Testing Asymmetry in the Vertical Price Transmission Process of the Sri Lankan Tea Market Using a Non-linear ARDL Cointegration Approach

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ABSTRACT

The objective of this study is to test the asymmetry in price transmission along the tea supply chain of Sri Lanka. Using monthly export prices, Colombo Tea Auction (CTA) prices, and producer prices for 2001-2020, the presence of asymmetry was tested for market pairs, export market-CTA, and CTA-producer markets. A non-linear autoregressive distributed lag (NARDL) model was used as the analytical technique. The empirical results of the study suggest that CTA is not integrated with the export market but integrated with the producer market. This suggests changes in the international markets are not transmitted along the tea supply chain. The price transmission process between CTA and the producer market is asymmetric in both magnitude and speed. The response of green leaf prices in the producer market is marginally higher and faster when the tea price in the CTA decreases than it increases. Further studies are needed to identify the root causes for the non-integration between the CTA and the export market and the asymmetry in the price transmission process between the CTA and the producer market.

Keywords: *Colombo tea auction, Farm gate price, Non-linear ARDL model, Tea Markets, Tea Auction Prices*

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Introduction

Tea is considered the most consumed beverage in the world which will have a massive market in the future with different modifications (Xu *et al.*, 2022). Throughout history, tea has been a leading export crop in Sri Lanka, and its contribution to total export was 11 percent in 2020 with an export revenue of 1324.37 US$ million (EDB, 2022). It provides around one million direct and indirect employment opportunities (CBSL, 2016). Sri Lanka has a remarkable history in the global tea market in terms of production and exports. In 1950, the Sri Lankan share of world tea exports reached 34 percent, making Sri Lanka the leading global black tea exporter in the world (Kelegama, 2010; Kruithof, 1951; Food and Agriculture Organization, 1950). However, in 2020 Sri Lankan share of the World Tea export was only 14% (ITC Supplement to Annual Bulletin of Statistics, 2020). Considering the importance of the tea industry to the national economy, it has been owned by frequent attention from economists and policymakers. Various studies have been conducted on this subject, focusing on different aspects such as productivity, labour issues, and global competitiveness. Some researchers have also assessed the integration of the Colombo tea auction with other international tea auction markets such as India, Kenya, Malawi, Mombasa, etc (Dharmasena, 2004, Sekhar, 2012; Rembeza and Radlińska, 2020; Tanui *et al*, 2012: Yong-mei *et al*, 2022). The finding of these studies suggests that most of the auction markets (Dharmasena, 2014; Sekhar, 2012; Yong-mei *et al.*, 2022; Tanui *et al.*, 2012). However, research that focused on the integration between the export market and the domestic market is dearth except for Dang and Lantican (2016) which assessed both the spatial and vertical market integration of the tea supply chain focusing on the Vietnamese tea market.

The present study examines the integration between key nods in the tea supply chain and asymmetry in the vertical price transmission process in the Sri Lankan tea markets by employing a Nonlinear ARDL (NARDL) cointegration approach. Specifically, this study assesses the vertical market integration between the following market pairs; (1) Export market – Colombo Tea Auction (CTA) and (2) CTA - producer market. The study also assesses the presence of asymmetry in the vertical price transmission process between these market pairs. Integrated markets enable efficient price transmission along the supply chain. In the long run, it facilitates countries to expand their trade and improve their competitiveness in the global market. An understanding of price transmission can prove to be advantageous in adjusting supply chain activities, thereby gaining a competitive edge and staying ahead of the competition by eliminating inefficiencies that might exist.

Many economists use market integration as a way to gauge market efficiency, but recent research shows that market integration is not a necessary nor a sufficient condition for efficiency (Barrett, 1996). However, market integration does reflect the efficiency of price transmission. Asymmetric price transmission refers to the difference in the speed or magnitude of market responses to price increases compared to price decreases in an integrated market. By examining market integration and asymmetry in price transmission, researchers can identify inefficiencies and market distortions that can disrupt the flow of price transmission. The awareness and analysis of price asymmetry in the agricultural sector can empower stakeholders within the value chain to make informed decisions, leading to improved market efficiency and outcomes.

Tea Supply Chain and Price Determination

The tea supply chains in Sri Lanka are highly regarded for their organization. Figure 1 illustrates the flow of products, from the green leaf producers and collectors to the processors, auctioneers, exporters, retailers, and ultimately, the consumers. Tea cultivation is done in two major production sectors namely estate and smallholdings according to the extent cultivated and land ownership. The tea smallholding sector is defined by statute as having an area of less than 50 acres in cultivation. The estate sector (more than 50 acres and Government ownership) is comprised of Regional Plantation Company (RPC) Estates and State-owned Estates. There are around 949 primary tea processing factories comprised of private, RPC factories, and State-owned processing factories. Of these factories, only 650 are operative factories and the rest are not operating currently. Most of the smallholders do not have the capacity to process tea leaves harvested in their lands and leaves are directly transported to primary processing factories or sold to middlemen, licensed collectors who bring leaves to the factories.

The primarily processed tea then enters several market channels such as CTC, directly sold to exporters or retailers. However, more than 90% are sold through auction. Processed tea is usually taken to auction by sellers or brokers. Buyers at the tea auction are either exporters or secondary processors. Tea sold at the auction market undergoes secondary processing (blending, flavoring, instant tea), packaging, and branding before dispatch either to the export market or retail market through wholesalers. Secondary processing and packaging convert undifferentiated commodities to differentiated products such as tea bags, flavored tea, blended tea, etc (Ariyawardana, 2001). Even though tea is a major beverage among Sri Lankans, the lion's share (96.3% in 2018) of the tea production in the country is annually exported to international tea markets, mainly to Middle East countries such as Iran, Iraq, and Turkey, and China (EBD, 2022).

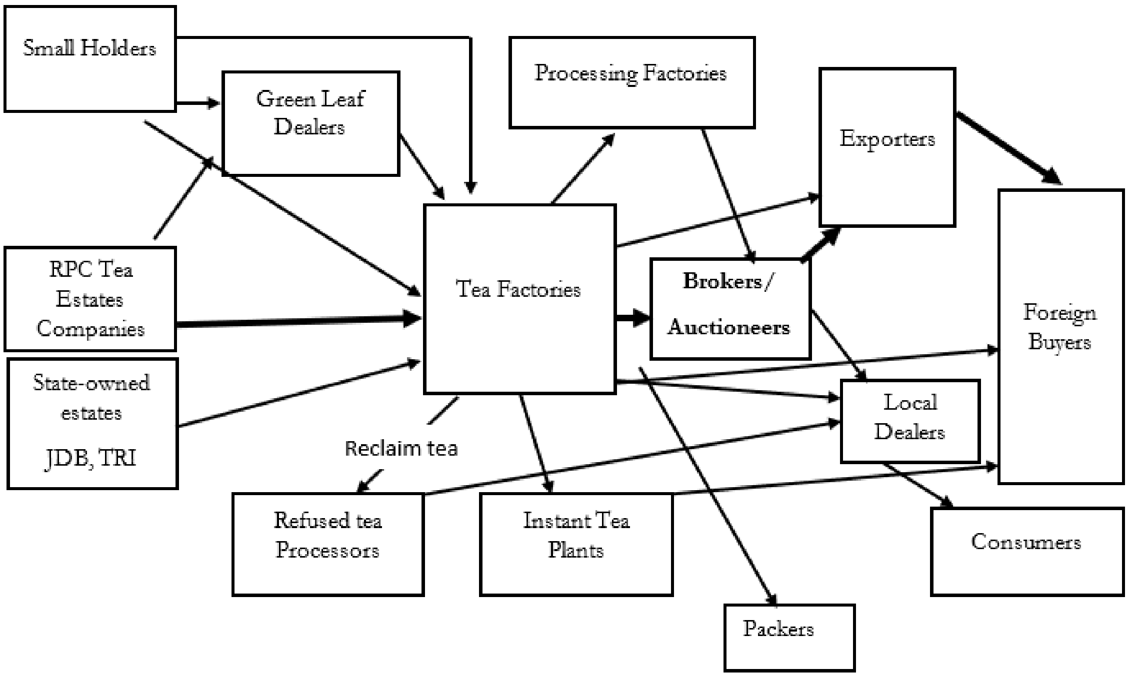

Figure 1. The Sri Lankan tea supply chain (adopted from Hemaratne, 2016)

Tea prices are determined at two market transactions namely, CTA and export point (Perera *et al.*, 2020). Colombo Tea Auction is the single largest tea auction center in the world which handles more than 300 million kilograms of black tea annually with almost 273 companies competing on behalf of principles from all over the world (Sri Lanka Tea Board, 2019; Sankalpana *et al*, 2018). Apart from the exporters, local supermarkets also buy a smaller percentage of tea from the Tea Auction. The price of black tea is determined at the CTA based on the demand and supply. Sellers or auctioneers take processed tea from tea factories to the auction. Before the auction, the auctioneers receive samples of every tea lot from the tea factories for testing and appraising. Upon testing, they prepare a broker's catalog and may also send samples to prospective buyers or their agents. At the auction, depending on the quality, buyers or brokers of buyers bid the price for a specific lot. If the sellers agree to the price, the transaction is completed. If the seller does not agree with the price, sellers can withdraw the lot from the auction. A broker charges 1-1.6% of the price realized at the auction in return for the service rendered and the rest is given to the tea processor. In determining the export market price, large exporters sign an agreement with buyers. Small exporters sign an agreement for a shipment.

Auctions are generally considered to be transparent, although some people have criticized the system for allowing collusion or unfair competition among buyers. This can lead to inefficiencies in the pricing structure, and lower prices for wholesalers (Thudugala, 1987). However, Motha and colleagues (2005) also have explained that the market operates as an oligopsony, with a few large firms dominating the market. Despite these concerns, a recent study has shown that auctions are quite competitive (Sankalpana *et al.*, 2018).

Prices for green leaves are determined based on the price realized at the Auction. To determine the farm-gate price of green leaves, several mechanisms have been adopted throughout history while addressing criticisms of each mechanism. In 1968, the green leaf price formula, given in Eq 1, was implemented to determine the green leaf price. According to the formula, the green leaf price is determined by the factory owners. After accounting for the cost of processing and the profit of the processor, a share of the price realized at the CTA has been given to the green leaf supplier.

$$Green\ leaf\ price = \frac{\text{Black tea price}-\{\text{Cost of processing}+\text{Processor's profit})}{4.65^{1}} \qquad (1)$$

This formula protects the processors from price risks at the cost of green leaf producers. Thus, in 1978, the formula was replaced by a guaranteed minimum price. However, due to the high inflation rate that prevailed in Sri Lanka since 1978, this minimum price was indexed to the inflation rate. Even though a guaranteed price protects the green leaf producers from price risk, it does not guarantee benefit sharing in the supply chain. To overcome the limitations of the guaranteed price, the Reasonable Pricing Formula was introduced in 1984. Accordingly, the price received by the factory (Net Sale Average) is divided among the processor and the green leaf supplier based on the proportion specified by the "Reasonable Pricing Formula". At the beginning of its adoption, a 25% share of the price realized at the CTA was given to the processor while the rest was given to the leaf supplier (Herath, 2003). In 1985, the share allocated to the processor and the producer was revised as 30% to the tea factory and 70% to leaf suppliers. These shares were again altered from 32% to 68% in 1987 and the same ratio is continuing currently as well.

These regulations are thought to minimize the inefficiencies in the price transmission process and ensure better passing of demand and supply changes across the tea supply chain. However, a scientific study to evaluate the price transmission process has not yet been conducted. It would be beneficial to have data-driven insights to improve the tea supply chain.

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[1]The denominator of 4.65 is the weight of green leaf required to make a unit weight of black tea and all the components are measured in the units of Rupees/kg.

Econometric Estimation

The presence of asymmetry in the price transmission (APT) process implies the asymmetric responses of prices in one market to price changes in another trading market. There are two main forms of asymmetry in the vertical price transmission process, (i) APT in magnitude and (ii) APT in adjustment speed. The former refers to a difference in the magnitude of the price transmission between markets that is conditional on the direction of the price in another market. The latter refers to the difference in time taken to respond conditionally to the direction of the price change in the connected market.

Studying the presence of APT is important due to its implication on resource allocations and welfare effects. Research that was done in both agriculture and non-agriculture markets proves that the presence of asymmetry is the norm rather than the exception (Fousekis, Katrakilidis, and Trachanas, 2016; Azzam, 1999; Bernard and Willett, 1996; Karrenbrock, 1991).

The most common reasons for the presence of APT are the non-competitive market, the presence of adjustment cost, and the market power (Panagiotou, 2021; Ben Abdallah *et al.*, 2020; Rezitis, 2019; Fousekis, Katrakilidis, and Trachanas, 2016; Meyer and Von Cramon-Taubadel, 2004). Not-so-common reasons cited in the literature include government intervention in the form of the minimum price, and distorted price reporting process (Bailey and Brorsen, 1989). Despite many theoretical speculations, only a few studies have empirically explored the reasons for the presence of APT.

The testing of the asymmetry of the price transmission process was started with the Wolfram–Hauck model suggested by Tweeten and Quance (1969) and advanced by Wolffram (1971) and Houck (1977). Later, the Threshold Error Correction Model (TECM), Threshold Auto-Regressive Models (TAR), Partial Adjustment Model (PAM), Regime Switching Model (RSM), and Non-Linear Auto Regressive Distributed Lag Model (NARDL) (Panagiotou, 2021; Abdallah *et al*, 2020; Rezitis, 2019; Fousekis, Katrakilidis, and Trachanas, 2016; Jojo, NA) were used for the same purpose.

The NARDL approach developed by Pesaran *et al*. (2001) to test the presence of asymmetry has several advantages over others in testing asymmetry, (i) the estimation of NARDL does not require price series to be integrated in the same order, I(d). As far as price series are not integrated I(2) (Menegaki, 2019), the NARDL approach can be used to test the asymmetry in the price transmission process. (ii) The NARDL approach performs better with small sample sizes than other multivariate cointegration procedures (Fousekis, Katrakilidis, and Trachanas, 2016).

The NARDL approach is an asymmetric version of the ARDL model.

The standard ARDL (p,q) model with two-time series Y_t and $X_t$is as follows;

$$\Delta Y_t = a_0 + \rho Y_{t-1} + \theta X_{t-1} + \gamma z_t + \sum_{j=1}^{p-1} a_j \Delta Y_{t-j} + \sum_{j=1}^{q-1} \pi_j \Delta X_{t-j} + e_t \quad (2)$$

The null hypothesis of the cointegration test is Y_t and $X_t$are not cointegrated. To account for asymmetry, Shin *et al*. (2014) introduced the NARDL model in which X_t is decomposed into its positive and negative partial sums as in Eq (3).

$$X_t = X_0 + X_t^+ + X_t^- \quad (3)$$

Where,

$$X_t^+ = \sum_{j=}^{t} \Delta X_j^+ = \sum_{j=1}^{t} \max(\Delta x_j 0) \; ; \; X_t^- = \sum_{j=1}^{t} \Delta X_j^- = \sum_{j=1}^{t} \min(\Delta x_j 0)$$

Then the long-run asymmetric cointegration relationship is expressed as

$$Y_t = \beta^+ X_t^+ + \beta^- X_t^- + u_t \quad (4)$$

In this equation, $\beta^+$and $\beta^-$are parameters to be estimated and they are associated with positive and negative changes of X_t. These are the long-run price transmission coefficients between the two markets. Incorporating Eq (4) in Eq (2), the below *NARDL (p,q)* can be obtained Eq (5).

$$he\ \Delta Y_t = a_0 + \rho Y_{t-1} + \theta^+ X_{t-1}^+ + \theta^- X_{t-1}^- + \sum_{j=1}^{p-1} a_j Y_{t-j} + \sum_{j=0}^{q-1} (\pi_j^+ \Delta x_{t-j}^+ + \pi_j^- \Delta x_{t-j)}^- + e_t \quad (5)$$

and that $\theta^+ = -\rho/\beta^+$and$\theta^- = -\rho/\beta^-$

Once the equation is estimated, the null hypothesis of no cointegration ($\rho = \theta^+ = \theta^- = 0$) is tested, under the approach proposed by Shin *et al*, (2014). The F_{PSS} (W_{PSS}) statistic can be used to test the null hypothesis of no cointegration between two time series. Here, the F_{PSS} statistics are compared against the lower and upper bound values produced by Shin *et al*, (2014). If the F_{PSS} value is above the upper bound value, the null hypothesis of no cointegration is rejected. If the F_{PSS} value is below the lower bound value, it is concluded that there is no adequate evidence to reject the null hypothesis. If the F_{PSS} value is in between the Upper and Lower bound values, it is concluded as inconclusive. Alternatively, t_{BDM} statistics also can be used to test the cointegration between two-time series.

The long-run asymmetry is assessed by testing the hypothand is $\beta^{+} = \beta^{-}$ while the short-run adjustment to a positive and negative shock is captured by testing using $\pi_j^{+} = \pi_j^{-}$ for all j = 1, …, q − 1 or the additive (weak-form) symmetry requiring $\sum_j^q {}_0^1\pi_j^{+} = \sum_j^q {}_0^1\pi_j^{-}$. These hypotheses are tested using the standard Wald test.

If the presence of asymmetry in the price transmission process is confirmed, the asymmetric responses to positive and negative shocks are respectively captured by the positive and negative dynamic multipliers associated with a unit change in x_t^{+} and x_t^{-} are as follows.

$$m_h^{+} = \sum_{j=0}^{h} \frac{\partial Y_{t+j}}{\partial X_t^{+}} \text{and } m_h^{-} = \sum_{j=0}^{h} \frac{\partial Y_{t+j}}{\partial X_t^{-}} \text{ with h= 0, 1, 2, …} \quad (6)$$

Results and Discussion

In testing the asymmetry in price transmission, the study used monthly prices of tea (expressed in US$ per 1kg) at the CTA, export market, and producer market. Monthly auction prices were collected from the World Bank commodity database for the period 2001 to 2020. Monthly average FOB prices for the above period were collected from the various issues of the Sri Lanka Tea Board Statistical Bulletin and monthly average producer prices for the same period were collected from the Sri Lanka Tea Board.

Table 1. Descriptive statistics of the price data

	Producer prices (US$/green leaf kg)	Auction prices (US$/Made tea kg)	FOB prices (US$/Made tea kg)
Mean	0.408	2.787	3.878
Standard deviation	0.117	0.806	1.069
Minimum	0.205	1.391	1.769
Maximum	0.626	4.270	5.435

As depicted in Figure 2, all price series, FOB, Auction, and producer, have shown an upward trend in price movement over the study period. All prices have shown a sudden surge in 2007. The graphs signal that the movement of prices is not common. More importantly, graphs show that the price gap has widened between Export-CTA and CTA-producer markets after 2007.

Table 2 presents the ADF test results. The results of the ADF test confirmed that all price series, Export Market Price (FOB), CTA price, and producer prices are integrated in order (1). This qualifies the price data for applying NARDL to the model.

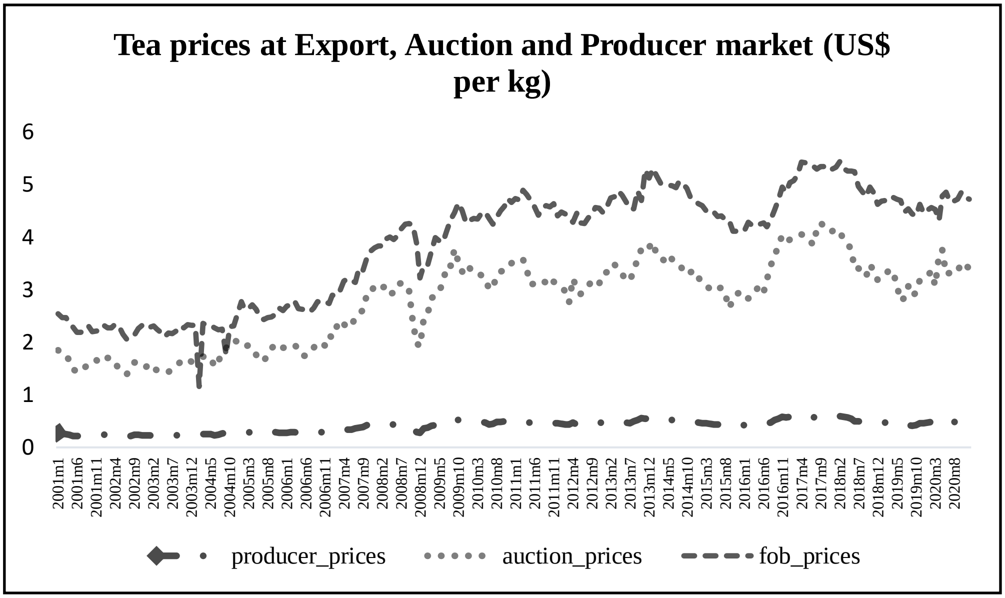

Figure 2. Trends in tea prices at different nodes of the supply chain

Table 2. Results of the ADF Test

	ADF Test statistics		**ADF Test statistics (First difference)**
Export market price (FOB)	-1.410	-2.482	-19.478***
CTA	-1.506	-1.506	-13.485***
Producer price	-1.405	-1.405	-12.067***

*** denotes significance at a 1% level

Next, the Engle-Granger causality test was performed to understand the direction of the transmission of price changes in the two markets. The Granger causality test confirmed that the direction of price movements between the Export market and CTA and CTA and the Producer is unidirectional (Table 3). Price changes are transmitted from top to bottom. More specifically, price changes generated in the export market granger cause price changes in the CTA, and price changes in the CTA granger cause price changes in the producer.

Table 3. Results of the Granger Causality Test

	chi2 values
FOB prices granger causes changes in Colombo Auction prices	12.170*** (0.002)
Colombo Auction prices granger causes changes in FOB prices	1.836 (0.394)
Auction prices granger causes changes in Producer prices	12.068*** (0.002)
Producer prices granger causes changes in Auction prices	3.3941 (0.183)

P-values are given within brackets. *** indicates significance at a 1% level

Once the direction of the causality is confirmed, the following two equations are estimated.

$$\Delta Y_{At} = a_0 + \rho Y_{At-1} + \theta^{+} Y_{Et-1}^{+} + \theta Y_{Et-1}^{+} + \theta^{-} Y_{Et-1}^{-} + \sum_{j=0}^{p-1} a_j Y_{At-j} + \sum_{j=0}^{q-1} \pi_j^{+} \Delta Y_{Et-j}^{+} + \sum_{j=0}^{q-1} \pi_j^{-} \Delta Y_{Et-1}^{-} + e_t \qquad \text{Eq (6)}$$

$$\Delta Y_{Pt} = a_0 + \rho y_{t-1} + \theta^{+} P_{At-1}^{+} + \theta P_{At-1}^{+} + \theta^{-} P_{At-1}^{-} + \sum_{j=1}^{p-1} a_j Y_{Pt-j} + \sum_{j=0}^{q-1} \pi_j^{+} \Delta Y_{At-j}^{+} + \sum_{j=0}^{q-1} \pi_j^{-} \Delta Y_{At-1}^{-} + e_t \qquad (7)$$

Equations 6 and 7 respectively relate the price transmission from Export to CTA and from CTA to the producer market. Here, Y_{At} is the Auction price at time *t*. Y_{Pt} is the Producer price at time *t*. Y_{Et} is the Export market price at time *t*.Y_{Et-1}^{+}, Y_{Et-1}^{-}, θP_{At-1}^{+}, $P_{At-1}^{-}$are partial sums of positive and negative changes in Y_{Et} and ΔY_{At} respectively. P and q are the optimum lag numbers taken based on the Akaike Information Criteria (AIC). According to the AIC, the NARDL (2,2) specification was found to be the most appropriate model to assess the presence of asymmetry in both market pairs.

Table 4 presents the Fpss statistics of the cointegration test. Accordingly, the Fpss value for the cointegration between CTA- Producer, 26.80, is above the upper bound value and hence the null hypothesis of no cointegration was rejected. The CTA and the Producer are cointegrated. However, Fpss value for the Export market-CTA was below the lower-bound value. CTA and the export market are non-cointegrated. However, the Gregory Hanson Cointegration tests confirmed that these two markets, CTA, and the export market are cointegrated with a structural break (Structural break is in 2008) (See Annex 1). This signals inefficiency in the price transmission process at the auction. As cited in Ganewatta and Edwards, 2000, some argue that the auction market does not behave competitively as multinationals operate through agents.

Table 4. Bounds testing for asymmetric cointegration.

Statistics	FOB to the Auction price	Auction to producer price
Fpss	3.4389	26.8082***
Tbdm	-2.2064	-8.9481***

Note: the critical values (bound) for the Fpss statistics are the critical FPss values have been obtained from Pesaran *et al*, 2001. The lower bound value is 3.79, while the upper bound value is 4.85 at the 5% significance level. At the 1% level, the lower bound value is 2.86 and the upper bound value is 5.58. The Critical tdbm values are -3.43 and -4.10 respectively for the lower bound and upper bound values. ***denotes rejection of the null hypothesis of no cointegration at the 1% level.

The adequacy of the dynamic specification was tested based on various diagnostic statistics. Jarque–Bera, Durbin–Watson, and Breusch–Pagan–Godfrey tests have been applied to analyze the issues of normality in error terms or residuals, serial correlation, and heteroscedasticity, respectively (Table 5). The diagnostic test results are satisfactory except for the Jarque–Bera test. The stability of the parameters was estimated using the Cumulative sum test for parameter stability (Figure 3). As Figure 3 indicates there is no evidence of parameter instability.

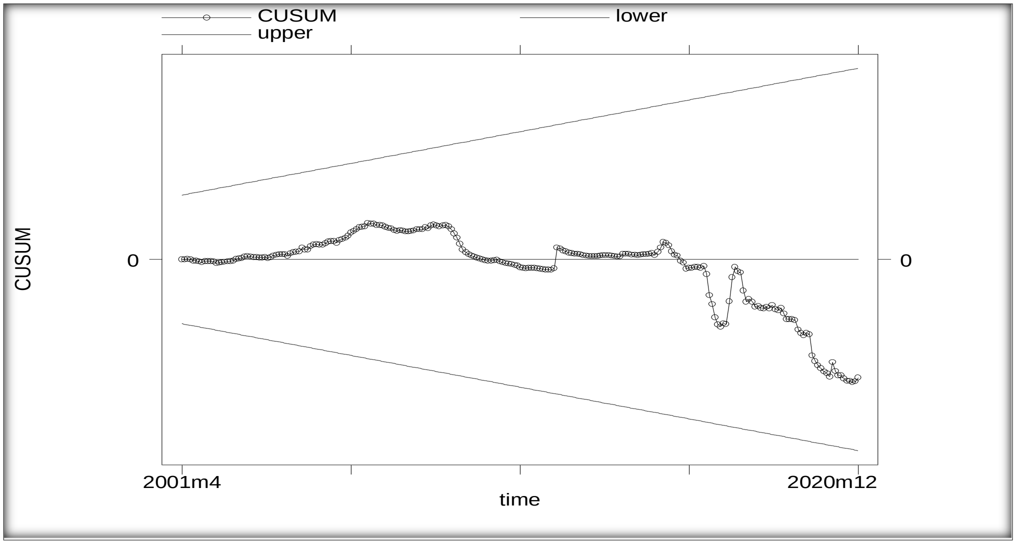

Figure 3. Cumulative sum (CUSUM) test on NARDL model. (2,2)

The results of the NARDL model revealed that the long-run price transmission coefficient is positive (0.147) as expected and significant at the 1% level, indicating that Auction price increases by 1 unit cause the producer price to move up by 0.147. Similarly, the Auction price decreases by 1 unit causing the producer price to move down by 0.148. Lower price transmission coefficients could be due to the difference in the product which is marketed at the CTA and supplied by the green leaf producers.

Even though the magnitude of the coefficients is very close to each other, the Wald test statistics suggest that this difference is statistically significant. There is an APT in magnitude between CTA and the Producer. Producer prices react more to price decreases at the CTA than price increases at the CTA. When APT in magnitude is present in the price transmission process, prices at one market do not return to the same level after equivalent positive and negative shocks to price changes in another market. Ultimately this leads to an increase in price margins between markets. This can be observed clearly in Figure 2.

Short-run coefficients in the NRDL models reflect the immediate change of the dependent variable to a change in the independent variable, whereas long-run coefficients capture the equilibrium relationship between dependent and independent variables. They show the long-run relationship after any short-term shocks have dissipated. The Wald test rejects the short-run symmetry for the market pair, CTA-Producer Market indicating asymmetry in the price adjustment speed. As Table 5 indicates, both the coefficients correspond to and are statistically significant. The coefficient suggests an immediate increase/decrease in the producer prices by 0.124 and 0.136 percentage points respectively. However, as the coefficients indicate, the asymmetry is not very strong. Asymmetric adjustment paths shown in Figure 4 indicate the adjustment path from an initial long-run equilibrium between the CTA - Producer to a new long-run equilibrium after a negative or positive unitary shock affecting the tea market. As the adjustment path indicates, it takes approximately four months to restore the equilibrium after a shock. As Figure 4 indicates, negative changes in CTA prices are reflected in the producer market at a higher speed than positive price changes in the CTA market.

Table 5. Estimates of the NARDL model

Price transmission from Colombo auction to producer NARDL model with Long-run and short-run asymmetry			Price transmission from the Export market to Colombo auction NARDL model with Long-run and short-run asymmetry		
Price transmission from CTA to producer			Price transmission from the Export market to CTA		
Variable	**Coefficient**	**Standard Error**	**Variable**	**Coefficient**	**Standard Error**
Constant	0.165***	0.018	Constant	0.240**	0.114
$p_{Pt}(-1)$	-0.601***	0.067	$p^{+}_{At}(-1)$	-0.014**	0.063
$p^{+}_{At}(-1)$	0.088***	0.010	$p^{+}_{Ext}(-1)$	0.070	0.053
$p^{-}_{At}(-1)$	0.089***	0.010	$p^{-}_{Ext}(-1)$	0.062	0.056
$\Delta p_{pt}(-1)$	0.056	0.062	$\Delta p^{+}_{At}(-1)$	0.137*	0.083
Δp^{+}_{At}	0.124***	0.004	Δp^{+}_{Ext}	0.279	0.123
$\Delta p^{+}_{At}(-1)$	-0.012	0.009	$\Delta p^{+}_{Ext}(-1)$	-0.023**	0.083
Δp^{-}_{At}	0.136***	0.004	Δp^{-}_{Ext}	0.094	0.092
$\Delta p^{-}_{At}(-1)$	-0.000	0.010	$\Delta p^{-}_{Ext}(-1)$	-0.028	0.116
Asymmetry Long-run Coefficients			***Asymmetry Long-run Coefficients***		
p^{+}_{At}	0.147***		p^{+}_{Ext}	0.504***	
p^{-}_{At}	-0.148***		p^{-}_{Ext}	-0.446*	
F stat	4.639**		F stat	1.127	
Short-run symmetry	7.165***		Short-run symmetry	2.968	
Statistics and Diagnostics			***Statistics and Diagnostics***		
R^2	0.934		R^2	0.992	
Portmanteau test	55.53 (0.052)		Portmanteau test	52.79 (0.085)	
Breusch/Pagan heteroskedasticity test	2.408 (0.121)		Breusch/Pagan heteroskedasticity test	0.095 (0.758)	
Ramsey RESET test (F)	0.881 (0.452)		Ramsey RESET test (F)	2.755 (0.043)	
Jarque-Bera test on normality	1738 (0.000)		Jarque-Bera test on normality	106.6 (0.000)	

*** denotes rejection of the null hypothesis at the 1% level, while ** denotes rejection of the null hypothesis at the 5% level.

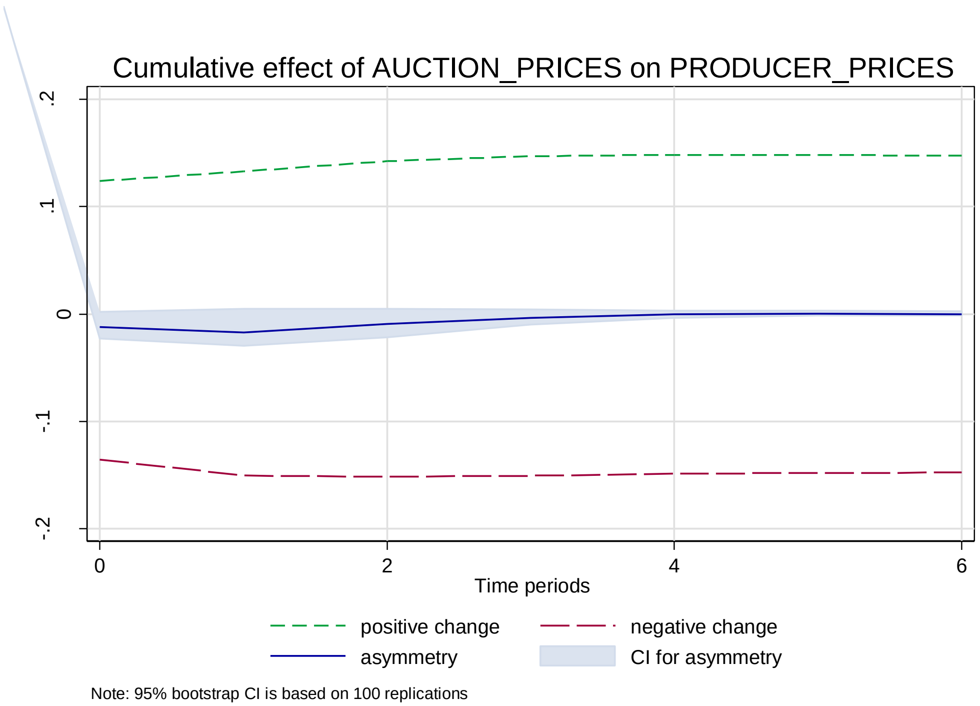

Figure 4. Cumulative effect of auction prices on producer prices

Overall, the study indicates non-integration between CTA and the Export market and the presence of asymmetry in magnitude and speed in the price transmission process between CTA and the producer market (Table 6). Non-integration between CTA and the export market suggests imperfect price transmission and welfare implications.

Table 6. Summary results of the study

Market pair	Causality in price transmission	Integration	Asymmetry
Export-CTA	Unidirectional (from export to CTA)	Not integrated	Not tested
CTA-Producer	Unidirectional (from CTA to producer market)	Integrated	Present

A study conducted in Vietnam, by Dang and Lantican (2016) that assessed the spatial and vertical market integration within the Vietnam tea market using Multivariate Autoregressive Distributed Lag models, also revealed that farmgate and processor markets for black tea markets were cointegrated. However, while the Vietnam export market was integrated with the Russian and World market, it was not integrated with some of its main trading partners. The researchers believe that a disorganized market could be the root cause of this issue, and they recommended implementing a central auction market to improve integration throughout the tea supply chain. However, the limitation of integration studies is that they only relied on price data, so they did not shed light on the causes for the non-integration or the presence of APT in the tea market. To validate the causes behind non-integration and the presence of asymmetry in the price transmission process, further research is required. To comprehend the lack of integration between the export and CTA market, it is crucial to conduct a thorough analysis of the power imbalance between buyers and sellers in the CTA industry. This will help shed light on the root of the problem and potentially pave the way for solutions to be implemented. Furthermore, since the price transmission between CTA and the producer markets is well-organized and a price formula is used to determine the prices, it can be suspected that the asymmetry in the price transmission could be a result of the presence of an asymmetry in the reporting of prices. However, research is needed to validate the causes behind the presence of asymmetry in the price transmission process.

Conclusions

In this study, a non-linear Auto Regressive Distributed Lag Model is used to test the APT in the Sri Lankan tea market. The results indicate that the Colombo Tea Auction is integrated with the producer market, but not with the export market. In non-integrated markets, trading partners are believed to operate on different pricing structures and hence could lead to suboptimal resource allocation in the industry ultimately leading to a domestic market that does not respond to changes in the world market. To overcome the welfare implication of non-integration between markets and remain competitive in the global market, the identification of root causes behind non-integration is of paramount importance. Thus, future studies to assess root causes are recommended.

However, this study also revealed that the price transmission process between the CTA and the producer market is asymmetric, in which the producer market absorbs price decreases at the CTA more than price increases. Furthermore, price decreases at the CTA are reflected at the producer level immediately than price increases. These results show the widening of the price margins between the two markets over time. The study recommends taking measures to avoid delays in price reporting mechanisms to eliminate asymmetry in the price transmission process.

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ANNEX:

In Table A2, according to the Johansen test results, trace and max test statistics indicate the existence of a cointegration vector among Export market prices and GDP Colombo Tea Auction Price. The Gregory-Hansen (1996) test which allows a structural break indicates the existence of a cointegration relationship with one structural break at the 1% significance level. According to the Gregory-Hansen test, the break-in in 2008 fifth month is significant.

Table A1. Cointegration test results

H_0	Trace statistics	Critical values (5%)	H_0	Max statistics	Critical values
r= 0	32.8103	15.41	r=1	31.073***	14.07
r<1	1.7370*	3.76	r=2	1.7370	3.76

Table A2. Cointegration test with a structural break

Gregory-Hanson test	Test statistics	TB
ADF	-7.62***	2008m6
Zt	-7.41***	2008m5
Za	-91.29***	2008m5

***denotes statistical significance at a 1% level.