5% brokens	-1.2691	0.8403
Karachi local price-Thailand 25% brokens	-1.2743	0.8388
Karachi local price-Vietnam 5% brokens	-1.3329	0.8214
Karachi local price-Vietnam 25% brokens	-1.3056	0.8297
Lahore local price-Thailand 5% brokens	-1.4365	0.7869
Lahore local price-Thailand 25% brokens	-1.4653	0.7765
Lahore local price-Vietnam 5% brokens	-1.6660	0.6941
Lahore local price-Vietnam 25% brokens	-1.5744	0.7337
Multan local price-Thailand 5% brokens	-0.7953	0.9330
Multan local price-Thailand 25% brokens	-0.7770	0.9353
Multan local price-Vietnam 5% brokens	-1.0684	0.8887
Multan local price-Vietnam 25% brokens	-1.0144	0.8992
Peshawar local price-Thailand 5% brokens	-1.1919	0.8608
Peshawar local price-Thailand 25% brokens	-1.1346	0.8744
Peshawar local price-Vietnam 5% brokens	-1.5843	0.7296
Peshawar local price-Vietnam 25% brokens	-1.1937	0.8603
Quetta local price-Thailand 5% brokens	-1.3186	0.8258
Quetta local price-Thailand 25% brokens	-1.2655	0.8413
Quetta local price-Vietnam 5% brokens	-1.3684	0.8101
Quetta local price-Vietnam 25% brokens	-1.3323	0.8216

Notes: These are Engle-Granger OLS-based (non-)cointegration tests. The lag specification throughout is based on the Schwarz criterion. All regressions include a deterministic constant. MacKinnon (1996) *p*-values are reported in the righthand column.

Table 4. Quantile regression results

y–x		τ = 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Pakistan average price-Thailand 5% brokens	$\hat{\beta}^{+}(\tau)$	0.2893	0.3794	0.3599	0.2526	0.2235	0.2070	0.1367	0.0933	-0.0488
	$CS_T(\tau)$	8.4769**	5.1024**	5.4206**	0.9355	4.1697**	2.9919**	6.1020*	8.8858**	11.9000**
Pakistan average price-Thailand 25% brokens	$\hat{\beta}^{+}(\tau)$	0.2624	0.4800	0.4396	0.4212	0.2013	0.1816	0.0871	0.0101	-0.0943
	$CS_T(\tau)$	5.7484**	6.4195**	0.9674	1.1737*	4.3569**	5.3576**	6.7155	9.0336**	16.5515**
Pakistan average price-Vietnam 5% brokens	$\hat{\beta}^{+}(\tau)$	0.1933	0.3947	0.3081	0.2172	0.1550	0.2511	0.1024	0.2247	0.0290
	$CS_T(\tau)$	6.4136**	9.3419**	2.9517**	3.4743**	4.3651**	0.9292	1.9054**	6.4511*	6.0952**
Pakistan average price-Vietnam 25% brokens	$\hat{\beta}^{+}(\tau)$	0.1291	0.3706	0.2953	0.2570	0.1521	0.2542	0.0487	0.2277	-0.0277
	$CS_T(\tau)$	6.3359**	9.5710**	2.8790**	3.6257**	4.4686**	2.1127**	1.9646**	6.3479**	6.1597**
Karachi local price-Thailand 5% brokens	$\hat{\beta}^{+}(\tau)$	0.0790	-0.0477	-0.0681	-0.1198	-0.0857	0.1073	0.0813	-0.0152	-0.1085
	$CS_T(\tau)$	1.9176**	2.3875**	3.0081**	3.6485**	3.9922**	0.8615	2.2815**	8.0957**	13.5688**
Karachi local price-Thailand 25% brokens	$\hat{\beta}^{+}(\tau)$	0.1276	-0.0531	-0.0709	-0.1314	-0.0065	0.0825	0.0437	-0.0847	-0.1471
	$CS_T(\tau)$	1.9153**	2.3870**	3.0272**	3.6320**	4.1739**	5.4474**	6.3835**	8.8560**	17.4657**
Karachi local price-Vietnam 5% brokens	$\hat{\beta}^{+}(\tau)$	0.0563	-0.0574	-0.0996	-0.1661	-0.1446	0.0817	0.0413	-0.0170	-0.1487
	$CS_T(\tau)$	1.9198**	2.4117**	2.9923**	3.6544**	4.3552**	1.0056	2.3575**	4.5345**	11.4613**
Karachi local price-Vietnam 25% brokens	$\hat{\beta}^{+}(\tau)$	0.0580	-0.0737	-0.1342	-0.1737	-0.1856	0.0530	0.0242	-0.0606	-0.2346
	$CS_T(\tau)$	1.9374**	2.4235**	2.9927**	3.6338**	4.3562**	3.5492**	1.7334**	5.8635**	9.4397**
Lahore local price-Thailand 5% brokens	$\hat{\beta}^{+}(\tau)$	0.2335	0.2496	0.3435	0.4915	0.4516	0.3733	0.2658	0.0966	0.0391
	$CS_T(\tau)$	1.1347	2.3236**	3.0704**	3.5656**	3.7907**	1.0810	3.6166**	5.4206**	2.0520**
Lahore local price-Thailand 25% brokens	$\hat{\beta}^{+}(\tau)$	-0.0857	0.2808	0.4944	0.6400	0.4915	0.3604	0.2004	0.0116	0.0381
	$CS_T(\tau)$	1.6984**	2.3311**	2.9921**	2.4455**	4.4328**	5.2625**	7.0699**	8.9780**	1.6914**
Lahore local price-Vietnam 5% brokens	$\hat{\beta}^{+}(\tau)$	0.0128	0.3552	0.3916	0.3892	0.3041	0.3835	0.1964	0.1746	0.1756
	$CS_T(\tau)$	1.6496**	2.5936**	3.0352**	3.7332**	4.3823**	3.5064**	1.8770**	3.2373**	7.5037**
Lahore local price-Vietnam 25% brokens	$\hat{\beta}^{+}(\tau)$	-0.2333	0.3388	0.4143	0.3675	0.3934	0.3592	0.1427	0.0968	0.0537
	$CS_T(\tau)$	1.6006**	2.4561**	2.9233**	3.6940**	4.4894**	1.3053*	4.9053**	3.3763**	6.7482**

Table 4. Quantile regression results (continued)

y–x		τ = 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Multan local price-Thailand 5% brokens	$\hat{\beta}^{+}(\tau)$	0.3305	0.3658	0.3324	0.3440	0.2828	0.1637	0.1210	0.2202	0.1533
	$CS_T(\tau)$	10.9045**	2.2721**	2.2916**	4.1633**	3.2681**	3.3660**	6.5619**	6.7338**	4.0420**
Multan local price-Thailand 25% brokens	$\hat{\beta}^{+}(\tau)$	0.3471	0.5374	0.4911	0.3372	0.2836	0.1095	0.0467	0.1641	0.1184
	$CS_T(\tau)$	15.6468**	4.9161**	1.6939**	3.6350**	4.5522**	5.4166**	6.8275**	9.9526**	10.5331**
Multan local price-Vietnam 5% brokens	$\hat{\beta}^{+}(\tau)$	0.2004	0.4087	0.2340	0.1881	0.2385	0.1755	0.2883	0.2683	0.3075
	$CS_T(\tau)$	1.9400**	9.1557**	2.8953**	3.6497**	4.4765**	3.2326**	2.2759**	1.5541**	1.8759**
Multan local price-Vietnam 25% brokens	$\hat{\beta}^{+}(\tau)$	0.1697	0.3343	0.2530	0.1496	0.1400	0.1104	0.1988	0.2631	0.2801
	$CS_T(\tau)$	1.9399**	9.0883**	2.7892**	3.6380**	4.3418**	5.3398**	0.8749	0.8879	0.5982
Peshawar local price-Thailand 5% brokens	$\hat{\beta}^{+}(\tau)$	0.6253	0.6217	0.4608	0.2879	0.1580	0.2981	0.3746	0.3687	0.2863
	$CS_T(\tau)$	15.1751**	8.4142**	4.8148**	3.1133**	4.2278**	0.7694	1.9569**	6.2646**	10.1961**
Peshawar local price-Thailand 25% brokens	$\hat{\beta}^{+}(\tau)$	0.4166	0.7368	0.4714	0.3320	0.2736	0.3466	0.3525	0.3302	0.1736
	$CS_T(\tau)$	15.2146**	5.9107**	3.0481**	3.5844**	4.3862**	4.1167**	5.7693**	9.2293**	10.7285**
Peshawar local price-Vietnam 5% brokens	$\hat{\beta}^{+}(\tau)$	0.2011	0.5017	0.3642	0.2476	0.2229	0.3014	0.4797	0.6793	0.7144
	$CS_T(\tau)$	1.4406**	9.5818**	2.4935**	2.7542**	1.3685*	2.3833**	2.9317**	2.3325**	1.6457**
Peshawar local price-Vietnam 25% brokens	$\hat{\beta}^{+}(\tau)$	0.0816	0.4319	0.3562	0.1979	0.2315	0.1929	0.4015	0.6912	0.2723
	$CS_T(\tau)$	2.3457**	1.3877*	1.3775**	3.1749**	1.7224**	1.1055	2.0160**	2.3406**	1.8871**
Quetta local price-Thailand 5% brokens	$\hat{\beta}^{+}(\tau)$	0.5361	0.4957	0.4800	0.3661	0.3327	0.0963	-0.0808	-0.2180	-0.3038
	$CS_T(\tau)$	17.4245**	10.5936**	7.9332**	6.3916**	4.9857**	2.0010**	6.5906**	9.1658**	14.4265**
Quetta local price-Thailand 25% brokens	$\hat{\beta}^{+}(\tau)$	0.6253	0.5313	0.4819	0.4140	0.3219	0.0515	-0.1458	-0.2835	-0.3670
	$CS_T(\tau)$	16.8153**	10.6911**	8.0546**	6.3141**	2.1038**	4.7127**	7.1071**	9.1732**	16.1941**
Quetta local price-Vietnam 5% brokens	$\hat{\beta}^{+}(\tau)$	0.6408	0.6037	0.5126	0.3665	0.3442	0.2127	0.0184	-0.0807	-0.1073
	$CS_T(\tau)$	16.4878**	10.5589**	7.9986**	6.4724**	5.1842**	3.5222**	2.9652**	5.3388**	3.7008**
Quetta local price-Vietnam 25% brokens	$\hat{\beta}^{+}(\tau)$	0.6351	0.5753	0.5148	0.3522	0.3060	0.0998	-0.0434	-0.1708	-0.1923
	$CS_T(\tau)$	15.9412**	10.5553**	7.9239**	6.5947**	5.1742**	2.4950**	2.6712**	6.4860**	8.8585**

Notes: $\hat{\beta}^{+}(\tau)$ and $CS_T(\tau)$ denote the fully modified coefficient estimate and CUSUM test. * and ** denote rejection of the null of cointegration at 5% and 1% levels, respectively. The cases where the cointegration null is not rejected are indicated with shading.