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Doctoral Thesis

Welfare Impact of Asymmetric Price Transmission on Bangladesh Rice Consumers

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UNIVERSITY OF THE PHILIPPINES LOS BAÑOS

Doctor of Philosophy in Agricultural Economics

MOHAMMAD CHHIDDIKUR RAHMAN

WELFARE IMPACT OF ASYMMETRIC PRICE TRANSMISSION ON
BANGLADESH RICE CONSUMERS

ISABELITA M. PABUAYON, Ph.D.

Adviser

Date: 05 June 2018

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MOHAMMAD CHHIDDIKUR RAHMAN


ISABELITA M. PABUAYON, Ph.D.

**WELFARE IMPACT OF ASYMMETRIC PRICE TRANSMISSION ON
BANGLADESH RICE CONSUMERS**


MOHAMMAD CHHIDDIKUR RAHMAN

**SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
UNIVERSITY OF THE PHILIPPINES LOS BAÑOS
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE
DEGREE OF**

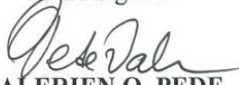
**DOCTOR OF PHILOSOPHY
(Agricultural Economics)**

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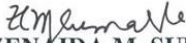
The dissertation attached here to, entitled “**WELFARE IMPACT OF ASYMMETRIC PRICE TRANSMISSION ON BANGLADESH RICE CONSUMERS**” prepared and submitted by **MOHAMMAD CHHIDDIKUR RAHMAN**, in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURAL ECONOMICS)** is hereby accepted.


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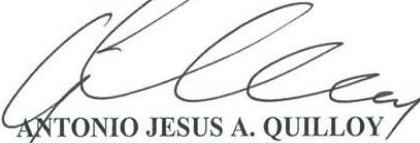

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BIOGRAPHICAL SKETCH

The author was born on December 15, 1989 in Netrokona district, Dhaka division, Bangladesh. He is the sixth child of Mr. Md. Araz Ali and Mrs. Khodaza Khatun.

He obtained his primary education from Kamalpur Kumudgonj Government Primary School. He completed his secondary education from Jalshuka Kumudgonj High School in 2004. He did his higher secondary education from Agricultural University College, Mymensingh in 2006. He graduated with a Bachelor of Science degree in Agricultural Economics from Bangladesh Agricultural University in 2010. He obtained his Master of Science degree in Agricultural Economics from the same university in 2012. He has started work as a scientific officer in the Agricultural Economics Division, Bangladesh Rice Research Institute since 2013.

In 2011, he got a fellowship from the International Water Management Institute to pursue his Master of Science degree. In 2014, the Lee Foundation through the International Rice Research Institute (IRRI) granted him a scholarship to pursue a PhD in Agricultural Economics in the University of the Philippines Baños. He is happily married to ‘Choudhury Nafisa Binte Hussain’ in 2016.

MOHAMMAD CHHIDDIKUR RAHMAN

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ABSTRACT

MOHAMMAD CHHIDDIKUR RAHMAN, University of the Philippines Los Baños, June 2018. **Welfare Impact of Asymmetric Price Transmission on Bangladesh Rice Consumers.**

Major Professor: Dr. ISABELITA M. PABUAYON

The study examined the pattern of vertical price transmission of rice market in Bangladesh. The dynamic relationship of rice prices along the supply chain was analyzed. The impact of rice price transmission on the consumer welfare was assessed. The market power along the supply chain has been measured. Based on the findings, policy has been suggested for efficient rice marketing to improve consumer welfare through reduction of market power.

Monthly farm, wholesale and retail rice prices covering the period October 2005 to June 2017 were collected from the Department of Agricultural Marketing, Bangladesh. Yearly price, demand, population and income data were collected from the Bangladesh Bureau of Statistics and Bangladesh Financial Review. The co-integrating bound test under autoregressive distribution lag approach, Vartia's algorithm for welfare measure, stochastic frontier approach for market power, and descriptive statistics were applied.

Results of the study indicated the presence of asymmetric relationship both in speed and magnitude among the prices at farm, wholesale, and retail levels. That is, significant asymmetric effects are both long run and short run. Empirical results suggest that processors (wholesalers/millers) enjoy a certain advantage over primary producers (farmers) and that retailers enjoy a certain advantage over processors. Moreover, final consumers are more likely to experience a decrease in their surplus from a price increase rather than to experience an increase in their surplus from a price decrease at the upstream. Although the welfare (consumer surplus) loss for each consumer due to price transmission asymmetry was very low, the aggregate welfare loss was much significant. The study also revealed that both the rice millers and wholesalers exerted a high degree of market power. The positive value of the Lerner Index confirmed that the rice market in Bangladesh was not competitive. It also indicated the existence of market influence dominated by the supply chain actors. Therefore, market power was one of the main causes of price transmission asymmetry in the rice supply chain of Bangladesh and the potential excess profit for the limited supply chain actors (millers and wholesalers) was very large.

It is recommended to improve the efficiency of vertical rice market integration in Bangladesh by government assistance. Establishment of farmers' organization can enhance their negotiation power to get better price. The government can offer incentives to establish storage in the rural areas, and easy loan or input support to enable farmers to

choose a better selling period of their product. The credit for paddy traders and rice wholesalers can reduce the procurement and controlling power of the rice millers. The existing government procurement and pricing policies (e.g., price floor and price ceiling) can be implemented at the local markets. The government can even impose the antitrust laws to foster competitive markets by controlling actions that limit competition such as mergers and acquisitions, price setting, and collusion pricing. The government can restart public purchasing and rationing systems, targeting the low-income group consumers (e.g., open market sell) in order to avoid huge fiscal costs. The establishment of a definite agency for the rice price regulation, procurement, and distributional decisions and actions is recommended for an efficient and competitive rice supply chain in Bangladesh.

CHAPTER I

INTRODUCTION

An Overview of the Bangladesh Rice Economy

The Contribution of Rice to Bangladesh's Economy

Rice is an essential foodstuff that captures the foremost part of agricultural income and employment in Bangladesh. It is the main food of about 160 million people of the country. It delivers about 48 percent of rural employment, about two-thirds of total calorie and one-half of the total protein intakes per person. About one-half of the agricultural GDP and one-sixth of the national income come from rice sector. Nearly all-farming families in Bangladesh cultivate rice. Rice is produced on about 10.5 million hectares of land that occupy about 75 percent and 80 percent of the total cropped and irrigated areas, respectively (Figure 1). Thus, rice has a crucial role in the livelihood of the people of Bangladesh (Murshid and Yunus, 2016).

Total rice production in Bangladesh was about 10.59 million tons in the year 1971 when the country's population was only about 70.88 millions. However, the country's production was about 35.0 million tons to feed her 160 million people at 2015. This indicates that the growth of rice production was much faster than the growth of population (Figure 2). This increased rice production has been possible largely due to the adoption of modern rice varieties on around 68 percent of the rice land that contributes to about 75 percent of the country's total rice production (BBS, 2016). Rice has been

growing almost all over the country. The unique contributor of modern rice varieties in Bangladesh is the Bangladesh Rice Research Institute (BRRI). BRRI has released 80 high yielding modern rice varieties and 6 Hybrid rice varieties (Appendix A).

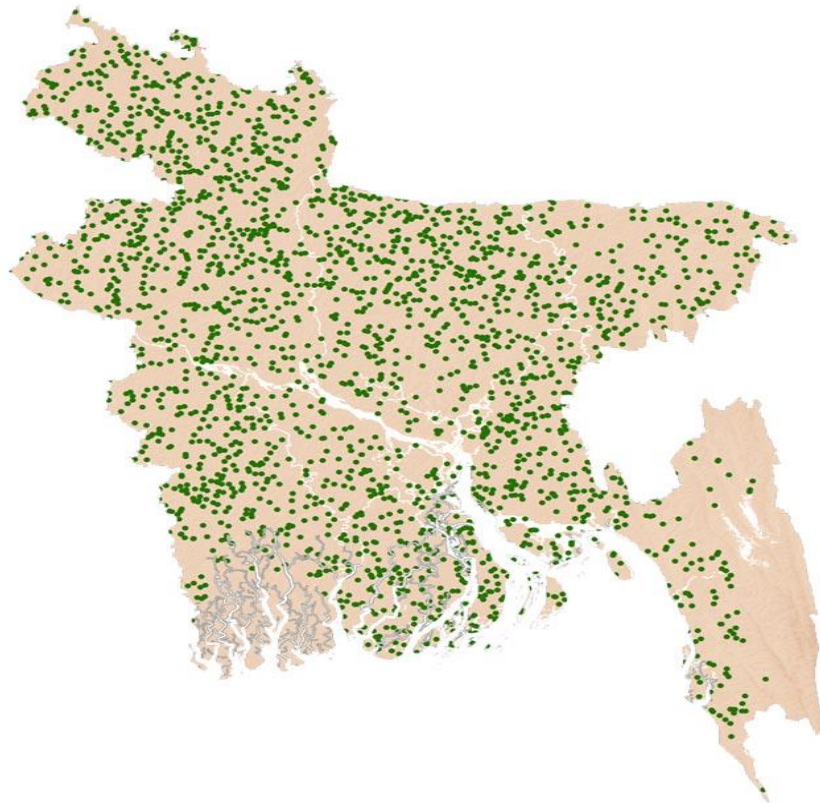


Figure 1. Rice growing areas in Bangladesh

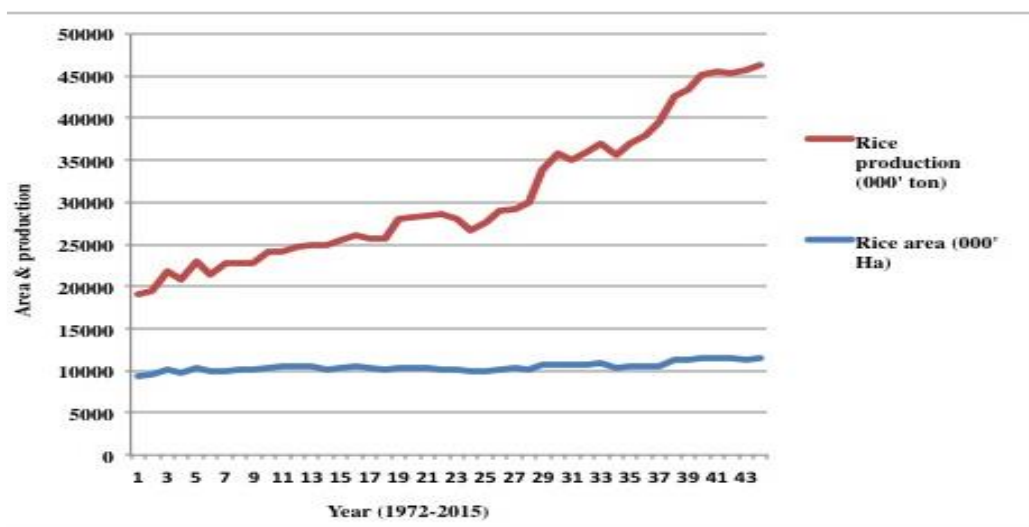


Figure 2. Area and production of rice in Bangladesh (data in Appendix B: BBS, 2016)

Challenges in Bangladesh Rice Sector

Bangladesh has almost attained self-sufficiency in rice. However, sustaining this level in the coming years may be difficult considering that the country's population continues to rise ominously and rice production growth has to be achieved with fewer resources (e.g., land and water). There is no reason to be complacent. The population of Bangladesh is still growing by two million every year and may increase by another 30 million over the next 20 years (Streatfield and Karar, 2008). Thus, Bangladesh will require additional 27.26 million tons of rice for the year 2020. During this time total rice area will also shrink to 10.28 million hectares. Rice yield therefore, needs to be increased from the present 2.74 t/ha to 3.74 t/ha (BRRI, 2011).

To combat the future situation, Bangladesh needs to consider (BRRI, 2017):

- Replacement of local varieties by modern varieties in *T. aman* season where possible.
- Limited increase in modern variety *Boro* area.
- Replacement of the present varieties by superior inbred, hybrid and super high yielding varieties.
- Increment of irrigation areas in both *Boro* and *T. aman* season.
- Application of superior resource management technologies.
- The use of quality seeds.
- Mechanization of rice cultivation particularly minimization of post harvest losses.

Sustainability is always a problem where intensified cropping systems are followed and crop residues are removed for fuel and feed. Cow dung, a traditional source of fertilizer, is being used as fuel in rural areas. The spread of modern rice varieties is

associated with an increased use of chemical fertilizer. However, the removal of fertilizer subsidies in the late 1980s caused imbalances in fertilizer use, wherein there was excessive consumption of nitrogen (N) and less phosphorus (P) due to unfavorable prices of largely imported P and potassium (K). The increased cost of fertilizer, chemicals, and fuel accounted for the high costs of rice production in Bangladesh relative to other Asian rice producers (e.g., India, Indonesia, Thailand, and Vietnam).

Drought is a common problem although the northwestern region of the country is more prone to it than elsewhere. Farmers deal with drought through supplemental irrigation during the late monsoon. Subsurface groundwater is available throughout the country. Irrigation by small-scale tube wells and low-lift pumps commenced in the late 1970s and spread extensively when the importation of agricultural machinery was liberalized in the late 1980s. Overexploitation of groundwater, however, is becoming an environmental concern with adverse effects on the supply of drinking water; there are suspected links to arsenic-contaminated water.

Although flooding occurs yearly, it causes severe damage only about once every 10 years. Usual flooding is merely a part of the ecosystem and helps maintain soil quality. The flood-prone areas are mainly suited for *Boro* rice, since water is available during the dry season and the cost of irrigation is low.

Soils in coastal areas are affected by salinity. Most soils are low in organic matter (many less than 0.5 percent) and subsequently low in N. Zinc and sulfur deficiencies are prevalent; replacement amounts of P and K are inadequate (BRRI, 2017).

Rice prices both in the upstream and downstream levels of the supply chain are the burning issue now-a-days. Farmers are not getting adequate price whereas the

consumers are suffering from the increasing trend of retail prices. Price of medium-coarse rice has risen the most in 2014, followed by the prices of fine and coarse rice. Prices of fine rice were 17 percent higher than what they were on the same day in 2013. *Najirshile* and *Miniket* are among the finer varieties of the grain. A year back, these fine varieties could be had between Tk. 34 to Tk. 48 per kg. Now they are selling for Tk. 40 to Tk. 56 per kg. The price of medium-quality rice has risen steeply by 18.57 percent. Last year on same time it cost Tk. 34-36 per kg. This year it is selling at Tk. 39-44. The price of coarse rice has risen by 12.90 percent. The prices have not shown any sign of falling, although fresh *Boro* harvest, the rice most extensively cultivated in the country, has already hit the market. The selling price of rice has risen sharply but production costs have not shown a similar increase, according to agriculture officials (bdnew24.com, 2014). Although, there has been significant increase in wholesale and retail prices, the farm price trend has been almost stable.

Background and Statement of the Problem

Rice accounts for a high caloric share in the diet of the Bangladeshi people. It has taken the monopoly position in the staple food items of the country. It is also the most important cereal crop produced, and occupies a major share of farmers' agricultural income and employment. A prerequisite for producers and consumers to benefit from the liberalized market environment is the ability of the market to function efficiently. However, if markets either spatially or vertically are constrained by factors such as imperfect market information, lack of credit availability to finance short-run inventories, insufficient and inefficient transportation, lack of management skills, exercise of market

power, hoarding by traders, retailer search behavior, trade promotions, etc., the potential benefits from liberalized markets cannot be attained.

The Bangladesh rice market was liberalized in different phases, with the first phase beginning in the mid-1980s following the advice from the World Bank and the IMF under the structural adjustment program (SAP). Domestic public procurement was minimized and transportation restrictions across regions were removed. The second phase of reforms continued in the 1990s when the rationing system, originally designed to support the low-income population in Bangladesh was completely abolished. As the outcome of these reforms, the Bangladesh government has virtually no role in the procurement and the distribution of rice. All of the reforms significantly changed the structure of the Bangladesh rice market from a publicly controlled market to a free market system dominated by the private traders operating at all levels in the rice value chain including wholesale and retail levels (Alam et. al., 2016).

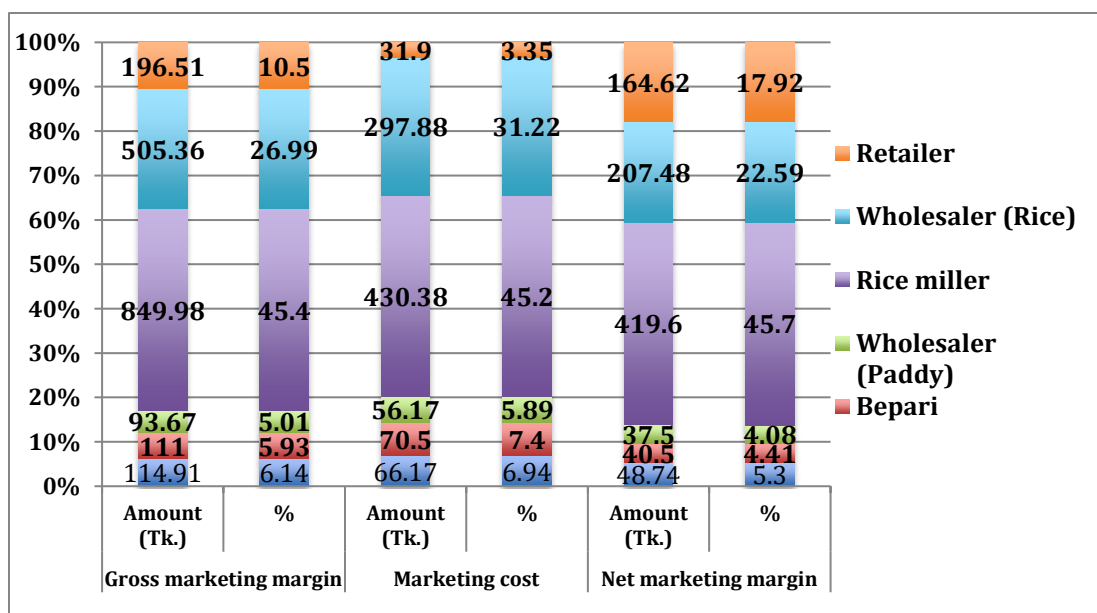
Private traders have contributed to the country's overall food security especially after a devastating flood in 1998 (Carlo and Dorosh, 2003). The contribution of the private sector was mainly to maintain stability in supply whenever there is a domestic production shortfall due to natural calamities in the country. However, the policy of liberalization has also greatly increased the number of market participants at the wholesale level and has created a fragmented marketing system. In this more liberal era, the level of control exercised by private traders in the rice market has led to a question of potential price manipulation. About 85–90 percent of total domestic rice consumption comes from domestic production, which in essence is procured and then sold to retailers by the private wholesale traders (Alam et. al., 2016). Under this marketing system, a

question that arises is how fair and efficient is the Bangladesh rice market in delivering product from producers to consumers. This question is of vital importance as Bangladeshi consumers spend a large proportion of their income on rice, while Bangladeshi producers earn the lion share of their income from rice production. Central to answering this question is the market behavior of private traders operating at wholesale and retail levels and their influence on rice prices.

The food grain marketing chains in developing countries tend to be long and complex because of the involvement of many small-scale intermediaries. There is a widely held belief that private traders operating at wholesale and retail levels leading to increase and unstable rice prices can manipulate the domestic rice market in Bangladesh. Such manipulation would have serious economic consequences for poor Bangladeshi households who are net buyers of rice, which accounts for approximately 40–50 percent of their total annual expenditures (Alam et al., 2016). Given this potential impact, government policymakers should be interested in evidences pointing towards the possible existence and sources of price manipulation. In the case of the Bangladeshi rice market, unreliable evidence and casual observation supports the idea of price asymmetry. Specifically, it is widely believed that price increases emanating at the farm or wholesale level are quickly passed on in terms of higher prices at the wholesale or retail level. However, it is also widely believed that farm or wholesale price decreases do not lead to similar price decreases at the wholesale or retail level. With this in mind, this study will investigate whether the widely held perception of asymmetric price transmission actually exists.

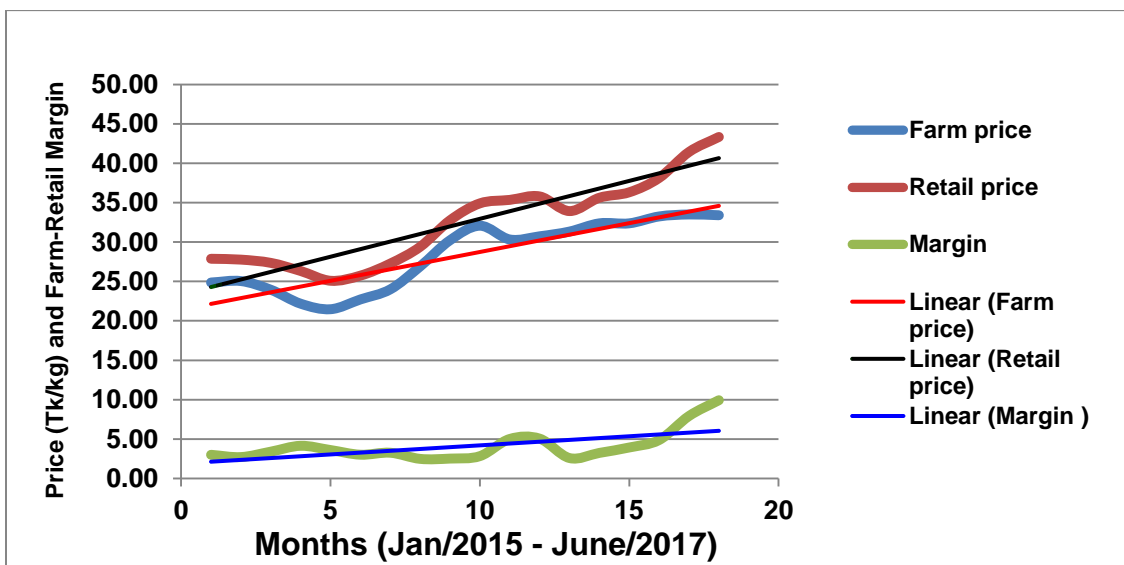
This study has also investigated the cause of price asymmetry in the rice supply

chain. The producers are not getting sufficient net return from paddy production whereas rice price volatility affects consumers. In this circumstance, Raha et al., (2012) conducted a study to show the marketing structure of rice in Bangladesh. The study showed that the rice millers are capturing about 45.7% of the net marketing margin, followed by the wholesalers (22.59%) (Figure 3). Sabur and Raha (2014) reported that 33% is the internal rate of return (IRR) of the rice mills in Bangladesh. CBECL BD (2014) reported on the possibility of oligopoly power by rice millers. Most of the millers purchase paddy from farmers through their commission agents or wholesalers, mainly during the harvest seasons with the aim to build stocks for processing and selling to markets for the rest of the year. The control over the rice processing sector by a few large mills may lead to monopoly and price control, which may go against the interests of both farmers and consumers if the mill owners do not follow ethical business practices. Regarding this information and the present scenario of increasing rice price spread between farm and retail levels (Figure 4), it is an urgent need to focus on the rice supply chain to investigate



whether the marketing agents are exercising market power.

Figure 4. Farm to retail rice price spread and margin (DAM, 2018)



As the consequences of asymmetric price transmission due to the existence of market power, it is an urgent need to estimate the potential loss of consumer welfare due to significant price transmission asymmetry along the rice supply chain. In this regard, the present study measures the change in the consumer's surplus (CS) due to the price transmission asymmetry. Measuring the changes in CS shows the amount of welfare

Figure 3. Share of different actors in gross marketing margin, marketing cost and net margin (Raha, et al. 2012)

losses faced by the consumers due to the price asymmetry. The social welfare loss due to price asymmetry is measured by estimating Dead Weight Loss (DWL).

Finally, the study used an established measure of consumer welfare (compensating variation) to quantify the magnitude of the loss. The magnitude of the welfare loss due to price asymmetry has important policy implications. If it is negligible, then attempts to reduce the asymmetry may be inefficient. If it is relatively significant, then further research should be conducted to understand the source of the problem and to pursue policies that may mitigate the welfare losses.

To address the problems stated above, these are the questions that must be addressed:

1. What is the price transmission scenario in the Bangladesh rice market? Symmetric or asymmetric?
2. Is the existence of market power the cause of price asymmetry?
3. What is the impact of price asymmetry on the consumer welfare?

Objectives of the Study

The general objective of this study is to measure the welfare impact of asymmetric price transmission of rice in Bangladesh. Specifically, the objectives are to:

1. Provide an overview of the Bangladesh rice market;
2. Examine the vertical price transmission along the rice supply chain of Bangladesh;

3. Determine the market power in the rice value chain as the cause of price transmission asymmetry;
4. Measure the welfare loss to rice consumers due to the asymmetric price transmission; and
5. Suggest/ recommend policy based on the findings of price transmission, market power and welfare analyses.

Significance of the Study

Since market performance plays a significant role in the Bangladesh economy, the extent of vertical integration and market power has implication for both macro and sectoral policy formulation and implementation.

Firstly, an understanding of vertical price movement serves as an input for managing efficient rice market formation in Bangladesh. Information on how rice price transmits in the market will guide policymakers in formulating policy for the efficient movement of rice price in order to maintain a relatively competitive rice market.

Secondly, assessment of the level of market power along the rice supply chain can provide the cause of price transmission asymmetry. These findings may help policymakers to determine the necessary areas of intervention for a better management of rice supply chain.

Thirdly, the estimation of the consumer welfare loss due to the rice price transmission asymmetry along the supply chain can provide clear understanding of the policymakers to implement appropriate food policies for the betterment of consumers,

traders and farmers.

Lastly, better-integrated rice market means faster information. This improves production decision making of farmers and increases their bargaining power. In a well-integrated market, the price signal will be transmitted quickly both vertically and horizontally. Traders and farmers then make better decisions of whether to increase their arbitrage activity of selling the product right away before an unfavorable price shock reaches them. Consumers also gain from a well-integrated market as it reduces the unbalanced supply and demand along the supply chain, and they are given better consumption or purchasing choices, as they face more efficient pricing situation.

The Ministry of Agriculture in Bangladesh collects agricultural market information through the Department of Agricultural Marketing to broadcast agricultural price information to mitigate information and price asymmetry along the supply chain and among the regional markets. Results of this study can be sent to information dissemination centers and market performance can be monitored over time, thereby helping the policymakers to identify constraints and accordingly design appropriate policies to improve rice market efficiency.

CHAPTER II

REVIEW OF LITERATURE

Price Transmission in Agricultural Markets

The analysis of price transmission generally examines the nature of the relationship between price series at different levels of the supply chain, or at spatially separated markets. Price transmission, therefore, can be defined as the relationship or interdependency between prices in two related markets, e.g., between the international and domestic prices of a commodity or among the producer, wholesale and consumer prices of a given commodity along the supply chain.

The issue of price transmission received a considerable attention, and many economists have generated an extensive literature on the empirical analysis of price transmission process and agricultural markets have been one of the central targets for this analysis. Price plays an indispensable role in the current market oriented economies, which integrates various levels of the markets vertically and/or spatially.

The vertical transmission of price shocks among various stages of the market is an important characteristic describing the overall operation of the market. Given that price is the primary mechanism by which various stages of the market are interconnected, the extent of adjustment and speed with which positive and negative shocks are transmitted into producer, wholesale, and retail levels is a significant factor showing the actions of participants at alternative market levels (Goodwin and Harper, 2000). Many observers have claimed that middlemen are more likely to increase prices than lower the prices of

food products. As a result, a reduction in producer price might not be rapidly and/or completely passed on to retail prices, whereas, an increase in producer price is usually passed on to retail price fully and possibly more rapidly.

Symmetric transmission of price changes from one stage of the market to another stage has often been interpreted as a sign of efficient and competitive market, while the presence of asymmetry is considered as an indication of market failure (for example, middlemen exercise of market power), including asymmetric information, poor infrastructure, or lack of perfect competitive markets. There are a large number of studies that examine the degree of price transmission along the marketing chains and most studies revealed the presence of asymmetries in price adjustment at the different marketing levels (e.g., Abdulai, 2002; Azzam, 1999; Hahn, 1990; von Cramon-Taubadel, 1998). Asymmetric Price Transmission (APT) refers to pricing phenomenon occurring when downstream prices react in a different manner to upstream prices change, depending on the characteristics of upstream prices and/or changes in those prices.

Types of Asymmetric Price Transmission (APT)

Over the past several decades producers, consumers, food industry interest groups, legislators, and policymakers have been concerned about the efficiency and equity of price transmission of agricultural and food products. Price asymmetry arises when a change in an input price is not transmitted equally and/or instantaneously to the output price. The price in the upstream level (farm level) does not transmit equally to the downstream level (retail level). Consumers often complain that retail prices increase more than increase in costs and they decrease less than fall in costs. In other words, it

arises when a change in a price that is interconnected to the other price is not transmitted equally between them either in speed and/or in magnitude.

APT could have important welfare and policy implications (Meyer and von Cramon-Taubadel, 2004). A possible implication of APT is that some group in the marketing chain is not benefiting from a price reduction, or producers might not benefit from a price increase at the retail level. Hence, APT implies a different distribution of welfare across agents following shocks at certain level of the marketing chain than would be obtained under symmetry.

Asymmetric Price Transmission with Respect to Speed and Magnitude

It should be noted that price asymmetry could occur within any aspects of the supply chain of the adjustment process. Vavra and Goodwin (2005) note that “price transmission might be asymmetric in its speed and magnitude, and could differ depending on whether the price shocks is positive or negative and is being transmitted upwards or downwards along the chain.” The distinction between asymmetry with respect to speed and magnitude is depicted in Figure 5, where the output price (P^{out}) is assumed to depend on the input price (P^{in}) that either decreases or increases at a certain specific point in time.

Figure 5 shows shock adjustment down the marketing chain. It illustrates that the magnitude of the response to a shock in P^{in} depends on the direction of the shock along the marketing chain. This implies that a decrease in input price at a given time period t will not provoke an equal decrease in output prices. However, an increase in input price of equal magnitude will trigger equal magnitude increases in output price. In Figure 6, it

is the speed of adjustment process, which causes APT. The figure shows that a negative shock in the P^{in} takes t_{1+n} periods to be fully transmitted to P^{out} though a corresponding negative shock of the same magnitude in P^{in} takes only t_1 periods to be fully transmitted to P^{out} .

Similarly, Figure 7 illustrates the case where price transmission is asymmetric with respect to both magnitude and speed. The combinations of these two types of asymmetry are conceivable where a positive shock at a given time in P^{in} (input price) takes two periods in time (t_1 and t_2) to be fully transmitted to P^{out} (output price), while a fall of the same magnitude in P^{in} needs three periods (t_1 , t_2 and t_3) and yet it is not transmitted completely.

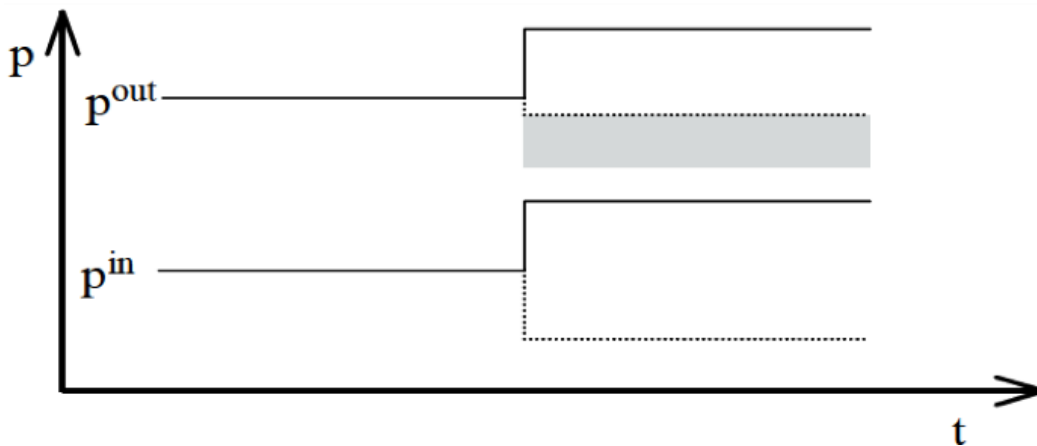


Figure 5. Asymmetric price transmission with respect to magnitude (Meyer and von Cramon-Taubadel, 2004)

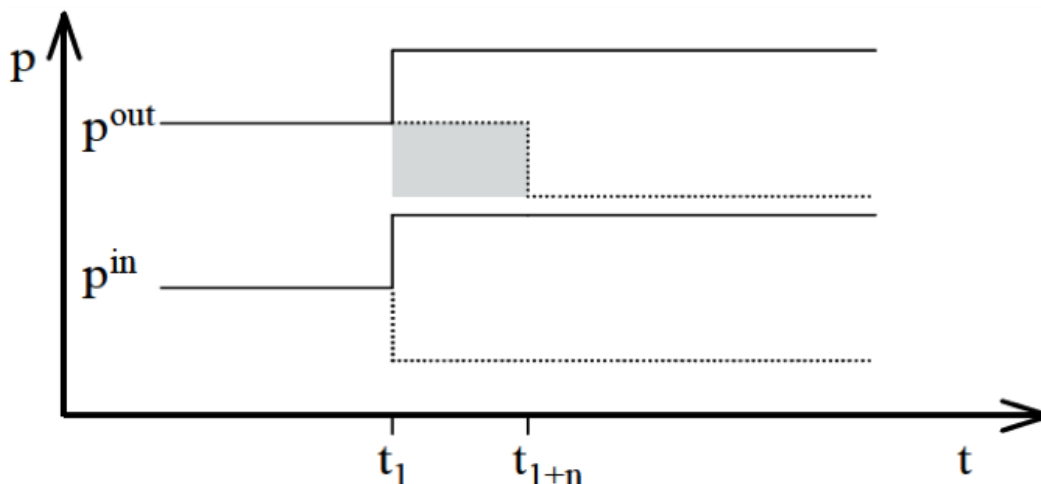


Figure 6. Asymmetric price transmission with respect to speed (Meyer and von Cramon-Taubadel, 2004)

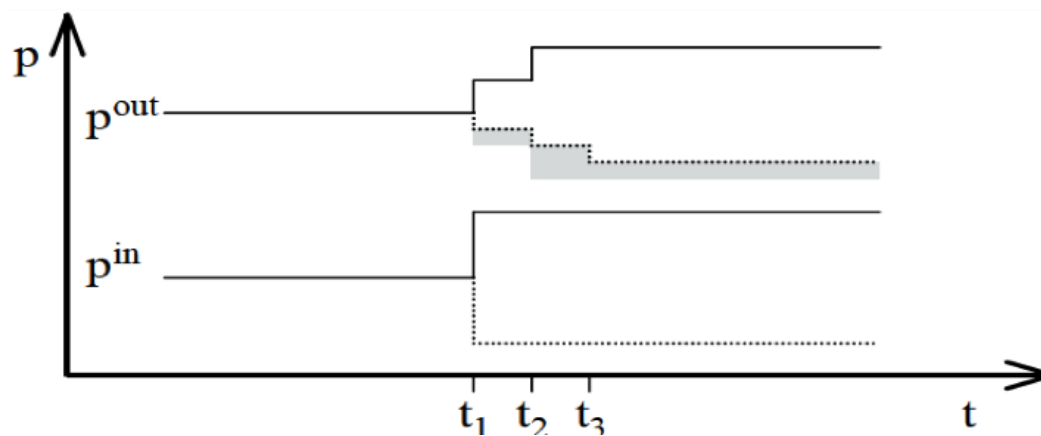


Figure 7. Asymmetric price transmission with respect to speed and magnitude (Meyer and von Cramon-Taubadel, 2004)

The shaded area in the figures represents the welfare effect associated with these two types of APT. To make matters less complex and easy to interpret, a constant, unchanging volume of transactions over time, i.e., completely price inelastic demand for the output good is assumed (Meyer and von Cramon-Taubadel, 2004). The authors further argued that APT with respect to speed leads to a temporary transfer of welfare, in

this case, from buyers to sellers of the goods, the degree of which depends on the length of the time period between t_1 and t_{1+n} as well as the transaction volumes involved and the size of the price changes (Figure 6).

Asymmetry with respect to the magnitude of price transmission leads to a permanent transfer of welfare (Figure 8) though its size depends on the transaction volumes involved and the changes in price. Similarly, APT with respect to both speed and magnitude leads to a combination of temporary and permanent welfare transfers (Figure 9). Whether a temporary or a permanent welfare transfer is of greater concern cannot be determined a priori; because a large temporary welfare transfer could outweigh the present value of smaller permanent welfare transfer depending on the numbers involved. However, if the price asymmetric in question results from the exercise of market power, then asymmetry with respect to magnitude, perhaps accumulated over a number of episodes, could be used as a way of secretly imposing or ‘easing in’ oligopoly or monopoly pricing. In this case, as noted above, APT will signify not only welfare transfer but also net welfare losses.

Negative vs Positive Asymmetric Price Transmission

According to Peltzman (2000), APT can be classified as positive and negative. If P^{out} reacts more fully or quickly to an increase in P^{in} than to a decrease, the asymmetry is termed ‘positive’ (Figure 8). Correspondingly, asymmetry is said to be ‘negative’ in a situation when P^{out} reacts more fully or quickly to a decrease in P^{in} than to an increase (Figure 9). This convention can be misleading if interpreted in a normative fashion; if P^{out} and P^{in} represent producer and retail prices for a commodity, respectively,

‘positive’ asymmetry is ‘bad’ for the consumer, while ‘negative’ asymmetry is ‘good’ for the sense that the former (latter) is associated with welfare losses (gains). In parallel, however, this highlights the importance of the distinction between positive and negative asymmetry, as it determines the direction of welfare transfers due to APT.

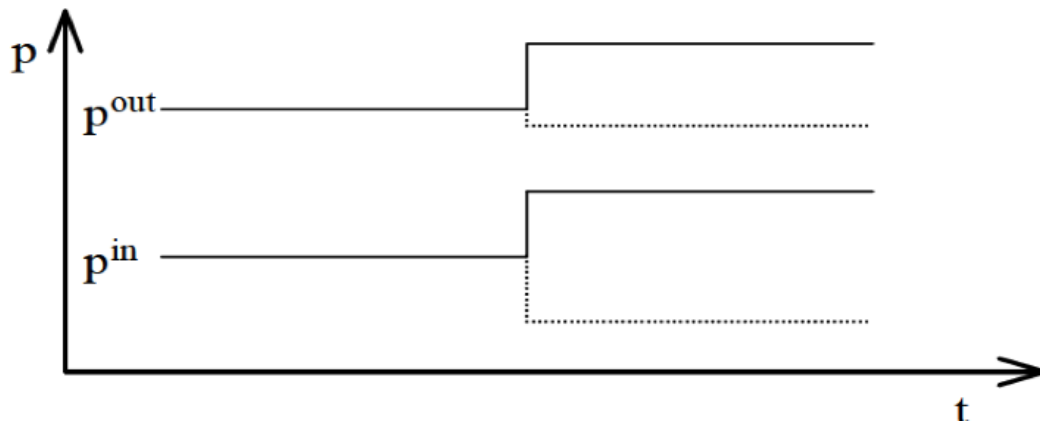


Figure 8. Positive asymmetric price transmission (Meyer and von Cramon-Taubadel, 2004)

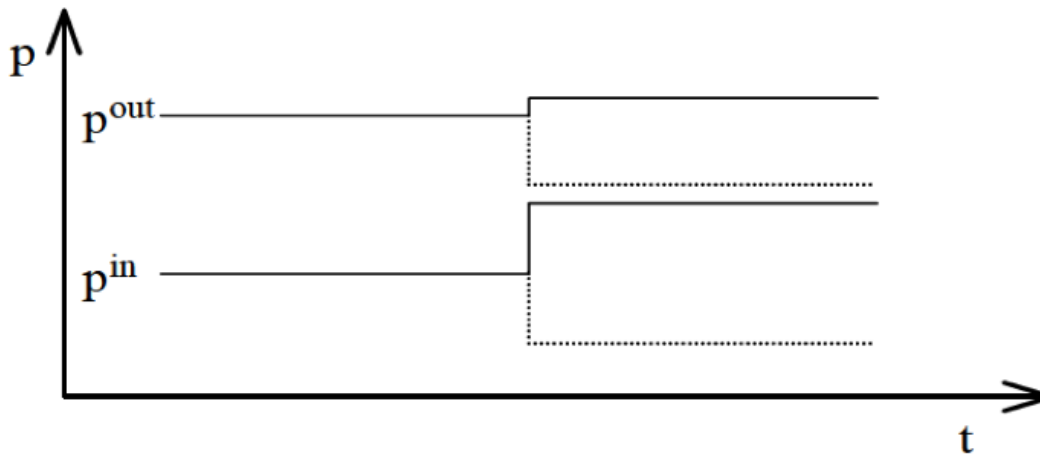


Figure 9. Negative asymmetric price transmission (Meyer and von Cramon-Taubadel, 2004)

As it has been assumed earlier that the output price (P^{out}) depends on the input (P^{in}) price, i.e., the shock origins at the input price (farm) level in the illustration with the presumption that the direction of causality runs from the input price (farm gate) to the output price (e.g., retail price). However, it should be noted that price transmission does not necessarily always flow from the input price to the output prices. In some cases a demand shift, which causes a change in output price, may be transmitted to input prices. For instance, Tiffin and Dawson (2000) showed that a long-run relationship exists between producer and retailer prices of lamb in UK, with causality running from retail to producer prices. According to their findings, price changes at the producer level result in short-run disequilibria and have no long-run impact on retail prices. In this context, it still makes sense to differentiate between the speed and magnitude of APT. In this case, different adjustments in input price (P^{in}) to positive and negative shocks in output price (P^{out}) could easily be illustrated using diagrams analogous to Figures 5, 6 and 7. Moreover, it would also be possible to illustrate further by adding another price level to the figure (e.g., wholesale price), assuming P^{in} and P^{out} are producer and retail price levels, respectively, to show the successive pass-through of a price shock that originates on either end of the marketing chain.

The distinction between positive and negative APT can be generalized. Positive APT, therefore, can be defined as a set of reactions according to which any price change that squeezes the margin (i.e., an increase P^{in} or a decrease in P^{out}) is transmitted more quickly and/or completely (to P^{out} or P^{in} , respectively) than a corresponding equivalent change that stretches the margin. On the contrary, a negative APT is when price changes

that stretch the margin transmit more quickly and/or completely than price changes that squeeze it.

Vertical vs Spatial Asymmetric Price Transmission

This criterion classifying APT is based on whether it affects vertical or spatial price transmission. Vertical Price Transmission (VPT) occurs when the price of a good rises due to the rising price of its inputs. For example, if the price of wheat rises, this causes millers to spend more money to buy wheat that leads them to raise the price of their flour to compensate the higher price of wheat. And further the bakers may raise the price of bread in order to compensate for the higher price of flour. Similarly, spatial price transmission occurs when the price of a commodity between spatially separated markets with a country is related, or how domestic prices adjust to international prices. For example, rice prices in a food-surplus region strongly affect rice prices in a food-deficit region within a country given that the two region markets are integrated. If the price of maize rises in one market, it will also rise in the other market because it costs more money to import.

As an example of vertical APT, farmers and consumers often complain that a rise in farm prices is more completely and/or quickly transmitted to wholesale and retail levels than a corresponding reduction of the same magnitude in farm prices. A similar example of spatial APT would be an increase in the US export price for wheat causing a more pronounced reaction in the Canadian export prices than equivalent decreases in the export price (Meyer and von Cramon-Taubadel, 2004). Spatial APT, like vertical APT, can be classified according to whether it is positive or negative, and according to speed and magnitude.

Reasons for Asymmetric Price Transmission

A wide range of empirical studies has investigated the nature of price transmission along various stages of the market levels. Most of the studies revealed the existence of APT. Although several empirical studies have examined the potential presence of APT, there are very few empirical studies that showed asymmetry in the adjustment process. A number of possible explanations have been offered as the causes of existence of APT along the different market levels. It is often presumed that APT depends on the nature of the product and the market structure. Despite the fact that many factors have been identified as causes for asymmetry in price transmission, it is worth mentioning some of the main proposed arguments often cited in the literature. Meyer and von Cramon-Taubadel (2004) and Vavra and Goodwin (2005) provided a comprehensive summary of the causes of vertical APT. The potential causes of APT can be categorized into three main groups for analytical purposes. These are: i) Existence of Market Power, ii) Adjustment and Menu Costs, and iii) Miscellaneous Causes. These causes are explained as follows:

Existence of Market Power

One of the most common and frequently cited reasons in the literature for asymmetric transmission is the presence of market power. Market power is “the ability of a firm (or a group of firms, acting jointly) to raise price above the competitive level without losing so many sales so rapidly that the price increase is unprofitable and must be rescinded” (Landes and Posner, 1981). More generally, market power is the power of a firm to increase price above its marginal costs by influencing its output supply, demand

or both in which it operates. Most works on the topic of APT refer to absence of competitive market structure as an explanation for asymmetry. Farmers at the beginning and consumers at the end of the marketing chain frequently believe that imperfect competition in processing and trading allows middlemen to use market power (Meyer and von Cramon-Taubadel, 2004). This market power is often expected to lead to a positive APT. Therefore, it is expected that increases in input prices, which reduce marketing margins, will be transmitted faster and/or more completely than the corresponding margin stretching price changes. It appears that this is in fact the case, in particular with agricultural and food products.

Von von Cramon-Taubadel (1998) argued that marketing chains for food products are often much less concentrated at the farm level than at higher levels. He suggested that asymmetry in the German pork market was caused by market power and inventory holding. He further explains market power as; “Oligopolistic processors, for example, might react collusively more quickly to shocks that squeeze their margins than to shocks that stretch it, resulting in asymmetric short-run transmission. In an attempt to hide the exercise of market power behind the 'confusion' created by major shocks, processors could also react less completely to shocks that stretch their margins, leading to asymmetric long-run transmission.”

The view of price asymmetries in the marketing chain, which links input prices to output prices, is not confined only to agricultural products but it is as a rule also extended to other commodity markets (e.g., interest rate and bank deposit). For instance, Brown and Yucel (2000) examined the US gasoline market and find asymmetries in the market and they interpreted the result as evidence of monopolistic behavior in the markets for oil

and petroleum products. Along the various stages of the production/supply chains, some agents may behave as price makers while some others as price takers, depending on the degree of concentration of the industry.

The majority of the studies, however, cited the presence of market powers among traders/firms, which enabled them to pass on input price increase to consumers, while input price decrease can be kept in the mark-up of the industry (Azzam, 1999; Goodwin and Holt, 1999; Muth and Wohlgenant, 1999). It is also argued that when price increases, retailers try to maintain their normal profit margin; however, when there is a fall in prices they try to capture the larger margins at least temporarily, which is higher than their normal margins.

Adjustment and Menu Costs

Adjustment and menu costs, as described by Vavra and Goodwin (2005), are all costs associated with changing retail prices and subsequently adapting retail logistics, wholesale costs, sales and altering its level of output. Costs refer to advertising and relabeling, but also to the impact on storage and volume discounts. Menu costs are often fixed and they are the same for small and large changes.

Ball and Mankiw (1994) pointed out that the use of menu costs by agents might lead to more resistance to decrease in prices than to increase in prices since the adjustment and menu costs (the costs involved in changing nominal prices, such as the cost of reprinting catalogues, etc.) to a new pricing formation may be costly for agents. In this case, any shock that raises a firm's price will prompt larger responses than shocks that reduce it. Moreover, in the presence of inflation and nominal input price changes the

use of menu and adjustment costs by firms may lead to more resistance to reduce prices than to increase them.

Bailey and Brorsen (1989) pointed out that asymmetries in price adjustments might be caused by asymmetries in the underlying costs of adjustments. Firms may face different adjustment costs depending on whether prices are falling or rising. For instance, meat packers, unlike feedlots, face significant fixed costs. Therefore, competition among different meat packers with high fixed costs and excess capacity might result in farm prices that are bid up quickly in response to raise demand for meat but may fall slowly as demand for meat falls. In the short-run, margins may be reduced in an attempt to keep a plant operating at or near capacity. Therefore, because of competition between different packers, farm prices may be bid up more rapidly than they are bid down (negative APT).

On the other hand, Peltzman (2000) made a case for positive APT, indicating that asymmetric adjustment was prevalent with retail price increasing faster as compared to declining with respect to the wholesale or farm price increase and decrease. He further concluded that the observed phenomena could not be explained by any standard economic theory and hence asymmetry was a rule rather than the exception in market price adjustment.

Adjustment costs can also arise if a firm increases or decreases its output and/or the price of its product. If these costs are asymmetric with respect to an increase or a decrease in output quantities and/or prices, the adjustment will be asymmetric. In the case of price changes, adjustment costs are also called menu costs. Kovenock and Widdows (1998) suggested that if changes in the input costs are deemed to be transitory, then the menu costs are likely to arise which may serve as an incentive not to adjust prices when

input costs decrease. These costs can be the cost of making new labels or re-pricing goods and informing customers and sales people about price changes.

Inventory management practices can also result in price asymmetry. Retailers may reduce their prices more gradually than reduction in farm-level prices to avoid early depletion of stocks. Reagan and Weitzman (1982) argued that firms will adjust the quantity produced and increase inventory in periods of low demand while, they will increase prices in periods of high demand. Balke et al., (1998) showed that the accounting method known as first in first out (FIFO) also leads to asymmetric adjustments. The FIFO method causes the firm not to adjust its output straight away when there is a change in costs, but wait until the stock is depleted which has been bought at the old prices.

Miscellaneous Causes

Apart from market power and adjustment costs, other possible explanations put forward to explain asymmetry depending on the market structure and the nature of the product. The nature of products also determines the transmission of changes in the producer price to changes in retail prices. Products that are perishable (e.g., vegetables, fruits, and fresh milk) are expected to have a relatively quick price transmission whereas products that are not as perishable as fresh produce (e.g., cereals) are expected to have a slower price transmission mechanism. This is because they can be stored easily and are traded in the futures market.

Ward (1982) suggested that retailers selling perishable products might hesitate to increase their prices when farm price increases for fear of reduced sales and they might end up holding unsold spoiled stocks. This would lead to negative APT. On the other

hand, Kinnucan and Forker (1987) pointed out that, in addition to other causes, government policies may lead to asymmetric price adjustment if agents believe that price movements in one direction may more likely to trigger government intervention than movements in another direction. More specifically, if a decrease in producer price is not transitory, it will prompt government intervention since it is more common that government will intervene if market shocks permanently lower farm prices than increase farm prices. Nevertheless, producer price increases have been believed to be permanent. Government policies such as price controls, therefore, can affect the transmission mechanism.

Although agricultural product retail and producer prices may drift apart in the short run due to various reasons (for example, due to policy changes, and seasonal factors), Palaskas (1995) argued that they cannot continue to be too far apart in the long run.

Empirical Studies on Price Transmission Asymmetry

The empirical literature that looks for evidence of asymmetries in the transmission mechanism of crude oil prices is extensive. Several studies have been developed by employing a variety of econometric regression models with the majority of them dealing with the gasoline market. The results differ across models, countries of investigation, stages of the market chain that are under scrutiny (production, wholesale or retail level), tax regimes and time periods of the data used and their frequency. Consequently, there cannot be an unambiguous rule stating that gasoline and natural gas prices or other macroeconomic variables, such as Gross Domestic Product (GDP), respond asymmetrically to crude oil price changes. In the case that all studies provide

evidence of asymmetries, this would mean a serious gap in the economic theory.

In an exceptionally comprehensive work, Peltzman (2000) looked into a substantial number of markets, including 77 consumer and 165 producer goods. Monthly data for the period 1982-1996 were employed to both the Distributed Lags and the Vector Autoregressive (VAR) models. Peltzman (2000) deduced that two out of three US product markets suffered from asymmetric behavior, that is to say prices rise faster to positive shocks than they fall to negative ones. The asymmetry was intense in sectors with a wide wholesale distribution system, but not in the responses of atomistic markets, i.e., a supermarket chain. He, additionally, found a negative correlation between the price volatility of input costs and the degree of asymmetry, as well as no relationship between the latter and inventory costs, market power and asymmetric menu costs.

Jimenez-Rodriguez and Sanchez (2004) looked into the impacts of oil price shocks on the GDP of the main industrialized OECD countries (G-7, Norway and the euro area as a whole). They developed a multivariate VAR analysis by using both linear and non-linear models. The first one was a simple VAR and the rest consisted of an asymmetric, scaled and net specifications approach. The VAR model included relative variables, such as GDP, exchange rates, oil prices, inflation, real wages and even short- and long-term interest rates. The data were on quarterly frequency basis, spanning the period 1972-2001. Asymmetry, even though statistically insignificant, was indeed found for the majority of the countries since a positive oil shock caused a larger increase in GDP than a decrease due to a negative one. More specifically, a rise of oil prices had a negative effect on the economic activity of oil importing countries (apart from Japan), while the results for the UK and Norway, which are net exporters, were contradictory

(negative and positive effects, respectively). The non-linear approaches provided, as it was expected, poorer results, especially the scale specifications. The latter took into account both oil price changes and the market volatility.

In relevance to the pass-through of crude oil to gasoline prices, the first one who considered the issue of asymmetries in price increases and decreases was Bacon (1991). He studied the “rockets and feathers” effect by analyzing the speed of adjustment of retail gasoline prices to cost changes in the UK area using fortnightly data, spanning the period 1982-1989. Applying the non-linear quadratic partial adjustment model, Bacon (1991) found that when production costs rise, the adjustment by the firms is fast and, within two months, there is full transmission in the final product price. By contrast, in the case of cost reductions, an extra week is needed. However, he failed to reject that the retail gasoline market in the UK was under strong competition, due to the slight difference of one week.

Karrenbrock (1991) studied the behavior of gasoline prices as well. More specifically, he employed monthly data from January 1983 to December 1990 to estimate the relationship between after-tax US retail gasoline prices and wholesale prices. After applying the distributed lags methodology, he concluded that premium and unleaded regular gasoline retail prices are affected for two months by both wholesale price increases and decreases. Although the length of time is the same, the pattern is somewhat different. The bulk of the wholesale price changes affect the consumers sooner in price boosts than reductions. Nevertheless, decreases are ultimately passed along to customers as much as increases. In contrast, when wholesale prices for leaded regular gasoline fall, the response is slower by one month than when they rise.

Shin (1994) dealt with the same issue of asymmetries in US oil products and emphasized that the results of each study varied due to different models and data that were applied, especially at the distribution stage. He used the quadratic partial adjustment model for the period January 1986-March 1992 (on a monthly frequency base) and found no evidence of any asymmetry between crude oil and wholesale gasoline prices at the transmission stage.

Borenstein et al., (1997) examined the short-run dynamic asymmetric responses of US gasoline market to crude oil price changes using weekly and semi-monthly data, spanning the period January 1986 to December 1992. With the assistance of the non-standard asymmetric Error Correction Model (ECM), they confirmed the common belief of asymmetry. Retail gasoline prices adjusted to oil increases in four weeks, while the respective time period for oil decreases was eight weeks. Additionally, the authors provided three potential explanations of the asymmetric cost pass-through mechanism of gasoline prices. To begin with, when crude oil prices fall, firms tend to stick to a previous gasoline price until demand forces them to alter it. Thus, a natural focal point is formed in favor of oligopolistic sellers. Another source of asymmetry could be the production and inventory adjustment costs that allow a faster accommodation of negative shocks to gasoline future consumption than that of positive ones. Finally, consumer search behavior affects retail gasoline responses as well. For example, it is difficult for consumers to specify whether high gasoline prices are due to a potential oil price volatility that affects all retailers or if this is only for a number of individual firms. Therefore, they search less for cheaper prices, the demand elasticity decreases and retailers enjoy higher profit margins.

Galeotti et al., (2003) coped with the issue of asymmetry in the gasoline market in a different way than the existing literature. Initially, updated monthly data from 1985 to 2000 for five European countries were used: Germany, France, United Kingdom, Italy and Spain. The asymmetries were separated into short and long run with the asymmetric ECM approach that was the same across all the countries in order for comparisons to be feasible. Subsequently, the authors investigated asymmetries not only in the distribution, but also in the production stage. Finally, they ran bootstrapped F-tests alongside with the conventional ones because the latter are not that suitable for a limited sample size. As a result, there was pronounced evidence of asymmetric responses to input increases and decreases across all countries, especially, in the distribution stage that is less competitive than the first stage.

In contrast with the literature published up to that point, Bachmeier and Griffin (2003) provided new evidence on the responses of gasoline prices to crude oil shocks. More specifically, they found that US wholesale spot gasoline prices responded asymmetrically to changes in crude oil costs for the time period 1985-1998. They introduced two novelties compared to previous studies, especially, to that of Borenstein et al., (1997) by using daily rather than weekly data and by adopting the standard Engle-Granger two-step estimation approach. The difference between positive and negative oil shocks was less than five cents of the dollar.

Radchenko (2005a) studied the responses of US retail gasoline prices to variations of crude oil prices by introducing two innovations. He separated the cost changes to long- and short-term oil shocks and employed the hidden Markov- switching model for weekly data from March 1991 to August 2002. He assumed that there is a different response of

gasoline prices depending on the time length of the shock. His conclusion was that if market participants viewed a crude oil shock as short-term, there would be a certain lag in the cost pass-through to gasoline prices. Refineries do not make profits by changing the production and inventory levels immediately. There is only a partial adjustment of prices that reflects the anticipation of opposite price movements in the future. On the other hand, long-term shocks result in immediate responses of gasoline prices. It is also highlighted that the reason of long lags existence found by previous researchers may be due to the fact that almost 97% of crude oil shocks are presumed as short-term.

Grasso and Manera (2007) emphasized the importance of applying the proper econometric approach for the investigation of a probable asymmetric relationship between crude oil and gasoline prices. They collected monthly data for France, Germany, Italy, Spain and United Kingdom from January 1985 to March 2003 and imported them to three separate models: the “asymmetric ECM”, the “threshold autoregressive (TAR) ECM” and the “ECM with threshold co-integration”. All three of them indicated the presence of a certain delay and asymmetry in the cost pass-through mechanism, yet the results varied depending on the country and the stage of the market chain. Long-run asymmetries, especially in the retail level, were found for all countries by using the asymmetric ECM and the ECM with threshold co-integration methodology, with stronger evidence to be presented by the first one. The TAR ECM model was the most suitable for the exploration of short-run asymmetries at the distribution stage of the transmission chain.

Al-Gudhea et al., (2007) approached the issue of asymmetry in the US gasoline market from an innovative perspective. They used the Momentum Threshold

Autoregressive (M-TAR) process for daily data from December 1998 to January 2004 and investigated for pair-wise asymmetric adjustment from the beginning of the distribution chain (crude oil, spot, wholesale, and retail level). However, instead of implementing the common monetary 1\$ innovations, the authors distinguished them to typical and unusually large crude oil shocks. The results indicated symmetric responses to large shocks for all stages except for the retail level, while any asymmetries decayed quickly. For small shocks, downstream prices responded differently to positive and negative upstream prices, as a consequence of consumer search costs and the restricted market power of the retailers.

The majority of the researchers so far have used VAR or ECM approaches which determine the asymmetric relationship between crude oil and gasoline prices by deriving the speed of adjustment and the short-run adjustment coefficients. Honarvar (2009) stressed the need of including the long-run equilibrium as well. He used the Crouching Error Correction Model (CECM), a non-linear hidden co-integration technique, for monthly data from September 1981 to December 2007 in the US gasoline market. Evidence of co-integration was found between the cumulative positive changes of crude oil prices and the corresponding negative components of gasoline prices. Market power of refiners and collusion are no longer reasons for long-run asymmetries. On the contrary, long-run gasoline prices were more affected by technological improvements on the demand side, rather than crude oil prices variation on the supply side.

Bermingham and O'Brien (2010) tested for a potential asymmetric pricing behavior in Irish and UK petrol and diesel markets. They developed an ECM-TAR model for monthly retail and refined oil prices from 1997 to 2009. Firms alter prices when input

costs changes are sizeable enough to justify the cost of adjustment. This is the reason that a non-zero threshold was used. The latter has to be accurate and economically and statistically significant. The results showed no evidence of asymmetry despite the common belief that retail prices react faster in crude oil increases than decreases. The authors attributed this finding to the high degree of competition in the particular retail fuel markets and the consequent modest profit margins. Additionally, Bermingham and O'Brien (2010) highlighted the importance of specifying the appropriate number of possible regimes. In this way, they could consider the price pressures not only from the ECM term, but also from a threshold variable. The asymmetries that were found in some of the cases, although statistically significant, were not important to be considered from an economic point of view.

Clerides (2010) investigated the correlation of weekly retail fuel prices (unleaded gasoline and diesel oil) and crude oil across European Union (EU) countries for the time period January 2000 to March 2010. He made use of the ECM methodology proposed by Borenstein et al., (1997) in which both short- and long-term price adjustments are considered. Moreover, final retail prices were separated into two categories, those with all taxes included and without them. He focused on three major issues: the symmetric case, the rate, and the speed of adjustment. Although there was a delay on the pass-through mechanism from crude oil price variations to unleaded gasoline and diesel, for most of the European countries, no evidence of any asymmetry was found. Only a small number of countries, like Cyprus, presented a weak asymmetric behavior, yet it was not economically significant. The author concluded that any additional profits firms might take advantage of from asymmetric pricing are low and temporary. Furthermore,

symmetry in the market does not induce the desired level of competition. It depends on the firms' return on capital that for permanent deviations from the "normal" levels could be huge.

L'oeilett and Lantz (2009) examined the asymmetric transmission from crude oil to retail fuel prices. They investigated the responses of gasoline, heating oil and diesel prices in France and Germany by using the asymmetric ECM methodology for weekly data from January 1998 to October 2008. Unlike the majority of previous studies, not only have they distinguished the transmission chain to refinery and distribution chain, but also the role of exchange rate was involved. Asymmetry was found for both countries in the diesel market, but their conclusions were contradictory for heating oil. This dissimilar cost pass-through mechanism was more intense at the refinery stage than it was at the distribution stage. Despite the held belief and the results of the previous literature, no evidence of asymmetry was proved in the responses of gasoline market. Additionally, the appreciation of the national currency seemed to attenuate the effect of crude oil shocks on retail prices, whilst the depreciation had no effect at all. The authors also explained the reasons of asymmetries that, in summary, were inventories and production costs, market power of retailers and imperfect competition and consumer search costs.

A problem that may be addressed in previous studies (Borenstein, et al., 1997; Bachmeier and Griffin, 2003; Radchenko, 2005a; Honarvar, 2009) is the incorporation of only two coefficients that represent the speed of adjustment, namely, the positive and negative deviations from the long-run equilibrium. The responses of retail prices may be different to large or small shocks. Valdkhani (2013) took also into account the magnitude of disequilibria. The area of his investigation involved 111 locations of the Australian

retail gasoline market and its responses to wholesale price changes. He employed weekly data that cover the period from October 2007 to January 2012 to an asymmetric ECM model. The ECM term was separated in large positive, large negative and small positive/negative deviations. The results for 28 locations were in accordance with Bacon (1991), who first demonstrated evidence of asymmetry in gasoline prices, while in 31 locations the opposite effect was obtained. This means that in 25% of the locations in Australia, if wholesale prices are considerably below the optimal market equilibrium, there will be a quicker price adjustment by retailers than if the prices were above this value.

De Salles (2014) examined the asymmetric relationship between crude oil and gasoline prices for a considerable number of countries. These were Brazil, the US, Belgium, France, Germany, Italy, Netherlands and the UK. The author ran both causality and co-integration tests and error correction mechanisms when the latter failed to reject the null hypothesis of the absence of co-integration. The time span of the data was from June 2006 until April 2013 and the observations had weekly frequency. Additionally, he utilized autoregressive conditional heteroscedasticity (ARCH), generalized ARCH (GARCH), integrated ARCH (IGARCH), and exponential GARCH models to estimate the variance of price returns. The results indicated both asymmetry and co-integration between the variables across all countries. However, the author argued that these conclusions varied depending on the data and the methodologies that were taken into account.

Atil et al., (2014) made use of the recently developed Non-linear Autoregressive Distributed Lag (NARDL) model to investigate the pass-through of the crude oil prices to the US gasoline and natural gas market. This methodology allows for both short and long

run non-linearities testing by decomposing the dependent variables into positive and negative partial sum decompositions. A quantification of the responses to positive and negative oil shocks is also feasible through the asymmetric dynamic multipliers. In other words, the dynamic adjustment of gasoline and natural gas prices from the old to the new equilibrium is observed. The authors used monthly data from January 1997 until September 2012. The non-stationarity of the price levels was an appropriate element of the NARDL methodology. The results indicated an asymmetric short-run relationship between crude oil and gasoline prices and a corresponding long run for natural gas prices. Moreover, there was a significantly greater impact on gasoline and natural gas values to oil decreases than increases. The oil price reduction affects in a positive way the budget of consumers and producers for the purchase of these fuels. The long-run equilibrium for oil and gasoline is restored after 8 months. Contrariwise, natural gas prices are more persistent to oil pass-through and additional time is needed for the convergence to long-run multipliers. They concluded that the quicker response of gasoline is due to the fact that it was formulated directly from crude oil. Furthermore, natural gas may have a slower response because it refers to a more regional market, while crude oil is internationally traded. Finally, the researchers issued the importance of these results for policymaking, speculators, commodity investments, and energy risk hedging. As far as the reasons of asymmetric behavior is concerned, a considerable number of papers have been published in an attempt of the researchers to investigate the potential factors that urge downward prices to respond in a dissimilar way to positive and negative upward price changes.

Lewis (2004) proposed an alternative methodology regarding the asymmetric price adjustment of the retail gasoline market. He developed a “reference search model” whereby consumers’ price expectations depend on previous gasoline prices that have been observed or purchased. The discrepancy between Lewis’s methodology and previous published studies (e.g., Borenstein et al., 1997; L’oeilett and Lantz, 2010) who also mentioned some possible reasons of asymmetry) relies on the fact that consumers are practically not provided with full knowledge of retail and wholesale gasoline prices. As a result, firms set a higher price and individuals’ gains by searching the necessary information are not significant. Lewis (2004) concluded that the margin size is the main determinant of the asymmetric price speed of adjustment rather than the upward or downward direction of cost changes. For instance, if a consumer observes a certain low gasoline price, his/ her search of a lower one will be reduced. The demand then becomes more inelastic and firms face less competition. Consequently, they can set higher prices and take advantage of the higher profit margins for as much time as they can. By contrast, cost increases result in more search and low margins and, therefore, in a faster response.

Radchenko (2005b) examined the relationship between oil price volatility and asymmetric effects in the gasoline market. He tested three potential explanations of the dissimilar responses of US retail gasoline prices to crude oil price ups and downs: the “standard search theory”, the “search theory with Bayesian updating” and the “oligopolistic coordination theory”. The first one states that a raise of the oil price volatility leads to less search by consumers and to a growth of retailers’ market power, therefore, to asymmetric increase. Contrariwise, the results, which were derived using a VAR model for weekly data from March 1991 to February 2003, supported the other two

theories. There was a negative correlation between oil price volatility and gasoline price asymmetry. More specifically, the asymmetry decrease due to an increase in the volatility of oil prices is based on a sooner adjustment of retail gasoline prices after a negative oil shock. The latter is explained by the oligopolistic coordination theory to which Radchenko (2005b) concluded as the reason of the asymmetric behavior of the gasoline market.

Tappata (2009) formalized a consumer search model in an attempt to prove that collusion among firms, the government and the media is not sufficient to explain the asymmetric behavior of several products. The latter could happen both in highly competitive and non-competitive markets. According to economic theory, ignorance in the market leads to temporary profits for firms. For instance, if the current marginal cost is high, consumers expect it to remain high and their search activity declines. Thus, in a situation of small cost reduction, firms earn by keeping the price high for a short time period. On the other hand, when the marginal cost is low and rises in the future, consumers intensify their searching process. Firms then have an incentive to raise the prices immediately in order not to experience any losses.

Cabral and Fishman (2012) developed a search theoretic methodology in an attempt to prove not only that consumer prices are sticky to cost changes, but they also respond in an asymmetric manner. The authors considered a model where consumer search costs could lead to output prices that are stickier than an industry's input costs. As a matter of fact, if a firm's costs change slightly, then it is in firm's favor not to alter the price. In this way, consumers hold back their searching activity because of their belief of no cost shocks. By contrast, a change in the price will urge consumers to search for a

better offer in rival companies, an action that outweighs potential profits from the price adjustment to a new equilibrium. They found an asymmetric pricing behavior as well, i.e., the price adjustment is faster to cost increases than decreases. A small rise in input costs results in a slight price growth. Consumers expect other firms to act in the same way and search less for more advantageous prices. On the other hand, firms fear the induction of consumer searching and do not change the product's price in the case of a small cost reduction.

As can be seen so far, a vast literature has been published regarding the asymmetric relationship between crude oil and gasoline prices. However, a definite rule cannot be established since the conclusions are far from unanimous. Perdiguero-Garcia (2010) attempted to study this variability of results. He accomplished a meta-analysis approach by introducing a broader dataset and new variables. The dependent variable was a dummy that takes the value of 1 if in a study asymmetric behavior has been proved, and 0 otherwise. The independent variables had to do with the type of asymmetry, the year of publication, the industry sector that a study analyzed, the number of years examined, the type of fuel, the geographical area, taxes, the quality and quantity of the data, and the model and estimator that were used. All these elements could explain the diverse results in the empirical literature. Evidence of asymmetry is less likely to be found in more recent articles, in studies that investigate the first stages of the transmission mechanism and in these whereby a great number of observations or monthly frequency have been used. By contrast, an analysis of the last stage of the industry, the use of the maximum likelihood estimator or the geographical aggregation of the data at the country level could lead to asymmetries. Perdiguero-Garcia (2010) concluded that there might be some

publication bias towards the studies in which asymmetric responses have been observed. Another relationship which is of crucial interest is that between crude oil and natural gas, with which several researchers have dealt, focusing either on the linear or the non-linear relationship of these two fuels. Again, the results have been sensitive to changes of the dataset and its frequency, the region of investigation and the model specification.

Serletis and Rangel-Ruiz (2004) studied the shared trends and cycles between natural gas and crude oil in the North American market. They used an autoregressive distributed lags (ARDL) model and a bounds testing approach for the investigation of a potential long-run relationship. The examined variables were the WTI crude oil and US Henry Hub natural gas prices from January 1991 until April 2001 and they were extracted on daily frequency. The results indicated a decoupling from the regular equilibrium, as a consequence of the recent deregulation of the oil and natural gas markets, and the hypothesis of similar trends was rejected.

Crude oil and natural gas prices are variables that contain a unit root. Thus, applying approaches like simple correlations and deterministic trends in order to investigate their historical relationship may lead to spurious conclusions. Villar and Joutz (2006) implemented a bi-variate vector error correction model (VECM) that covered the period January 1991 to December 2005 and proved that WTI crude oil and Henry Hub natural gas prices share a long run co-integrating relationship. Additionally, a one month temporary shock of 20% magnitude to oil can cause a 5% effect on natural gas prices. The latter is decreased to 2% within 2 months. There was clear unidirectional causal relationship from crude oil to natural gas. The reason is that oil refers to an international market; whilst US natural gas is traded in a more domestic one and can not affect world

prices. As far as the natural gas demand side is concerned, an increase in oil prices leads to an increase both of the demand and the natural gas prices because the two fuels are substitutes and consumers prefer the most economical solution. The results for a positive oil shock from the supply side were ambiguous since a rise of oil prices could lead both in a boom and a reduction of natural gas prices. The short-run inelasticity of natural gas supply causes a dominant effect of oil to the first. The authors concluded that there was a stable and statistically significant long-run relationship between these two products; despite the time periods of large spikes that one or both of them experienced which temporarily ruined the common trend.

Brown and Yücel (2007) presented two simple rules of thumbs that are used in the energy industry for natural gas pricing. The first one states that there is a 10-1 relationship between the price of a barrel of crude oil and one million British Thermal Units (BTUs) of natural gas. This ratio is reduced to 6-1 in the second rule of thumb because a barrel of WTI crude oil contains 5.825 million BTUs. However, neither of the rules is suitable to define the relationship of the two fuels over the last three decades, because they over- and under-forecast, respectively, natural gas prices. It was also observed that when there was an upward trend for both prices, the 10-1 rule was displaced by the 6-1 ratio. In contrast, the first rule of thumb seems to explain better the correlation of the two in the case of negative shocks. Additionally, the authors made use of an ECM approach with weekly data from January 1997 to July 2006 and indicated that there was a long-run relationship between crude oil and natural gas prices, despite the short-run variations, a conclusion that is in accordance with the study by Villar and Joutz (2006). In the case of a temporary decoupling, natural gas prices adjust to oil price

changes in a rate of 8% per week, causing the gap to narrow within a very short time period. Weather, seasonality, natural gas storage, inventory levels and other additional factors were taken into account as well.

Aloui et al., (2014) examined the non-linear connections between crude oil and natural gas. They studied the extreme co-movements between the prices of the two fuels as well as the degree and nature of relative dependence during bullish and bearish periods and their implications on volatility forecasting. The applied methodology was the copula-GARCH model and the relative daily prices covered the period from January 1997 to October 2011. The results indicated that the long-run relationship between WTI crude oil and Henry Hub natural gas prices was strengthened during bull market phases when economic growth and demand tended to increase, something that was not applied in the corresponding bear periods. The researchers attributed this situation to four possible reasons. First of all, arbitrageurs take advantage of profit opportunities during bullish, rather than bearish periods. Moreover, consumers react faster when the prices of crude oil and natural gas are in high levels. A third cause is the fact that in periods with strong economic growth, the demand for all fuels tends to move up, contrary to times with financial and physical crises when the demand magnitude is significantly reduced. Finally, the natural gas market requires heavy investments for its transmission and distribution system, for which longer-term contracts are required. They utilized the extreme value copula- GARCH (EVC-GARCH) model as well. The latter helped them to measure in a more precise manner the Value at Risk, which is an instrument of assessing the maximum losses of a number of investments, that is to say the portfolio risk.

Summarizing, the vast majority of the articles deal with US and selected European countries. The most common examined time periods are the 1980s and 1990s and only some of the most recent studies made use of updated data. The frequency of the variables has been either weekly or monthly, although fortnightly data were employed in some of the cases. Most of the researchers approached the issue of asymmetry in the latest stage of the transmission mechanism, that is, the responses of retail prices to wholesale price changes, and only few looked into this on the refinery level. The econometric methodologies that have been used depend on the author and how he/she needed to approach the subject. This is the main reason of the diversity of the results as far as the asymmetric behavior of a variable is concerned. Latest developments in econometric models were applied only in a few recent studies, in which both short- and long-run asymmetric pricing effects were tested and estimated. As far as the connection between crude oil and natural gas is concerned, it seems that the two fuels share a long run co-integrating relationship, although the latter depends on the applied model, the dataset and the nature of the economy. In Table 1 below, all the examined studies and their results are summarized in chronological order.

Table 1. Summary of the literature review

Study	Country	Product	Sample	Frequency	Methodology	Conclusions
Bacon (1991)	UK	Retail gasoline	1982- 1989	Biweekly	Non-linear quadratic partial adjustment model	Asymmetry: slower adjustment to decreases than increases by one week.
Karrenbrock (1991)	US	After-tax retail gasoline	1983- 1990	Monthly	ARDL	Symmetry for premium and unleaded regular, asymmetry for leaded regular.
Shin (1994)	US	Wholesale gasoline	1986- 1992	Monthly	Quadratic partial adjustment model	No evidence of asymmetry.
Borenstein et al., (1997)	US	Retail gasoline	1986- 1992	Weekly and biweekly	Non-standard asymmetric ECM	Asymmetry: slower adjustment to decreases than increases by four weeks.
Peltzman (2000)	US	77 consumer and 165 producer goods	1982- 1996	Monthly	VAR and ARDL	Asymmetry in sectors with wide distribution system.
Galeotti et al., (2003)	DE, FR, UK, IT, SP	Wholesale and retail gasoline	1985- 2000	Monthly	Asymmetric ECM	Asymmetry for all countries, especially at the distribution stage.
Bachmeier & Griffin (2003)	US	Wholesale gasoline	1985- 1998	Daily	ECM with SR asymmetry	No evidence of asymmetry.
Lewis (2004)	US	Retail gasoline	2000- 2001	Weekly	Reference price search model	The margin size is the main determinant of the asymmetric speed of adjustment.
Jimenez- Rodriguez and Sanchez (2004)	OECD countries	-	1972- 2001	Quarterly	VAR	Asymmetry of GDP responses to oil shocks for the majority of the countries.
Serletis and Rangel-Ruiz (2004)	North America	Natural gas	1991- 2001	Daily	ARDL	Decoupling of the regular equilibrium.

Table 1. Continued...

Study	Country	Product	Sample	Frequency	Methodology	Conclusions
Al-Gudhea et al., (2007)	US	Wholesale and retail gasoline	1998- 2004	Daily	M-TAR	Asymmetry at retail level that decayed quickly.
Radchenko (2005a)	US	Retail gasoline	1991- 2002	Weekly	Hidden Markov-switching model	Responses depend on the shock time length.
Radchenko (2005b)	US	Retail gasoline	1991- 2003	Weekly	VAR	Asymmetry is explained by the oligopolistic coordination theory.
Villar and Joutz (2006)	US	Natural gas	1991- 2005	Monthly	VECM	WTI crude oil and Henry Hub natural gas prices share a LR co-integrating relationship.
Brown and Yücel (2007)	US	Natural gas	1997- 2006	Weekly	ECM	WTI crude oil and Henry Hub natural gas prices share a LR co-integrating relationship.
Grasso & Manera (2007)	FR, DE, IT, SP, UK	Wholesale and retail gasoline	1985- 2003	Monthly	Asymmetric ECM, TAR ECM, ECM with threshold co-integration	SR and LR asymmetry, depending on the country and the market stage.
Honarvar (2009)	US	Retail gasoline	1981- 2007	Monthly	ECM	LR gasoline prices are more affected by technological improvement.
Tappata (2009)	-	-	-	-	Consumer search model	Asymmetry due to firms' production costs and consumers' lack of information.
Bermingham & O'Brien (2010)	IR, UK	Retail petrol and diesel	1997- 2009	Monthly	TAR ECM	No evidence of asymmetry.
Clerides (2010)	EU	Retail unleaded gasoline and diesel oil	2000- 2010	Weekly	Non-standard asymmetric ECM	No evidence of asymmetry.

Table 1. Continued...

Study	Country	Product	Sample	Frequency	Methodology	Conclusions
L'oeillet & Lantz (2010)	DE, FR	Retail gasoline, heating oil and diesel	1998- 2008	Weekly	Non-standard asymmetric ECM	No evidence of asymmetry for gasoline, asymmetry in the diesel market, contradictory results for heating oil.
Perdiguero-Garcia (2010)	-	-	-	-	Meta-analysis approach	Evidence of asymmetry in recent studies that investigate early stages.
Cabral and Fishman (2012)	-	-	-	-	Search theoretic model	Evidence of asymmetry.
Valdkhani (2013)	AUS	Retail gasoline	2007- 2012	Weekly	Non-standard asymmetric ECM	Evidence of asymmetry in 25% of the locations.
De Salles (2014)	BR, US, BE, FR, DE, IT, NL, UK	Retail gasoline	2006- 2013	Weekly	ECM, ARCH, GARCH, IGARCH, exponential GARCH	Evidence of asymmetry and co-integration.
Atil et al., (2014)	US	Retail gasoline and natural gas	1997- 2012	Monthly	NARDL	SR asymmetry for gasoline, LR asymmetry for natural gas.
Aloui et al., (2014)	-	Natural gas	1997- 2011	Daily	Copula-GARCH model	The LR relationship between WTI crude oil and Henry Hub natural gas prices was strengthened during bull market phases.

Note: AUS=Australia, BE=Belgium, BR=Brazil, DE=Germany, EU= European Union, FR=France, IR=Ireland, IT=Italy NL=Netherlands, SP=Spain, UK=United Kingdom, US= United States of America, OECD=Organization for Economic Co-operation and Development

Recent Empirical Studies on Linear and Non-linear ARDL

The empirical studies that looked for evidence of asymmetries in the transmission mechanism using Autoregressive Distribution Lag (ARDL) model are of a considerable number. Karantininis et al., (2011) used non-linear ARDL model to analyze price transmission in the Swedish food market chain. They examined how retail prices for milk, pork, beef, and cereals respond to price changes at the farm and processing levels. Based on theories of asymmetric price transmission, the study aimed to answer the question whether a price increase results in a slower decline towards the price equilibrium than a price reduction. Based on the bounds-testing procedure advanced by Pesaran et al., (2001) the price series were tested for co-integration relationships between all three levels of the food chain and the result showed that co-integration exists between all series, except for farm-gate prices and retail prices at the milk market, indicating that price transmission exists and there is a high degree of integration in the vertical food market chain. Then an error correction model based on asymmetric co-integration (NARDL), developed by Shin et al., (2009), that takes the positive and negative price changes into account in both the short and the long run, was applied. The analysis showed that asymmetries are present in all categories, but the results are mixed and symmetric relationships are also present.

Ayşe Ulkuhan Demir (2015) wrote an essay on the non-linear dynamics of the finance-growth nexus as a part of PhD thesis. The study examined the relationship between financial structure and economic development for Germany, the USA, France and Turkey between 1989 and 2012. Nonlinear Autoregressive Distributed Lags (NARDL) model was employed to investigate whether a dynamic change exists in the

financial structure of these countries in response to a change in their stage of economic development suggested by the view of 'new structuralism'. Unlike previous literature, which classified the financial systems of Germany as bank-based, the USA as market-based and France and Turkey as in an intermediate position between these two forms, the findings of the first essay presented in this work supports 'new structuralism'.

Ibrahim (2015) analyzed the relations between food and oil prices for Malaysia using a nonlinear autoregressive distributed lags (NARDL) model. The bounds test of the NARDL specification suggests the presence of co-integration among the variables, which included the food price, oil price and real GDP. The estimated NARDL model affirms the presence of asymmetries in the food price behavior. In the long run, the study found a significant relation between oil price increases and food price. Meanwhile, the long run relation between oil price reduction and the food price was absent. Furthermore, in the short run, only changes in the positive oil price exerted significant influence on the food price inflation. With the absence of significant influence of oil price reduction on the food price both in the long run and in the short run, the role of market power in shaping the behavior of Malaysia's food price was likely to be significant.

Vouzavalis Grigorios (2016) investigated the asymmetric pass-through of oil prices to natural gas and gasoline prices under the non-linear autoregressive distributed lags (NARDL) modeling approach proposed by Shin et al., (2013). Both short- and long-run non-linearities were tested by deriving the positive and negative partial sum decompositions of the dependent variable. In addition, it was feasible through the econometric analysis to quantify the respective responses to positive and negative oil price shocks from the asymmetric dynamic multipliers. The obtained results indicated an

asymmetric relationship in most of the cases, yet with a different price transmission mechanism each time.

Lacheheb and Sirag (2016) examined the relationship between oil price changes and inflation rate in Algeria. The study adopted a method that was able to capture for asymmetries in the relationship between oil price and inflation known as nonlinear autoregressive distributed lags (NARDL). The estimated model revealed the existence of nonlinear effect of oil price on inflation. Specifically, the study found a significant relation between oil price increases and inflation rate, whereas, a significant relation between oil price reduction and the inflation was absent.

Iqbal and Babcock (2016) used a comprehensive dataset of 104 countries for corn, 54 countries for soybeans, 82 countries for wheat, and 77 countries for rice. These were used to estimate globally comprehensive but heterogeneous (country-specific) transmission elasticities between international prices and domestic producer prices. The study mainly utilized the traditional two-step Engel-Grange co-integration model and the recently developed nonlinear autoregressive distributed lags (NARD) model to estimate the transmission elasticities. Results showed mixed evidence on the existence of long run relationship between international and domestic prices. For corn, 66 out of 104; for soybeans, 27 out of 54; for wheat, 47 out of 82; and for rice, 49 out of 77 countries, failed to have a long run relationship. For corn and soybeans, the long run relationship was evident in top producing countries whereas the converse was evident for wheat and rice, particularly for rice. The study showed that the pass-through of international to domestic prices was asymmetric. Majority of the cases these asymmetries were negative, i.e., the domestic producer prices react less fully to an increase in international prices than to a

decrease and were acute in the short run than the long run. The study also estimated the crop specific short run global mean transmission elasticities.

Bahmani-Oskooee et al., (2018) determined which country's policy uncertainty measure has an impact on oil prices. Using both the linear and the nonlinear Autoregressive Distributed Lag (ARDL) methods, they found that while policy uncertainty measures of Canada, China, Europe, Japan, Russia, South Korea, and the U.S. have short run effects, short run effects last into the long run asymmetric effects only in the case of China. This might reflect the importance and recent surge in China's engagement in world trade.

Nsabimana and Habimana (2017) examined the effects of the likely change in rainfall on food crop prices in Rwanda, a landlocked country where agriculture is mainly rain-fed. The empirical investigation was based on nonlinear autoregressive distributed lag (NARDL) co-integration framework, which incorporates an error correction mechanism and allows estimation of asymmetric long run and short run dynamic coefficients. The results suggested that food crop prices were vulnerable to rainfall shocks and that the effect was asymmetric in both the short and long run. Moreover, there was evidence of seasonal differences, with prices falling during harvest season and rising thereafter. Considering the ongoing threat of global climate change, and in order to cope with rainfall shortage and uncertainty, increase food affordability and ultimately ensure food security throughout the year, there was a need to develop and distribute food crop varieties and crop technologies that reduce the vulnerability of farming to rainfall shocks.

Ekananda and Suryanto (2018) observed the factors affecting domestic soybean prices, including government intervention through BULOG; by using Bound Testing Co-

integration method with ARDL approach. The results showed that in the short term, the world soybean price variables in the t-period and exchange rate affect the domestic soybean prices positively and significantly. The variable volume of soybean imports, GDP, and the role of BULOG as sole importer in the t-period do not affect the domestic soybean price significantly. In the long run, the t-period import tariff has a negative and significant effect.

Pal and Mitra (2016) examined the potential asymmetric transmission from crude to oil product prices in India. Instead of linking oil product pricing only with rise and fall of crude price, they analyzed the effect of crude price fluctuations by decomposing the crude price changes in quantiles by holding multiple thresholds. Use of multiple threshold nonlinear autoregressive distributed lag (MTNARDL) model improves precision in estimating the asymmetric effect of the crude price changes on oil product prices over that of the single threshold NARDL model. It was observed that the asymmetric price transmission was high across all oil products, when higher and lower quantiles of crude price fluctuations were compared. This showed that the price of oil products increases when crude prices go up; however, the advantage of the sharp fall of crude prices was not fully transmitted to the oil products.

Dauids et al., (2017) evaluated the extent of price transmission between Zambia, South Africa and Zimbabwe under two exogenous regimes defined by periods of open trade and trade controls imposed by the Zambian government. It used secondary data of monthly white maize prices in these three markets to quantify the long and short run price relationships under different regimes with ARDL model. While several authors have noted that trade is not a prerequisite for price transmission between markets, this study

finds evidence that the imposition of policies that inhibit trade also influences the rate and nature of price transmission between markets. Periods of open trade were characterized by efficient transmission of prices from Zambia to Zimbabwe, which is in line with typical trade patterns, but during periods of trade controls, no relationship was found between Zambian and Zimbabwean markets, with prices being transmitted from South Africa to Zimbabwe instead. Table 2 represents the summary of the recent price transmission studies that used ARDL/NARDL model.

Table 2. Summary of the recent empirical studies on linear and non-linear ARDL

Study	Content	Model
Karantininis et al., (2011)	Analyzed price transmission in the Swedish food market chain	NARDL
Ibrahim (2015)	Analyzed the relations between food and oil prices for Malaysia	NARDL
Vouzavalis Grigorios (2016)	Investigated the asymmetric pass-through of oil prices to natural gas and gasoline prices	NARDL
Lacheheb and Sirag (2016)	Examined the relationship between oil price changes and inflation rate in Algeria	NARDL
Nsabimana and Habimana (2017)	Examined the effects of the change in rainfall on food crop prices in Rwanda	NARDL
Pal and Mitra (2016)	Examined the potential asymmetric transmission from crude to oil product prices in India	Threshold NARDL
Davids et al., (2017)	Evaluated the extent of price transmission between Zambia, South Africa and Zimbabwe	ARDL

Price Transmission Studies in Bangladesh

Rice is one of the most important food crops in Bangladesh, an essential element in ensuring food security, employment, and income. Hence, rice is a commodity that has received much attention in Bangladesh. There are a significant number of studies on Bangladesh rice sector. However, only a few studies have been in the field of rice market integration. Majority of the Bangladesh rice market integration studies used spatial market integration whereas Alam et al., (2016) analyzed vertical price transmission asymmetry.

Ahmed and Bernard (1989) used Ravallion model in Bangladesh rice markets in addition to the simple method of using paired correlation coefficient between markets. In case of *Aus* rice, only 48 out of 190 pairs of correlation were statistically insignificant. All remaining coefficients were highly significant. Out of the 48 insignificant coefficients, 18 related Chittagong to other districts in the northern and southern part of Bangladesh. In case of *Aman* rice, 63 out of 190 pairs were statistically insignificant. However, 51 out of the 63 insignificant correlations pertain to Barisal, Patuakhali, Dinajpur and Bogra. The first three were extremely backward in infrastructural development. Their results rejected the market segmentation hypothesis for all the markets considered.

Sabur (1990) used correlation coefficients of monthly wholesale prices of different vegetables in the selected spatially separated urban markets in Bangladesh. All the correlation coefficients were highly significant. This indicated that the urban markets were significantly correlated in respect of their price change due to good communications among the traders and transportation facilities. The estimated correlation coefficients

revealed that all the selected retail and wholesale markets in the Dhaka city were in competition with each other. The correlation coefficients obtained from the weekly prices of different primary markets were low and insignificant, which was an indication of low relationship of weekly vegetables prices. Thus, weekly vegetables prices, compared to monthly prices were less related among the selected markets, indicating that price changes in one market was not immediately reflected in other markets.

Goletti et al., (1995) explored several issues related to market integration, according to a two-stage approach. The first stage used time series methods to construct four measures of market integration; the second stage introduced structural variables to explain market integration. The analysis was applied to rice markets in Bangladesh, and used a set of new and a comprehensive data that included weekly prices of rice over a period of three years for 64 districts, and structural variables at the district level. The major conclusion of the first stage was that the degree of market integration in Bangladesh was rather moderate. The second stage showed that the different measures of market integration responded differently to the same structural factors. The various measures of integration proposed in this study might be capturing various dimensions of market integration and therefore argued for further study to deepen the understanding of the process of price transmission over spatial distance.

By using monthly wholesale prices of coarse rice, Dawson and Dey (2002) applied a dynamic vector autoregressive model and Johanson's co-integration procedure to examine long-run spatial rice market integration in Bangladesh. They conclude that rice markets are perfectly integrated and that Dhaka dominates near markets but is dominated by more distant markets.

Hossain and Wim Verbeke (2010) investigated the extent of market integration after rice market liberalization by using weekly market price data from six regional markets in Bangladesh. The overall results of the market integration analysis indicated that, although the six regional markets in Bangladesh were co-integrated (i.e., they had a stable long run relationship), these markets were only weakly integrated in the short run. Granger causality results were unidirectional causality originating from Dhaka to Khulna and Barisal and from Sylhet to Dhaka, while Dhaka leads the price formation process only for Sylhet. There was also bi-directional causality between Dhaka and Chittagong, and Dhaka and Rajshahi. The short-run results indicate that these rice markets are not well integrated while long-run integration is evident, suggesting that the markets move together in the long term. The spread of adjustment appears to be the inverse of distance and directly related with ease of transport. They did not use Error Correction Model (ECM) for their study.

Alam et al., (2012) examined spatial price integration among five major Bangladesh rice markets in the presence of threshold effects to account for the impact of transaction costs in the price adjustment process. Hansen and Seo (2002) threshold co-integration test and threshold vector error correction model confirmed the presence of threshold effects. Results highlighted the importance of directing policy goals towards reducing transaction cost to engender greater pricing efficiency in Bangladesh rice markets.

Huda, F. A. (2014) used co-integration and vector error correction approaches to analyze the effect of global commodity market factors and domestic exchange rate development on domestic food price in Bangladesh. He applied bi-variants co-integration

approach for the analysis of shock transmission and developed an error correction model. The overall magnitudes of the pass-through suggested that only 46 per cent of the total world shock passed through the domestic economy.

Sapkota et al., (2015) investigated causal and price transmission relationships between wholesale and retail prices for five fish species in Bangladesh. Causal relationships between wholesale and retail prices were tested using the Granger causality test while asymmetries in price transmission were examined using the Houck and Ward approach as well as the error-correction approach. The results showed that the direction of causality in prices was from retail to wholesale in many of the value chains analyzed. In general, the price transmission was found to be symmetric in the short-run while a mix of symmetric and asymmetric was found in the long run. The results also showed variation in price transmission behavior between aquaculture and capture fisheries products. The retailers of aquaculture products, compared to their fisheries counterparts, were less likely to be in a position to easily pass through falling prices to wholesalers and farmers. For aquaculture products, elasticities of price transmission from retailer to wholesaler were generally greater from increases in price than from decreases in price.

Taslim and Hossain (2015) used vector error correction model, co-integration, and causality and found evidence that although domestic price and international price move together in the long run, the speed of adjustment towards equilibrium was not symmetric: positive shocks were transmitted at a faster rate compared with the negative ones. They investigated the soybean oil market in depth and found that this was not necessarily the result of collusion among the traders; the behavior of the soybean oil price can be explained by the interplay of competitive market forces in the specific context of edible

oil industry in Bangladesh. The level of stocks, price and supply expectations and the particular structure of the domestic edible oil market all contribute to the evolution of soybean oil prices.

Alam and Jha (2016) conducted a study on “Asymmetric threshold vertical price transmission in wheat and flour markets in Dhaka (Bangladesh): seemingly unrelated regression analysis”. The study employed threshold co-integration that took into account the asymmetric adjustment towards a long run equilibrium and short run price transmission. The paper investigated the non-linear price adjustment in short and long run in vertical markets of wheat and flour in Bangladesh. Using monthly wholesale and retail prices of wheat and flour the study developed an asymmetry threshold error correction model for three vertical chains, namely, (i) wholesale and retail markets of flour, (ii) wholesale markets of wheat and flour, and (iii) wholesale markets of wheat and retail markets of flour. It found evidence of threshold effects in vertical wheat-flour markets. The speed of adjustment towards the long run equilibrium was different when the price deviations exceed the threshold value from when price deviations were below the threshold. Additionally, they found evidence of short run price asymmetries implying that downstream price responds faster when upstream price increases than when the latter falls.

Alam et al., (2016) conducted a study as “Asymmetry Price Transmission in the Deregulated Rice Markets in Bangladesh: Asymmetric Error Correction Model”. They attempted to investigate the existence of asymmetry between wholesale and retail rice prices in Bangladesh. Maximum likelihood estimation (MLE) based co-integration test was applied to determine long-run equilibrium relationship. They examined whether the

wholesale market dominates the retail market in terms of price discovery and price leadership or vice versa. Finally, they analyzed whether the wholesale-retail price relationship is asymmetric with respect to price increases and price decreases. To test the asymmetric price transmission, the study used the asymmetric error correction-EG approach. The results show that wholesale and retail prices were co-integrated, and wholesale market played a leadership role in determining retail prices, which was in line with industrial organization theory. The results confirm the fear and concerns of consumers about the existence of price asymmetry. Table 3 represents the price transmission studies in Bangladesh.

Table 3. Price transmission studies in Bangladesh

Study	Content	Model
Alam et al., (2012)	Spatial price integration among five major Bangladesh rice markets	TVECM
Alam et al., (2016)	Asymmetric Price Transmission in the Deregulated Rice Markets in Bangladesh: Asymmetric Error Correction Model	VECM
Sapkota et al., (2015)	Investigated causal and price transmission relationships between wholesale and retail prices for five fish species in Bangladesh	ECM
Alam and Jha (2016)	Asymmetric threshold vertical price transmission in wheat and flour markets in Dhaka (Bangladesh): seemingly unrelated regression analysis	TVECM

Studies on Market Power of Agri-Food Sector

Bhuyan and Lopez (1998) estimated the oligopoly power of U.S. food and tobacco industries. They computed oligopoly-induced allocative efficiency losses in 38 US foods and tobacco manufacturing industries using conduct, demand and cost parameters estimated with a New Empirical Industrial Organisation (NEIO) approach. Allocative efficiency loss estimates in these industries amounted to US\$15.2 billion or over five per cent of sales for 1987. Statistical tests showed that these losses were generally higher than previous estimates, possibly due to the allowance of non-constant marginal costs and revised estimates of demand elasticities and conduct.

Nevo (2001) estimated market power in the ready-to-eat cereal industries. This paper empirically estimated price-cost margins, but more importantly empirically separated these margins into three sources: (i) that which is due to product differentiation, (ii) that which is due to multi-product firm pricing, and (iii) that due to potential price collusion. The results suggested that given the demand for different brands of cereal, the first two effects explained most of the observed price-cost margins. The study concluded that prices in the industry were consistent with non-collusive pricing behavior, despite the high price-cost margins. Leading firms were able to maintain a portfolio of differentiated products and influence the perceived product quality. It is these two factors that lead to high price-cost margins.

O'Donnell et al., (2007) tested market power in the Australian grains and oilseeds industries. They assessed competitive buying and selling behavior in the Australian grains and oilseeds industries using a more realistic empirical model and a less

aggregated data set than previously available. The study specified a duality model of profit maximization that allows for imperfect competition in both input and output markets and for variable-proportions technologies. Aggregate input-output data were used to define the structure of the relevant industries, and time series data were then used to implement the model for 13 grains and oilseeds products handled by seven groups of agents. The model is estimated in a Bayesian econometrics framework. The study found evidence of flour and cereal food product manufacturers exerting market power when purchasing wheat, barley, oats and triticale; beer and malt manufacturers exerting market power when purchasing wheat and barley; and other food product manufacturers exerting market power when purchasing wheat, barley, oats and triticale.

Kaditi (2011) estimated food retailers' market power in Greece and showed the affect of increased competitive pressure on it. This paper examined whether ownership and increased competitive pressure affect food retailers' market power, analyzing whether all actors involved in the food supply chain deviated from the pricing behavior that exists under perfect competition. The study estimated price-cost margins, relaxing the assumptions of perfect competition and constant returns to scale. The obtained results showed that foreign investments and consolidation have a positive and significant impact on the market power of food processors and retailers. Food processors, agricultural producers and wholesalers had lower price-cost margins than retailers, which suggest that these actors price closer to marginal costs being more concerned with maximizing social welfare or that the former had higher costs than retailers.

Kalantzi (2013) measured market power in the Greek manufacturing industry with emphasis on the food industries. Three different approaches based on the "new empirical

industrial organization” (NEIO) were used with the view to measuring the degree of market power and evaluating the competitive conditions. The first approach is the conjectural variation approach, which provides estimates regarding the actual degree of market power. The second approach is the Hal-Roeger approach and investigates the market structure and more specifically the mark-up. The third approach developed comprises an extension of the Hal-Roeger approach and offers contemporaneous estimates about the degree of market power and the markup. Moreover, the welfare losses were estimated using a formal model of oligopoly. The technical efficiency was measured following the “data envelopment analysis” (DEA), while its sources were determined based on the Simar and Wilson’s Algorithm.

Lopez et al., (2015) used the stochastic frontier (SF; Kumbhakar, Baardsen and Lien, 2012) approach in order to estimate oligopoly power in 36 US food industries. In this approach, mark-ups are treated as systematic deviations from a marginal cost-pricing frontier. They apply the analysis to the food industries using NBER-CES Manufacturing Industry Database, which covers a span of 31 years from 1979 to 2009. Empirical results showed that all the food industries in the sample exercise exhibit at least some degree of oligopoly power, but most in a moderate manner. The estimated mean Lerner index is approximately 0.06, generally much lower than that obtained using the conventional NEIO approaches. The SF model used provides a novel and promising framework to test and measure the degree of market power in agricultural and food markets.

Cechura et al., (2015) analyzed market power in the output milk processing in 24 EU member states. They analyzed the market power based on a mark-up model and the application of stochastic frontier (SF) methodology. The paper presents an analysis of

market power in the output milk-processing market. In particular, the paper identified market failures in the output milk-processing market in 24 EU member states. The analysis was based on a mark-up model and the application of stochastic frontier methodology. The results showed that market failures are pronounced on the EU output milk-processing market. However, the abuse of oligopoly market power was not large on average, despite the fact that the study can find significant differences among the countries. The mark-up distribution is skewed toward lower values. That is, only a small or almost no degree of market power characterized the majority of companies; however, there were companies (about 10 %) with considerably high oligopoly market power.

Panagitou and Stavrakoudis (2016) used stochastic frontier approach (SFA) to estimate the aggregate degree of market power exerted by the US beef and pork packing industries. The aggregate degree of market power in both the input market (cattle and hogs) and the output market (beef and pork) was estimated using annual time series data for the period 1970- 2009. The empirical results revealed that the farm-to-wholesale price spread was 4.91% and 4.16% above the marginal processing costs, in the beef and pork packing industries, respectively. These findings indicate that rather a small percentage of the farm-to-wholesale price spread can be attributed to market power in both U.S. meatpacking sectors. Table 4 represents the recent market power studies on agri-food sector.

Table 4. Recent market power studies on agri-food sector

Study	Content	Model
Kalantzi (2013)	Measured market power in the Greek manufacturing industry with emphasis on the food industries	NEIO
Kumbhakar et al., (2012)	A New Method for Estimating Market Power with an Application to Norwegian Sawmilling	Generated (SFA) to estimate market power
Lopez et al., (2015)	Estimated oligopoly power in 36 US food industries	SFA
Cechura et al., (2015)	Analyzed market power in the output milk processing in 24 EU member states	SFA
Panagitou and Stavrakoudis (2016)	Estimated the aggregate degree of market power exerted by the U.S. beef and pork packing industries	SFA

Studies on Consumer Welfare Measure

There are some studies on the empirical measurement of consumer welfare. These studies used the demand function (Marshallian, Hicksian) for the estimation of change in the consumer surplus, compensating variation, equivalent variation as well as dead weight loss with the change in price.

Hausman (1981) derived an exact analytical expression for the compensating variation from linear, log-linear, and quadratic demand functions. He noted that Roy's identity relates the ordinary demand functions to the indirect utility function, and if the Slutsky substitution matrix is symmetric and negative semi definite, the indirect utility function can be inverted to derive the expenditure function, and then the compensating variation can be calculated.

Vartia (1983) provided efficient algorithms to calculate the compensated welfare measures using only the Marshallian demand system. Although the welfare measures

must be iteratively computed, the welfare change between two equilibrium situations faced by the consumer can be exactly compared for a general class of Marshallian demands.

Arjan Ruijs (2009) evaluated the distribution and welfare effects of changes in block price systems. A method was discussed to determine, for a Marshallian demand function, equivalent variation in case of a block price system. The method was applied to analyze welfare and distribution effects of changing water prices in the Metropolitan Region of Sao Paulo. Results showed that there is a trade-off between average welfare and income distribution. A pro-poor price system might result in lower average welfare than a flat price system, but in higher individual welfare for the poor. Moreover, there was a trade-off between revenues for the water company and income distribution. Even though pro-poor price systems might not be as good for average welfare as flat price systems, their direct effects on poverty were important. Introducing pro-poor price systems, however, might have financial consequences for the water companies.

Osei-Asare and Eghan (2013) analyzed the effects of food price inflation on Ghanaian households using GLSS-5 household data. Expenditure endogeneity and truncated expenditures were controlled in the estimation process using the “Augmented Regression Approach” and Heckman’s two-stage procedure, respectively. Symmetry and homogeneity conditions were rejected in the unconstrained LA/AIDS model. The study revealed that cereals and bread; fish; vegetables; and roots and tubers will continue to constitute important share of Ghanaian food expenditure as they collectively constitute 67% of future food expenditure. Food price inflation between 2005 and 2011 had eroded real household food purchasing power by 47.18%.

Zheng et al., (2010) used estimated asymmetric error correction models (ECM) for producer, wholesale, and retail pork and beef prices to compute the compensating variation associated with asymmetric price transmission for US consumers. Overall, the phenomenon did not have a substantial impact; the expected welfare loss for the average US beef and pork consumer was about US\$1.10 per year, which was less than 1% of annual per-capita retail expenditures.

Waheed et al., (2012) examined the welfare effects of trade liberalization on Basmati rice within Pakistan's economy. Welfare gains (or losses) in terms of consumer and producer surplus were estimated for the pre- and post-WTO periods. Welfare gains associated with the then existing protection policies were compared with those when these policies were removed, if trade were fully liberalized for both periods. The analysis reveals that there has been a significant difference between domestic and foreign prices, suggesting tax on producers of Basmati rice in both pre- and post-WTO periods. However, the quantum of difference was comparatively less during the post-WTO period. Welfare analysis estimated higher losses for producers compared to gains to the consumers during both pre- and post-WTO periods. However, losses in the producers' surplus were comparatively less during the post-WTO period, suggesting that government in line with the WTO regime adopted certain measures. Similarly, simulation results demonstrate greater gains to producers than losses to consumers in the case of world market being liberalized.

Justification of the Study

Renowned economist Mahabub Hossain (1945-2016) made substantial contributions to research on development economics and agricultural policy in South and Southeast Asia. Throughout his long career as an active researcher and research manager, he has contributed to advancement of knowledge in many fields such as agrarian structure and land reforms; rural non-farm activities; technology, credit and infrastructure policies; income distribution and poverty; and Asian rice economy. He worked for the economic development of Bangladesh, South and Southeast Asian rice sector. However, he did not focus on the market, and pricing mechanism of rice sector.

Based on the review of literature, the latest price transmission asymmetry study in Bangladesh has been conducted by Alam et al., (2016). They used the vector error correction (VECM) model to investigate the existence of asymmetry between wholesale and retail rice prices. None of the studies used the linear and/or non-linear ARDL model in the agriculture and/or rice market of Bangladesh. The market power study is also absent in the case of Bangladesh. This study has used the standard methods such as ARDL approach of Pesaran et al., (2001) assuming that adjustment of variables follows a linear path, and Non-linear ARDL (NARDL) approach of Shin et al., (2014) assuming that the adjustment process could be nonlinear. Application of NARDL approach provides more evidence of non-linear adjustment of variables as well as asymmetric effects. On the extension of this, the study used the predicted symmetric and asymmetric prices and Vartia's (1983) algorithm to the established rice demand function to measure the consumer welfare and dead weight loss associated with price transmission asymmetry. The study also used the recently established stochastic frontier approach

(SFA) by Khumbhakar, Baardsen and Lien (2012) to measure the existence of the degree of market power as a cause of larger spread and asymmetric transmission of price along the rice supply chain.

CHAPTER III

CONCEPTUAL FRAMEWORK

Concepts of Price Transmission Asymmetry

Price outcomes in vertically related markets have been studied by agricultural economists for years. The relationships between farm and retail food prices and the farm share of retail food expenditures have important economic and political implications. Gardner (1975) developed the modern theory of linkages among the price outcomes in a competitive food industry. He examined the implications of simultaneous equilibrium in three related markets: retail food, marketing services and farm output. He considered a competitive food marketing industry using two factors of production, namely, purchased agricultural goods and other marketing inputs, to produce food sold in the retail market. Gardner also discussed the viability of simple mark-up pricing rules and the determinants of the farm share of the retail food dollar. Figure 10 illustrates the basic market structure of the Gardner framework.

For the farm and retail market levels, the primary supply and demand for food products is represented by the farm-level supply curve and the retail-level demand curve. The demand for farm products at the farm level is derived from the retail demand for food products, so the farm-level demand curve is known as derived demand. Accordingly, the retail-level supply of food products is derived from the primary supply of farm products. In Figure 10, the equilibrium prices in the farm and retail markets are denoted as F^* and R^* , respectively, and the equilibrium quantity that flows through the

farm-to-retail marketing channel is Q^* . The price spread or marketing margin is the difference between price outcomes at different market levels. In this case, the farm-retail price spread or marketing margin is $R^* - F^*$.

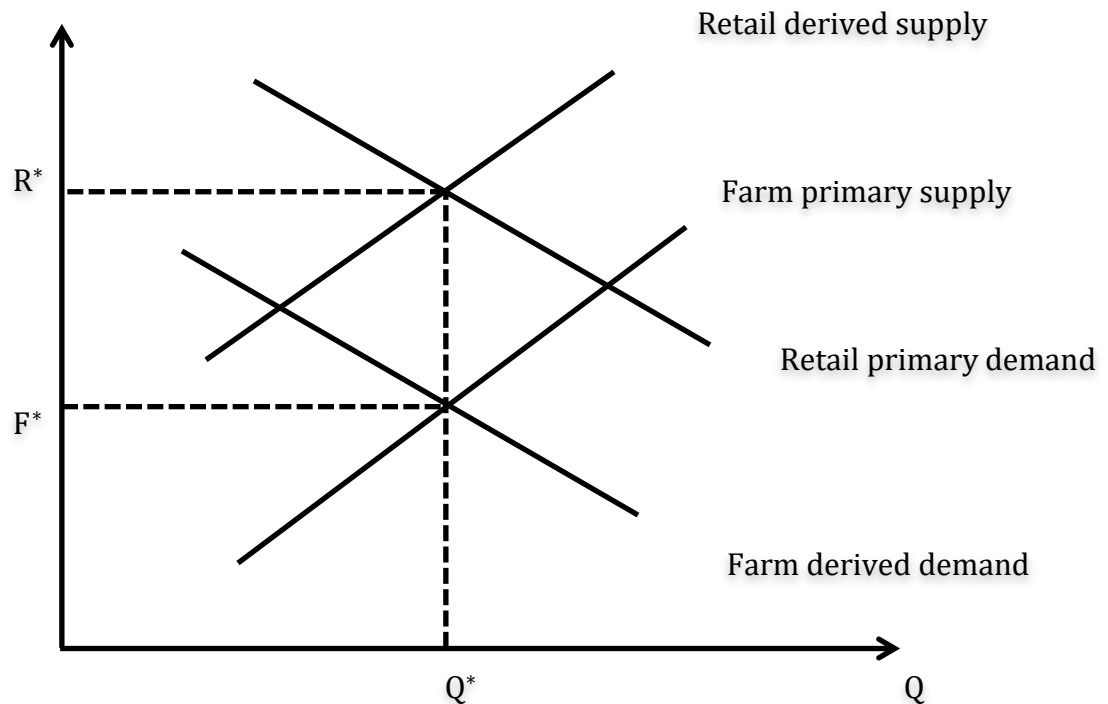


Figure 10. Basic structure of Gardner model of linkages among the price outcomes in the competitive food industry (Zheng, 2004)

Vertically linked markets are often described in terms of ‘upstream’ and ‘downstream’ markets. This study focused on agricultural price outcomes at three market levels, namely, farm, wholesale and retail. Generally, the farm level is viewed as the upstream market, and farm products flow downstream through wholesale and retail markets to the consumer. Farm price (F_t) refers to the price received by farmers at the

farm gate, wholesale price (W_t) refers to the price received by processors, and retail price (R_t) is the price faced by consumers in supermarkets and other retail food outlets. The three price spreads can be referred to as the wholesale-retail spread ($R_t - W_t$), the farm-wholesale spread ($W_t - F_t$), and farm-retail spread ($R_t - F_t$). This definition refers to the gross margin, which includes the marginal cost of marketing services plus profit. The marginal cost of marketing services includes the normal profit to perform the services. In a perfectly competitive market, the marketing margins are equal to the marginal costs of marketing services only. Under imperfectly competitive markets, the margin may include excess profit.

Asymmetric price transmission refers to the phenomenon when downstream prices respond to upstream price increases and decreases at different rates. Typically, wholesale or retail prices respond more quickly when farm prices are rising more than they are falling, or retail prices respond more quickly when wholesale prices are rising than when wholesale prices are falling. The asymmetric pricing phenomenon has been observed in a wide range of agricultural and non-agricultural markets and there are several plausible causes. Asymmetric marketing costs may be one potential source of asymmetric price transmission.

Following Tomek and Robinson (1990), the supply and demand for marketing services are shown in Figure 11. The demands for marketing services are assumed perfectly inelastic, and the supply of marketing services (S) slopes upward, which implies increasing marginal cost of marketing services. Under demand D_1 , the equilibrium price of the marketing services is P_1 . When the upstream price decreases, the downstream quantity demanded increases, and the quantity of marketing services demanded increases

from $D1$ to $D2$. The new equilibrium price of marketing services becomes $P2$. When the upstream price increases, the quantity of marketing services demanded decreases as a result of decreased downstream demand. The price change will be asymmetrically transmitted if the price of marketing services returns to $P1$ as demand shifts back to $D1$. Otherwise, the price response may be asymmetric if the marginal cost structure follows another path as demand shifts from $D2$ to $D1$.

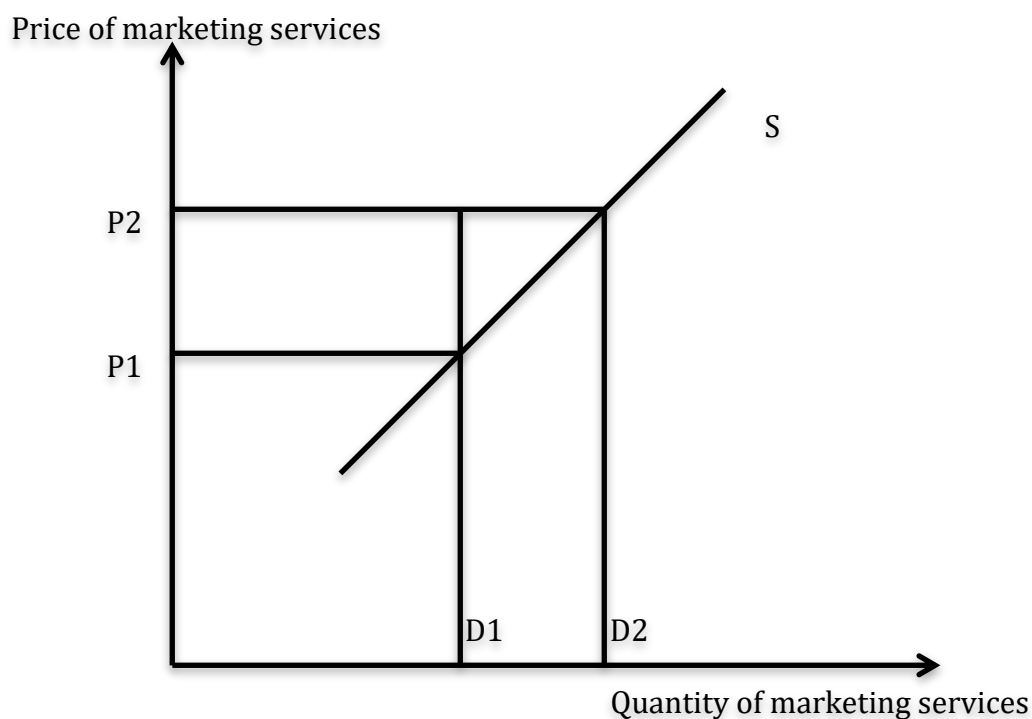


Figure 11. Supply and demand curves of marketing services (Zheng, 2004)

Figure 12 illustrates one plausible time path for the upstream and downstream prices under asymmetric price transmission, which is explained by Zheng (2004). The upstream price starts to decrease at time $T-t$, the downstream price also decreases with it, but at a slower rate. The price trend reverses at point T . The downstream price begins to

increase and returns to its original equilibrium price at time $T+t$. At the same time, the downstream price increases at the same rate as the upstream price. If the downstream price response occurs at the same rate before and after T , then price asymmetry does not exist.

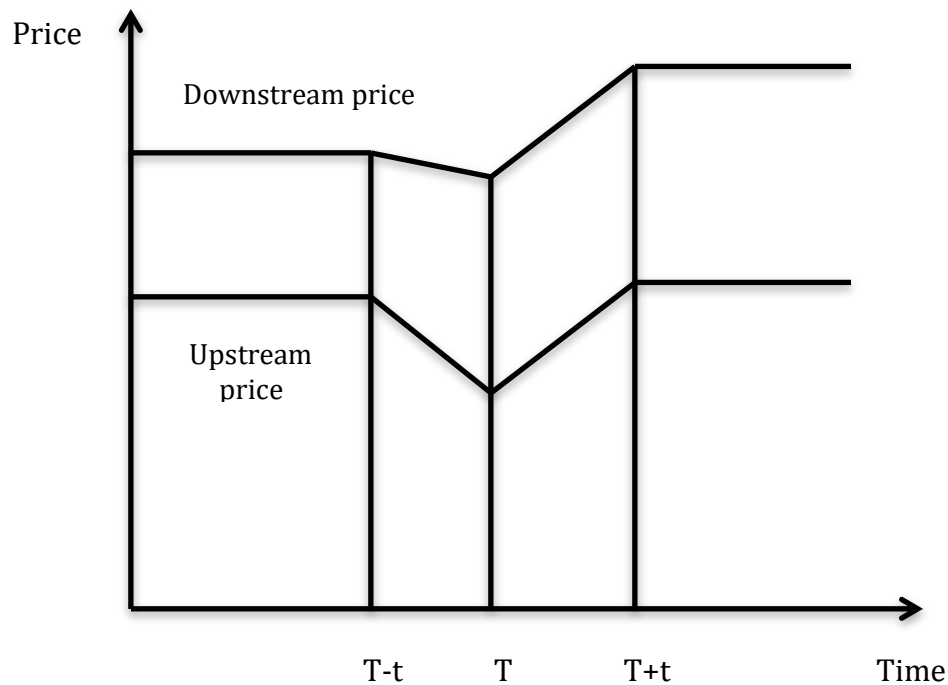


Figure 12. Sample time path for an asymmetric price adjustment (Zheng, 2004)

Asymmetric price adjustment may lead to social welfare loss because consumers may not be able to benefit from lower food prices, and farmers would not benefit from increased food consumption. For example, if the farm price declines, the retail price decreases by less than it would under a symmetric response and consumer demand would not increase as much as it would under symmetry. As a result, the socially optimal consumption level would not be reached and a social welfare loss occurs. Further,

depending on the cause of asymmetric price adjustment, the welfare losses suffered by farmers or consumers may be transferred to processors or retailers as excess profits under some market imperfections.

Asymmetric price transmission in more competitive markets generates lower social welfare losses, and the losses will be more evenly distributed among the market players. Consequently, the welfare impact of asymmetric price transmission on producers can be estimated from the supply function although it depends critically on the market structure. However, the consumer welfare component may be estimated from the market demand structure. For this reason, this study focused on measuring the impact of asymmetric price transmission on consumer welfare in Bangladesh rice market. There are several established methods to evaluate the welfare implications of price changes, namely, consumer surplus and equivalent or compensating variation.

Model for Estimating Price Transmission Asymmetry

The usual linear Autoregressive Distributed Lag ARDL (p,q) co-integration model (Pesaran and Shin, 1999; Pesaran et al., 2001) with two time series $\{y_t\}$ and $\{x_t\}$ ($t = 1, 2, \dots, T$) has the following form:

$$\Delta y_t = \alpha_0 + \rho y_{t-1} + \theta x_{t-1} + \gamma z_t + \sum_{j=1}^{p-1} \alpha_j \Delta y_{t-j} + \sum_{j=0}^{q-1} \pi_j \Delta x_{t-j} + e_t \quad (1)$$

Where z_t is a vector of deterministic regressors (trends, seasonals, and other exogenous influences, with fixed lags) and e_t is an iid (independent and identically distributed) stochastic process. Under the null hypothesis (i.e., y_t and x_t are not co-integrated), the coefficients of the lagged levels of those two variables in Equation (1) are jointly zero

($\rho = \theta = 0$). Pesaran et al., (2001) showed that the assumption of no co-integration could be tested either by means of a modified F-test, denoted as F_{PSS} or by means of a Wald-test, denoted as W_{PSS} . The test procedure relies on two critical bounds; the upper bound and the lower one. If the empirical values of the F_{PSS} or the W_{PSS} statistics exceed the upper bound, the null hypothesis is rejected (i.e., there is evidence of a long-run equilibrium relationship between y_t and x_t). If they lie below the lower bound, y_t and x_t are not co-integrated. If they lie between the critical bounds, the test is inconclusive.

The ARDL approach of testing co-integration has several features. Firstly, it performs better in small samples compared to the alternative multivariate co-integration procedures. Secondly, it is more efficient than the standard Engle and Granger two-step approach (typically employed in estimating asymmetric EC and TVEC models). Thirdly, it does not require the restrictive assumption that all series are integrated of the same order allowing for the inclusion of both $I(0)$ and $I(1)$ (but not $I(2)$) time series in a long-run relationship. This not only provides considerable flexibility but it also avoids potential “pre-test bias”, that means, specification of a long-run model on the basis of $I(1)$ variables only (Pesaran et al., 2001; Romilly et al., 2001).

The combination of stochastic regressors in the standard ARDL approach is linear, implying symmetric adjustments in the long- and the short-run. To account for asymmetries, Shin, et al. (2014) introduced the Nonlinear Autoregressive Distributed Lag (NARDL) model in which x_t is decomposed into its positive and negative partial sums, that is,

$$x_t = x_0 + x_t^+ + x_t^- \quad (2)$$

where

$$x_t^+ = \sum_{j=1}^t \Delta x_j^+ = \sum_{j=1}^t \max(\Delta x_j, 0) \quad \text{and} \quad x_t^- = \sum_{j=1}^t \Delta x_j^- = \sum_{j=1}^t \min(\Delta x_j, 0) \quad (3)$$

Then, the asymmetric long-run equilibrium relationship can be expressed as:

$$y_t = \beta^+ x_t^+ + \beta^- x_t^- + u_t \quad (4)$$

where β^+ and β^- are the asymmetric long-run parameters associated with positive and negative changes in $\{x_t\}$, respectively. Shin et al., (2014) showed that by combining (4)

with the ARDL (p,q) model (1) the NARDL (p,q) model is obtained as follows:

$$\begin{aligned} \Delta y_t = & \alpha_0 + \rho y_{t-1} + \theta^+ x_{t-1}^+ + \theta^- x_{t-1}^- + \sum_{j=1}^{p-1} \alpha_j \Delta y_{t-j} + \sum_{j=0}^{q-1} (\pi_j^+ \Delta x_{t-j}^+ + \pi_j^- \Delta x_{t-j}^-) \\ & + e_t \end{aligned} \quad (5)$$

Where, $\theta^+ = -\rho/\beta^+$ and $\theta^- = -\rho/\beta^-$

The empirical implementation of a NARDL model involves four steps. The first is to estimate the coefficients in (5) by standard OLS. The second, is to verify the existence of an asymmetric co-integrating relationship between the levels of the series $\{y_t\}$, $\{x_t^+\}$, and $\{x_t^-\}$. Under the approach proposed by Shin et al., (2014), the null hypothesis of no co-integration (i.e., $\rho = \theta^+ = \theta^- = 0$) can be tested using the F_{PSS} (W_{PSS}) statistic. The third is to test for long- and for short-run symmetries. For long-run symmetry, the relevant null hypothesis (H_0) takes the form $H_0: \beta^+ = \beta^-$ (i.e., $-\theta^+/\rho = -\theta^-/\rho$) and it is tested by means of a standard Wald test. For short-run symmetry, the relevant null hypothesis can take either of the following forms: the pair-wise (strong-form) symmetry requiring $\pi_j^+ = \pi_j^-$ for all $j = 1, 2, \dots, q-1$ or the additive (weak-form) symmetry requiring $\sum_{j=0}^{q-1} \pi_j^+ = \sum_{j=0}^{q-1} \pi_j^-$. These hypotheses are tested by means of a standard Wald test as well. Provided that there is asymmetry (either long-run or short-run or both), the

fourth step involves the derivation of the positive and negative dynamic multipliers associated with unit changes in $\{x_t^+\}$ and $\{x_t^-\}$. These are calculated as:

$$m_h^+ = \sum_{j=0}^h \frac{\partial y_{t+j}}{\partial x_t^+} \quad \text{and} \quad m_h^- = \sum_{j=0}^h \frac{\partial y_{t+j}}{\partial x_t^-} \quad (6)$$

with $h = 0, 1, 2, \dots$ for x_t^+ and x_t^- , respectively. Whereas $h \rightarrow \infty$, then $m_h^+ \rightarrow \beta^+$ and $m_h^- \rightarrow \beta^-$. Depicting and analyzing the paths of adjustment and/or the duration of the disequilibrium following initial positive or negative perturbations in prices, m_h^+ and m_h^- add useful information to the long- and short-run patterns of asymmetry.

Model for Estimating Welfare Change

Consumer Surplus

Consumer surplus (CS) measures the welfare of consumers who purchase a product at a particular price. It is defined as the difference between what the buyers are willing to pay for a commodity, and the amount they actually pay. It is the amount that consumer gain from being able to purchase a product for a price that is less than what they would be willing to pay. Consumer surplus can be computed from the Marshallian market demand curve for a product. The market demand curve shows the quantity of the good that would be demanded by all consumers at each price that consumers would be willing to pay for any quantity supplied to the market. In Figure 13, p_1 and q_1 are the equilibrium price and quantity, and the area CBp_1 is the consumer surplus. Welfare effects of asymmetric price transmission scenario have been estimated using simple welfare analysis (Zheng, 2004). To conduct welfare analysis, changing in consumer surplus (ΔCS) has been determined based on demand and price linkage equations.

The associated welfare effects can be estimated using the following model:

$$\Delta CS = - \int_{P_S}^{P_{AS}} D(P) dp \quad (7)$$

where P_S is the estimated symmetric price from the symmetric ARDL model and P_{AS} is the estimated asymmetric price from the asymmetric NARDL model. This means if estimated asymmetric price (P_{AS}) is higher than symmetric price (P_S) then consumers are losing as shown by the (-) sign, and vice versa.

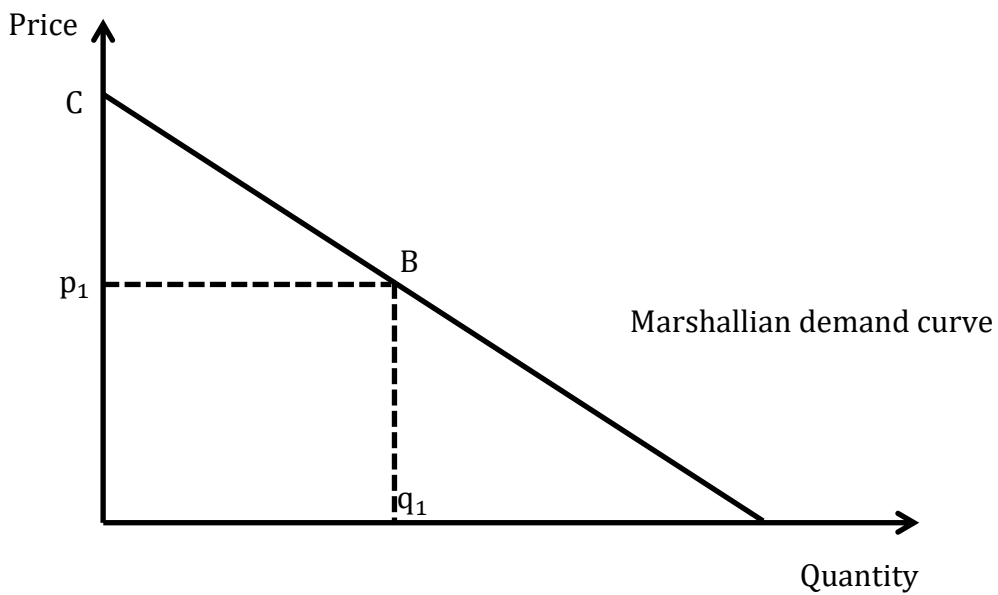


Figure 13. Consumer surplus and Marshallian demand

Equivalent Variation and Compensating Variation

Given prices and income under a base scenario (p_0, m_0) and a new scenario (p_1, m_1) where m_0 is the original income and m_1 is the new income, the equivalent variation (EV) is defined as the amount of money that must be added to the base scenario to make it equivalent to the new scenario in preference term. EV may be mathematically expressed as $V(p_0, m_0 + EV) = V(p_1, m_1)$, where $V(p, m)$ is the indirect utility function (Zheng, 2004). The compensating variation (CV) is defined the amount of money that must be taken away from the new scenario to compensate for the change and leave the consumer at the same utility level as with the original situation. CV may be mathematically defined as $V(p_0, m_0) = V(p_1, m_1 - CV)$. In terms of the so-called Hicksian demands illustrated in the Figure 14, CV or EV is the area between the Hicksian demand curve, the initial and final prices, and the price axis, ABP_1P_0 . Hicksian demand represents price-quantity combinations with same utility levels.

EV, CV and CS are all the plausible measures of the welfare impacts due to price changes, and each has its own advantages. EV and CV are not commonly used because they are defined in terms of Hicksian demand, which cannot be directly estimated from observed prices, quantities and incomes. CS may be computed from estimated Marshallian demand, but due to the income effect, there are errors in using CS to approximate the compensating and equivalent variations (Zheng, 2004).

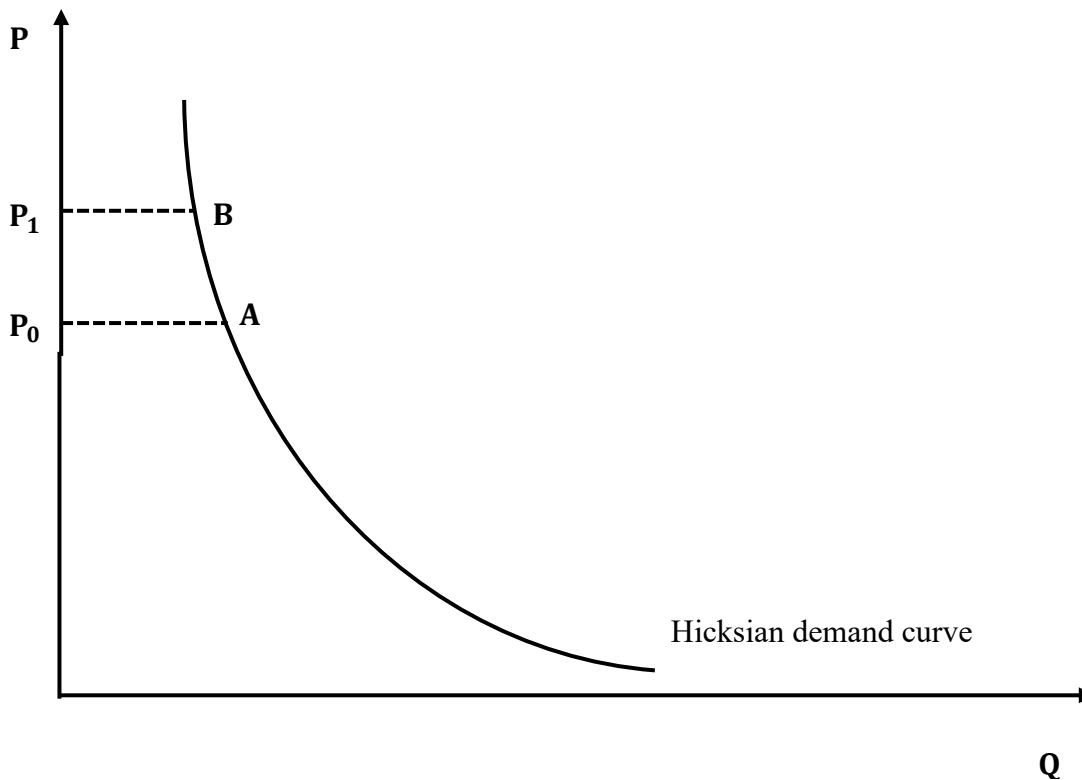


Figure 14. Hicksian demand curve (Zheng 2004)

Figure 15 illustrates the differences between CS, EV, and CV. Compensating variation (CV) is the area $P_1^1 P_1^0 bc$ under the Hicksian demand curve compensated to indirect utility level $V_0(P^0, m)$. This curve crosses the Marshallian demand curve at P_1^0 . Similarly, equivalent variation (EV) is the area $P_1^1 P_1^0 ad$ under the Hicksian demand curve compensated to indirect utility level $V_1(P^1, m)$. This curve crosses the Marshallian demand curve P_1^1 . Consumer surplus (CS) is the area $P_1^1 P_1^0 ac$, defined by the Marshallian demand curve. If the good is normal, then the following relationship holds: $CV \geq CS \geq EV$. If the good is inferior, the inequalities reverse. If there is no income effect, then $CV = CS = EV$. In general, income elasticities and associated income effects for agricultural products are relatively small, such that the CS approximation to CV and EV may be reasonably close for most agricultural goods.

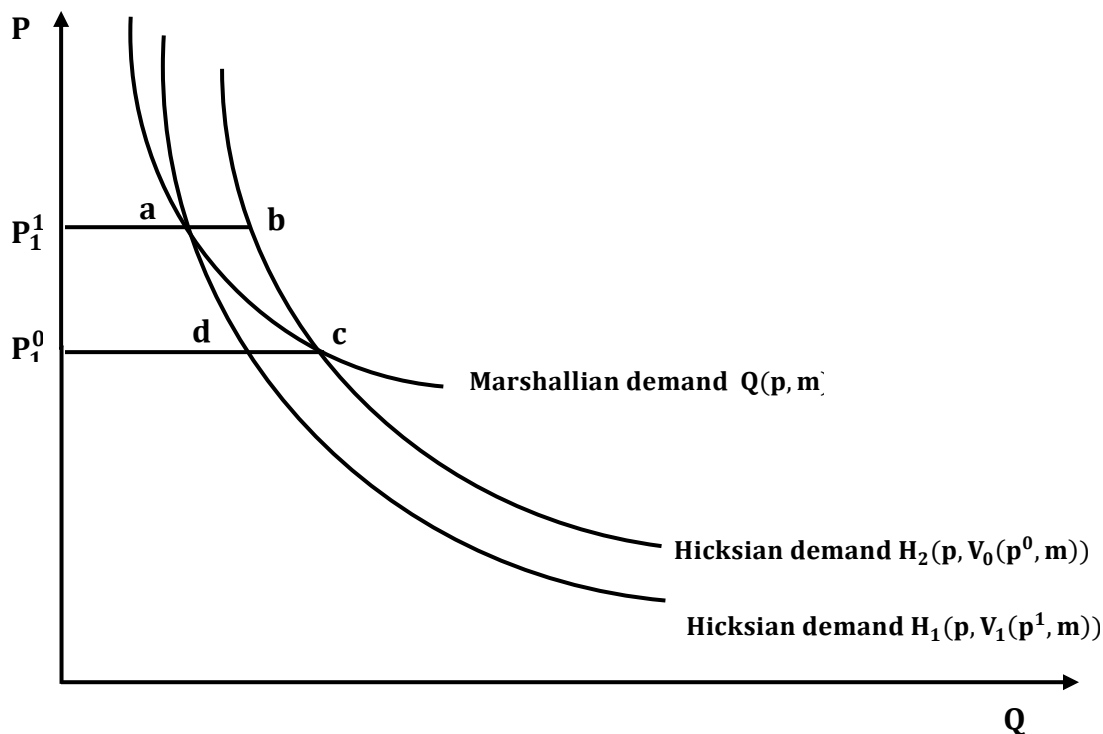


Figure 15. Relationship among CS, CV and EV (Zheng 2004)

According to Willig (1976), the observed consumer's surplus can be used to approximate the unobserved compensating and equivalent variations, which are the correct theoretical measures of the welfare impact of changes in prices and income on an individual. He derived accurate upper and lower bounds on the percentage errors of approximating CV or EV using CS. Willig introduced the following rules of thumb for a single price change: if $|\eta^+ A/2m^0| \leq 0.05$, $|\eta^- A/2m^0| \leq 0.05$, and $|A/m^0| \leq 0.9$, then we have

$$\eta^- |A|/2m^0 \leq (C - A)/|A| \leq \eta^+ |A|/2m^0 \quad (8)$$

$$\text{and } \eta^- |A|/2m^0 \leq (A - E)/|A| \leq \eta^+ |A|/2m^0 \quad (9)$$

where, A is the consumer's surplus area under the Marshallian demand curve and between the two prices, C is compensating variation corresponding to the price change, E is equivalent variation corresponding to the price change, m^0 is consumer's base income, and η^+ and η^- are the largest and smallest values of the income elasticity of demand in the region under consideration. Clearly, $C = A = E$ if $\eta^- = \eta^+ = 0$.

Hausman (1981) derived an exact analytical expression for the compensating variation from linear, log-linear, and quadratic demand functions. The study notes that Roy's identity relates the ordinary demand functions to the indirect utility function, and if the Slutsky substitution matrix is symmetric and negative semi-definite, the indirect utility function can be inverted to derive the expenditure function, and then the compensating variation can be calculated. Roy's identity is

$$(dV/dP_i)/(dV/dm) = -Q_i(P, m) \quad (10)$$

where, V is the indirect utility function, m is income, P_i is the price of good i , and Q_i is the Marshallian demand function for good i . By integrating equation (10), the indirect utility function can be derived from the demand function. Then, by inverting the indirect utility function, since they are dual functions, the expenditure function $e(P, V)$ can be derived. Lastly, the compensating variation from the expenditure function can be calculated as:

$$CV = e(p_1, V_0) - e(p_0, V_0) \quad (11)$$

Vartia (1983) provided efficient algorithms to calculate the compensated welfare measures using only the Marshallian demand system. Although the welfare measures must be iteratively computed, the welfare change between two equilibrium situations

faced by the consumer can be exactly compared for a general class of Marshallian demands. Vartia's main algorithm to calculate compensated income is

$$C_k^m = C_{k-1} + 1/2 (Q(p_k, C_k^{m-1}) + q_{k-1})(p_k - p_{k-1}) \quad (12)$$

where, C_k^m is compensated income for partition k and iteration m , k is the number of equal steps the price change is divided into, Q is the Marshallian demand function, q_{k-1} is the quantity from the previous step ($k-1$), and p_k is price. C_k is iteratively computed for m steps until $|C_k^m - C_k^{m-1}|$ is less than some negligible value. After convergence, $C_k = C_k^m$ is set.

Once compensated income is calculated, the following equation is used to compute CV:

$$CV = C_k - y_0 \quad (13)$$

where, y_0 is initial income and C_k is compensated income.

To illustrate Vartia's main algorithm, suppose a price increase is observed from p_0 that is partitioned into K steps, i.e., $p_0 < p_1 < \dots < p_K$. Following (11), the compensating variation from the partitioned price changes can be computed as $CV = \sum_{k=1}^K \Delta_k$ where $\Delta_k = e(p_k, V_0) - e(p_{k-1}, V_0)$. Under the Hicksian demand curve, the CV components may be computed as $\Delta_k = \int_{p_{k-1}}^{p_k} H(p, V_0) dp$, and the compensated income associated with the price changes up to partition k is $C_k = y_0 + \sum_{j=1}^k \Delta_j$ and $CV = C_k - y_0$. For example, the CV for a price increase from p_0 to p_1 is the area in Figure 14 between the prices and to the left of the Hicksian demand curve, $H(p, V_0)$. Further, the integral expression for Δ_k may be estimated with the discrete approximation

$$\Delta_k \approx \frac{1}{2} (p_k - p_{k-1}) [H(p_k, V_0) + H(p_{k-1}, V_0)] \quad (14)$$

The associated discrete approximation to CV approaches the actual value as the number of partition components becomes asymptotically large and $K \rightarrow \infty$. In Figure 14, the approximation to Δ_k is presented by the area between prices p_0 and p_1 and to the left of the average quantity, $[H(p_k, V_0) + H(p_{k-1}, V_0)]/2$.

Although the Hicksian demand function is not directly observable, the known identity $H(p, u) \equiv Q(p, e(p, u))$ can be used to estimate Δ_k from the Marshallian demand function. In particular, $H(p_k, V_0)$ can be replaced with the Marshallian demand function evaluated at the compensated income for partition k , $Q(p_k, C_k)$. To compute the compensated income, equation (14) can be restated as:

$$C_k - C_{k-1} \approx \frac{1}{2}(p_k - p_{k-1})[Q(p_k, C_k) + Q(p_{k-1}, C_{k-1})] \quad (15)$$

The objective of Vartia's main algorithm is to solve (15) for C_k conditional on C_{k-1} , p_{k-1} , and p_k . The algorithmic representation of (15) stated in (12) indicates that the iterative search for the solution value of C_k until the algorithm converges and $|C_k^m - C_k^{m-1}|$ is negligibly small (i.e., the steps are indexed with m).

Graphically, the Vartia algorithm shifts the Marshallian demand curve rightward in Figure 16 to reflect the income compensation, and the demand identity implies that the Marshallian demand curves intersect the Hicksian demand curve at the desired points if the income adjustment is correctly chosen. As the algorithm proceeds from one step to another, the compensated income value C_k is further adjusted in order to shift the Marshallian curves rightward and to iteratively build the estimate of CV.

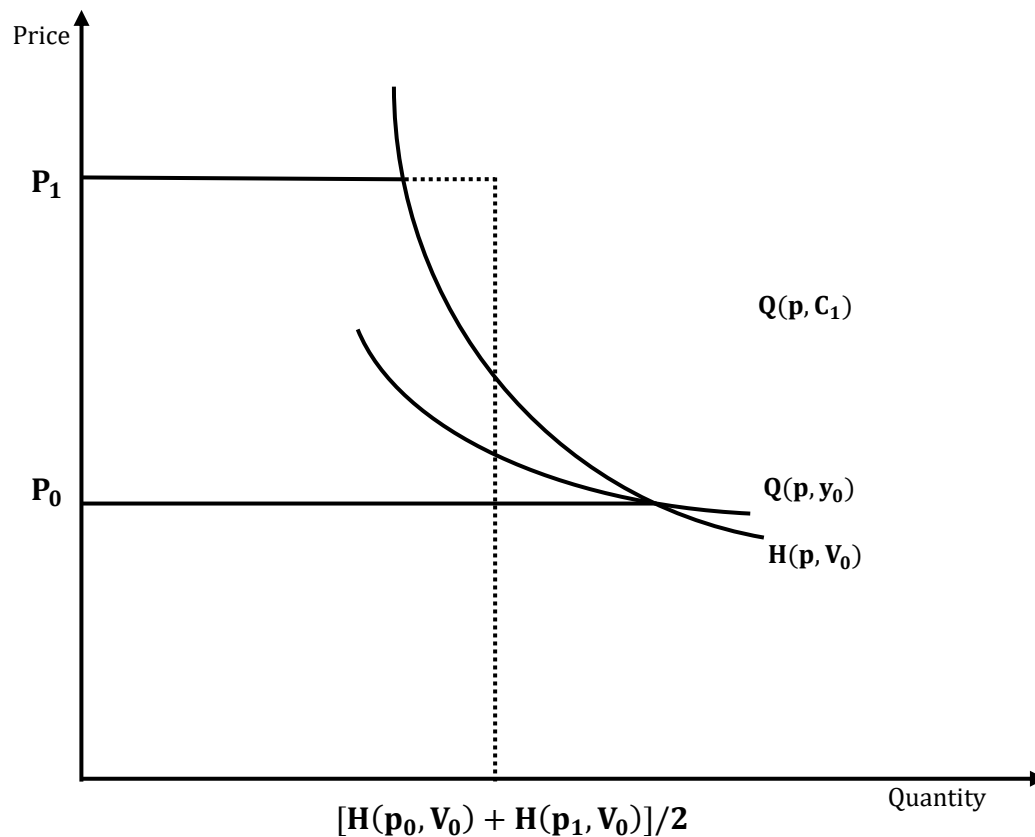


Figure 16. Illustration of Vartia's main algorithm (Zheng 2004)

Model for Estimating Market Power

The Stochastic Frontier (SF) model provides a novel and promising framework to test and measure the degree of market power in agricultural and food markets. The model starts from the basic set-up of an industry exhibiting oligopoly, where the output price set exceeds marginal cost of production ($P > MC$) (Lopez et al., 2015). The gap between price and marginal cost is attributed to oligopoly power mark-up and is treated as a one-sided deviation. Thus, the model can be presented as:

$$P = MC + \eta \quad (16)$$

Where $\eta \geq 0$, P is the output price and MC is the marginal cost of production. Multiplying Y/C (where, Y is the output and C is the total cost) on both sides of equation (16), the first-order condition for cost minimization is:

$$\frac{PY}{C} = \frac{\partial \ln C}{\partial \ln Y} + u \quad (17)$$

Where $u \geq 0$, PY/C is the revenue share in total cost, $\partial \ln C / \partial \ln Y$ is the scale elasticity and u is nonnegative one-sided term representing the mark-up. The illustration for $\partial \ln C / \partial \ln Y$ can be attained from the trans-log cost function.

$$\begin{aligned} \ln C = & \beta_0 + \sum_{j=1}^J \beta_j \ln W_j + 0.5 \sum_{j=1}^J \sum_{k=1}^J \beta_{jk} \ln W_j \ln W_k + \beta_Y \ln Y + 0.5 \beta_{YY} (\ln Y)^2 \\ & + \sum_{j=1}^J \beta_{jY} \ln W_j \ln Y + \beta_T T + 0.5 \beta_{TT} T^2 + \sum_{j=1}^J \beta_{jT} \ln W_j T \\ & + \beta_{YT} T \ln Y \end{aligned} \quad (18)$$

where β 's are unknown parameters to be estimated. Y is output, T is the technology index, and W 's are inputs' prices. However, if the focus is to estimate only mark-ups, (17) will be estimated, not the entire cost function (18). From (18) the expression for cost elasticity, $\partial \ln C / \partial \ln Y$ becomes

$$\frac{\partial \ln C}{\partial \ln Y} = \beta_Y + \beta_{YY} \ln Y + \sum_{j=1}^J \beta_{jY} \ln W_j + \beta_{YT} T \quad (19)$$

Note that the above relationship in (19) measures cost elasticity that is intimately related to the return to scale measure. More formally, it is presented as:

$$E_{CY} = \frac{\partial \ln C}{\partial \ln Y} = \frac{\partial C Y}{\partial Y C} = \frac{MC}{AC} \quad (20)$$

where, E_{CY} is cost elasticity and AC is long run average cost. Returns to scale (RTS) is uniquely related to E_{CY} , i.e., $RTS = 1/E_{CY}$. This means that there is constant returns to

scale when $E_{CY} = 1$, increasing returns to scale (economies of scale) when $E_{CY} < 1$, and decreasing returns to scale (diseconomies of scale) when $E_{CY} > 1$. If (17) and (19) are combined with the v term appended, the equation is:

$$\frac{PY}{C} = \beta_Y + \beta_{YY}\ln Y + \sum_{j=1}^J \beta_{jY} \ln W_j + \beta_{YT}T + u + v \quad (21)$$

Note that the composed error term ($u + v$) in (21) is exactly the same as the one in a stochastic cost frontier. Thus, the same approach can be used to estimate the model in (21). Since the stochastic frontier approach uses the maximum likelihood method that is based on distributional assumptions on the error components, the literature is adopted and the following distributional assumptions are made:

$$u \sim N^+(0, \sigma_u^2) \quad (22)$$

$$v \sim N(0, \sigma_v^2) \quad (23)$$

Where N^+ means a half-normal distribution (i.e., u is a normal $(0, \sigma_u^2)$ random variable truncated at zero from below). The cost function is homogeneous of degree one in input prices, and therefore the relevant parametric restriction for estimating (21) is $\sum_{j=1}^J \beta_{jY} = 0$. After imposing this restriction, (21) can be expressed as

$$\frac{PY}{C} = \beta_Y + \beta_{YY}\ln Y + \sum_{j=1}^J \beta_{jY} \ln \tilde{W}_j + \beta_{YT}T + u + v \quad (24)$$

Where $\tilde{W}_j = W_j/W_j$. The expression in (24) is similar to a stochastic cost frontier because the composed error term ($e = u + v$) is the sum of the two-sided noise term v and the one-sided term $u \geq 0$. Note that the expression in (24) is not a cost function and the interpretation of the one-sided term is not cost inefficiency. Furthermore, (24) is not affected by the presence of technical inefficiency in the cost function. The one-sided error

term in (24) is uniquely related to mark-up.

Since the interest is in estimating u , which is related to mark-up, the estimation procedure outlined for a cost frontier is followed. The likelihood function is derived to estimate the parameters of the model using the distributional assumptions specified in (22) and (23). The parameters are then estimated using the maximum likelihood (ML) method.

If mark-up is defined as the fraction by which P exceeds MC , i.e., $\theta = (P - MC)/MC$, it can be related to u . Using (17), it can be shown that $\theta = u \frac{\partial \ln Y}{\partial \ln C} = u \frac{AC}{MC} = u \frac{1}{E_{CY}} = u / \frac{\partial \ln C}{\partial \ln Y}$. Thus, after estimating u , one can estimate θ as:

$$\hat{\theta} = \hat{u} / \hat{\beta}_Y + \hat{\beta}_{YY} \ln Y + \sum_{j=1}^J \hat{\beta}_{jY} \ln \tilde{W}_j + \hat{\beta}_{YT} T \quad (25)$$

Estimates of θ from (25) can be used to obtain Lerner's index measure of mark-up (\mathcal{E}) from the relationship $\mathcal{E} = \theta / (1 + \theta)$. In contrast, direct computation of Lerner's index requires information on output price and estimates of MC .

Hypotheses of the Study

According to the review of literature and previous studies, the wholesale to retail price transmission behavior of the Bangladesh rice market is asymmetric. The null hypotheses that have been addressed in this study are:

1. There is asymmetric price transmission of the Bangladesh rice supply chain considering farm, wholesale and retail levels;

2. The consumer welfare changes due to the price transmission asymmetry in the Bangladesh rice market; and
3. The existence of market power along the rice supply chain is the cause of price transmission asymmetry.

CHAPTER IV

METHODOLOGY

Study Areas

This study considered the whole Bangladesh for rice price transmission asymmetry analysis. In order to measure the market power along the rice supply chain, a survey has been conducted in the seven major rice markets of Bangladesh. These are Dhaka, Rajshahi, Barisal, Chittagong, Khulna, Sylhet, and Rangpur (Figure 17).

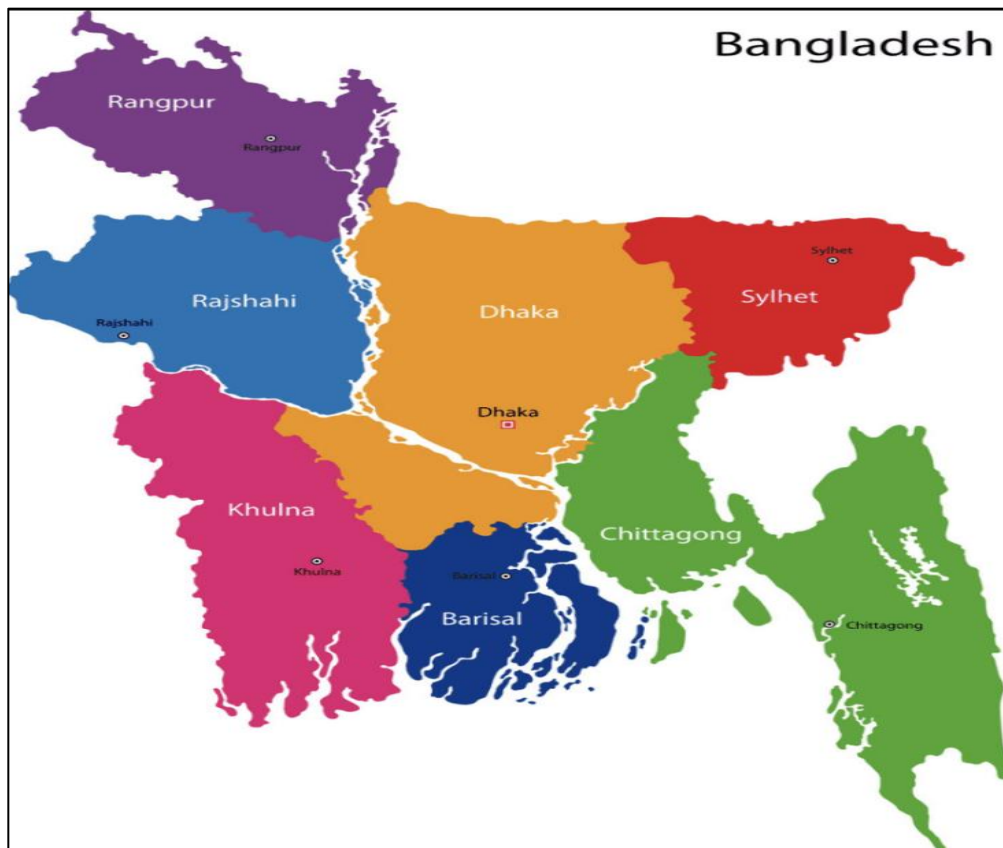


Figure 17. Major rice markets of Bangladesh

Types and Sources of Data

The secondary rice price data for the empirical analysis have been collected from the Department of Agricultural Marketing (DAM), Bangladesh (<http://dam.portal.gov.bd>). These are the monthly price of rice expressed in Taka per kilogram at the farm, wholesale, and retail levels for analyzing symmetric and asymmetric price transmission. They refer to the period October 2005 to June 2017. DAM has adjusted farm level paddy price with a conversion ratio $2/3$ of the retail price. Because, farm level price was collected as the paddy price and the conversion ratio from paddy to rice is $2/3$. For the estimation of demand functions of rice, the annual data covered the period 1973 to 2016.

In order to estimate the rice demand function, the national level data on domestic demand for rice in '000 ton; domestic wholesale price in Bangladeshi Taka per ton; population of Bangladesh in million; and Gross National Income per capita (GNI) in Bangladesh have been collected from Bangladesh Economic Review (<http://mof.portal.gov.bd>) and Bangladesh Bureau of Statistics (<http://www.bbs.gov.bd>).

The data used for empirical analysis of market power of rice millers and wholesalers are cross-sectional primary data collected from the rice millers and wholesalers in seven major markets in Bangladesh with a structured and pretested interview schedule in 2017. In this survey, 160 mills and 240 wholesalers were selected. Data collected on the output for the millers and the wholesalers are the milled rice and the amount of rice sold in ton, respectively. The inputs employed at the rice processing stage are raw materials (paddy), labor, capital, energy, other materials, and transportation. Price and quantity data on these inputs were collected via face-to-face interviews.

In order to sample 160 rice mills from the 660 registered mills with seven markets as strata, the study used stratified sampling with proportional allocation used by Ghaffar (2013). The total number of mills by market was stratified and the sample size from each market was selected following the formula below:

$$n_h = (N_h/N) * n, h = 1, \dots, 7 \quad (26)$$

where $n = \sum_{h=1}^7 n_h$. N_h is the number of mills in market h , N is the total number of mills (660), and n_h is the sample size in market h .

Table 5. The distribution of sample rice mills by market

Stratum (h)	N_h	n_h
Dhaka	120	29
Rajshahi	110	27
Rangpur	98	24
Chittagong	96	23
Barisal	86	21
Khulna	85	20
Sylhet	65	16
Total	$N = 660$	$n = 160$

The study used the random sampling technique to survey 240 wholesalers in the seven major markets. The wholesalers adjacent to the sampled rice millers were considered to sample the wholesalers.

Analytical Tools

Empirical Procedure of Asymmetric Price Transmission Analysis

This section explained some concepts related to the time series properties of the data, namely: stationarity, co-integration, and causality. The autoregressive distributed lag (ARDL) model provides the co-integration test results to present the co-integrating relationship among the dependent and independent time series variables. Further, causality test helps to determine the direction of price changes at different levels of the marketing channel, and thus determine which variables should appear on the right hand side of the model as explanatory variables.

The study applied the time series techniques on Bangladesh rice markets to assess the components of price transmission. The sequence of the tests for the components of transmission is as follows:

- i. The study started by testing for the order of integration for each series of prices utilizing the Augmented Dickey-Fuller (Dickey and Fuller 1979) and the Phillips and Perron tests (Phillips and Perron 1988). In the event that the series have a different order of integration, it can be concluded that the prices are not integrated in the same order. In this case, it can resort to assessing the dynamics of the relationship by means of Autoregressive Distributed Lag (ARDL) models.
- ii. After that, an important preliminary step is the selection of the Vector Autoregressive (VAR) lag order. The study followed the Akaike Information Criterion (AIC) and the Schwarz Information Criterion (SIC) for monthly VAR models to select the appropriate lag of the time series variables.

- iii. When the tests indicated that the series are integrated of the same order (say $I(1)$), the study could proceed by testing the null hypothesis of no co-integration against the alternative hypothesis of one co-integrating vector using the Johansen procedure (Johansen 1988, 1991), or by testing the null hypothesis of no co-integration following Engle and Granger (1987). However, the Autoregressive Distributed Lag (ARDL) model provides the evidence of co-integration of the time series variables with the bound testing approach. Therefore, this study did not go for the additional co-integration tests, besides ARDL bound test.
- iv. Before the specification of ARDL model, the study used the Granger causality (1969) test to examine the direction of causality among the time series co-integrated variables.
- v. In the next stage, based on the results on the direction of causality, the ARDL and Nonlinear ARDL (NARDL) were specified and the null hypothesis of symmetry following Pesaran et al., (2001) and Shin et al., (2014) was tested. The results on the nature of price transmission were analyzed.

It is important to note that the above testing framework did not identify the factors that affect price transmission. In other words, it is not possible to distinguish whether price transmission is shaped by transaction costs or by the degree of market power exerted by agents in the supply chain. This is the reason why the study measured the existence of market power in the rice supply chain.

Unit Root Test

A stationary process has the property that the mean, variance, and autocorrelation structure do not change over time. The study used the Dickey-Fuller test to examine if the series is stationary. Said and Dickey (1984) made an important extension of the Dickey-Fuller test known as the Augmented Dickey-Fuller (ADF) test. They showed that the Dickey-Fuller unit root test, although originally developed for an autoregressive (AR) representation of known order, is asymptotically valid for a general autoregressive moving average (ARMA) process of unknown order. To conduct the Dickey-Fuller test, the observed variable was regressed on its one-period lagged value:

$$y_t = \alpha + \beta t + \phi_1 y_{t-1} + \varepsilon_t \quad (27)$$

If the null hypothesis that $\phi = 1$ is rejected, the series is stationary. The parameter ϕ_1 of the AR (1) process must satisfy the condition $|\phi_1| < 1$ to ensure stationarity (Box and Jenkins (1976)).

Testing Causality in the Johansen Vector Error Correction Model (VECM)

Jayanta, Sajjad, and Baulch, (1997) measured the relationship and causality between wholesale and retail prices of coarse rice across the two major Bangladesh cities (Dhaka and Chittagong). Jayanta et al., (1997) used conventional Granger causality F-tests in a simple regression framework. To identify the causal relationship, the vector autoregressive error correction model was specified as:

$$\Delta Y_t = \mu_1 + \sum_{i=1}^K \beta_i \Delta X_{t-i} + \sum_{j=1}^L \beta_j \Delta Y_{t-j} + \alpha_1 Z_{t-1} + \varepsilon_{t,1} \quad (28)$$

$$\Delta X_t = \mu_1 + \sum_{i=1}^K \beta_i \Delta X_{t-i} + \sum_{j=1}^L \beta_j \Delta Y_{t-j} + \alpha_2 Z_{t-1} + \varepsilon_{t,2} \quad (29)$$

Where Z_{t-1} is the lag of error correction term (ECT), Y_t and X_t are the price series. In Equations (28) and (29), the Granger causality decision is given as:

- a) $\alpha_1 \neq 0, \alpha_2 \neq 0$, which implies bidirectional causality, it means that there exists a feedback long run relationship between the variables and no individual price plays a leadership role.
- b) $\alpha_1 = 0$ but $\alpha_2 \neq 0$, implies a unidirectional causality and the retail price Granger causes the wholesale price; the retail price is weakly exogenous.
- c) $\alpha_1 \neq 0$ but $\alpha_2 = 0$, implies unidirectional causality and the wholesale price Granger causes the retail price; the wholesale price is weakly exogenous.

Specification of Symmetric ARDL and Asymmetric NARDL model

The Autoregressive Distribution Lag (ARDL) model represents the linear relationship or association between the time series variables whereas the non-linear ARDL (NARDL) represents the non-linear relationship. A linear relationship is one where increasing or decreasing one variable n times will cause a corresponding increase or decrease of n times in the other variable too. Most relationships in economics are, unfortunately, nonlinear. Each unit change in the x variable will not always bring about the same change in the y variable. A nonlinear relationship is a type of relationship between two entities in which change in one entity does not correspond with constant change in the other entity. This might mean the relationship between the two entities is unpredictable or virtually absent (MEO school of research:

<http://saeedmeo.blogspot.com>).

The Non-linear ARDL model recently developed by Shin, et al. (2014) uses positive and negative partial sum decompositions allowing detecting the asymmetric effects in the long and the short-term. Compared to the classical co-integration models, NARDL models present some other advantages. Firstly, they perform better for determining co-integration relations in small samples. Secondly, they can be applied irrespective of whether the regressors are stationary at level or at the first difference (i.e., $I(0)$ or $I(1)$). They cannot be applied, however, if the regressors are $I(2)$. The asymmetric NARDL framework of Shin et al., (2013) is particularly suitable for the research problem as it allows not only to gauge the short- and long-run asymmetries, but also to detect hidden co-integration. For example, a positive shock of oil prices may have a larger absolute effect in the short-run while a negative shock has a larger absolute effect in the long run (or vice-versa).

According to Shin et al., (2013), some preconditions for ARDL/NARDL are:

- 1) Variables should be $I(0)$, $I(1)$ but none of the variables could be $I(2)$.
- 2) Lags must be appropriate.
- 3) Error must be serially independent.
- 4) Model must be dynamically stable.

There are six steps in NARDL estimation (Shin et al., 2014). These are:

- Step 1: Checking for unit root. The purpose of unit root test for ARDL is only to confirm that none of the variables is stationary at second difference.
- Step 2: Generate positive and negative series for the variables to see asymmetric nonlinear relationship.

- Step 3: Run NARDL, ECM based.
- Step 4: Test co-integration, using bound test approach.
- Step 5: Check for the asymmetries.
- Step 6: Checking for multiplier effect.

Considering rice retail price as dependent variable and the effects of wholesale and farm prices on it, the ARDL model can be written as:

$$\begin{aligned} \Delta r p_t = & \alpha_0 + \rho r p_{t-1} + \theta_1 w p_{t-1} + \theta_2 f p_{t-1} + \sum_{j=1}^{p-1} \alpha_j \Delta r p_{t-j} + \sum_{j=0}^{q-1} \pi_j \Delta w p_{t-j} \\ & + \sum_{j=0}^{q-1} \eta_j \Delta f p_{t-j} + e_t \end{aligned} \quad (30)$$

And the general NARDL model can be written as:

$$\begin{aligned} \Delta r p_t = & \alpha_0 + \rho r p_{t-1} + \theta_1^+ w p_{t-1}^+ + \theta_1^- w p_{t-1}^- + \theta_2^+ f p_{t-1}^+ + \theta_2^- f p_{t-1}^- + \sum_{j=1}^{p-1} \alpha_j \Delta y_{t-j} \\ & + \sum_{j=0}^{q-1} (\pi_j^+ \Delta w p_{t-j}^+ + \pi_j^- \Delta w p_{t-j}^-) + \sum_{j=0}^{q-1} (\eta_j^+ \Delta f p_{t-j}^+ + \eta_j^- \Delta f p_{t-j}^-) + e_t \end{aligned} \quad (31)$$

Where, rp , wp and fp are the log of retail, wholesale and farm rice prices, respectively. fp^+ , fp^- , wp^+ , wp^- are partial sums of positive and negative changes in fp and wp , respectively. Model (31) relates to the price transmission from the farm to the retail through wholesale level.

For the price asymmetry analysis with NARDL model, this study used Eviews 10 software. Using Eviews 9 or Eviews 10 has some advantages in ARDL/NARDL estimation. The reasons for using Eviews 10 for the estimation are as follows (Hossain academy: <http://www.sayedhossain.com>):

- ARDL is a model, which consists of lag of the dependent variable and lags and leads for other variables too. And it may contain both the long run and short run (ecm) dynamics.
- Conventional co-integration techniques require large observations whereas ARDL can produce robust result even in small observations.
- Lag length criteria: Appropriate number of lags for each of the independent variable and the most parsimonious model is chosen automatically.
- It estimates Pesaran et al., (2001), ARDL model which may include I (1) and I (0) variables (but not I (2)).
- Tests for co-integration using bound test approach are provided in the module.
- It includes a provision of estimating the error term (co-integrating coefficient), short run and long run coefficients directly.

Specification of Rice Demand Function

The domestic demand (D) of rice in Bangladesh is assumed to be influenced by own price (P), Bangladesh's national income per capita (GNI) and size of Bangladesh's population (POB). The linear regression model used to estimate the domestic rice demand function of Bangladesh is:

$$D = \alpha + \beta_1 P + \beta_2 POB + \beta_3 GNI + e \quad (32)$$

Where, α and β 's are the parameters to be estimated. The domestic demand (D) is the amount of rice (thousand ton) consumed per year, P is the annual wholesale price of milled course rice (Tk./ton), POB is the population of Bangladesh in million, and GNI is the Gross National Income per capita in Bangladesh.

Specification of Stochastic Frontier Model for Estimating Mark-up

The trans-log cost function for the rice millers and wholesalers is shown below (equation 33) considering transportation cost as an input.

$$\begin{aligned}
\ln C = & \beta_0 + \beta_Y \ln Y + \frac{1}{2} \beta_{YY} (\ln Y)^2 + \beta_L \ln w_L + \beta_M \ln w_M + \beta_E \ln w_E + \beta_{Tr} \ln w_{Tr} \\
& + \beta_K \ln w_K + \beta_O \ln w_O + \beta_{YL} \ln Y \ln w_L + \beta_{YM} \ln Y \ln w_M \\
& + \beta_{YE} \ln Y \ln w_E + \beta_{YT} \ln Y \ln w_T + \beta_{YK} \ln Y \ln w_K + \beta_{YO} \ln Y \ln w_O \\
& + \frac{1}{2} \beta_{LL} (\ln w_L)^2 + \beta_{LM} \ln w_L \ln w_M + \beta_{LE} \ln w_L \ln w_E \\
& + \beta_{LTr} \ln w_L \ln w_{Tr} + \beta_{LK} \ln w_L \ln w_K + \beta_{LO} \ln w_L \ln w_O \\
& + \frac{1}{2} \beta_{MM} (\ln w_M)^2 + \beta_{ME} \ln w_M \ln w_E + \beta_{MTr} \ln w_M \ln w_{Tr} \\
& + \beta_{MK} \ln w_M \ln w_K + \beta_{MO} \ln w_M \ln w_O + \frac{1}{2} \beta_{EE} (\ln w_E)^2 \\
& + \beta_{ETr} \ln w_E \ln w_{Tr} + \beta_{EK} \ln w_E \ln w_K + \beta_{EO} \ln w_E \ln w_O \\
& + \frac{1}{2} \beta_{TrTr} (\ln w_{Tr})^2 + \beta_{TrK} \ln w_{Tr} \ln w_K + \beta_{TrO} \ln w_{Tr} \ln w_O \\
& + \frac{1}{2} \beta_{KK} (\ln w_K)^2 + \beta_{KO} \ln w_K \ln w_O + \frac{1}{2} \beta_{OO} (\ln w_O)^2 + \beta_T T \\
& + \frac{1}{2} \beta_{TT} T^2 + \beta_{YT} \ln Y T + \beta_{LT} \ln w_L T + \beta_{MT} \ln w_M T \\
& + \beta_{ET} \ln w_E T
\end{aligned} \tag{33}$$

where C = total cost, Y = output, w_L = price of labor, w_M = price of raw material, w_E = price of energy, w_{Tr} = price of transportation, w_K = price of operating capital, w_O = price of other materials, and T = time period. The symmetric restriction in equation (33) can be applied as $\beta_{LM} = \beta_{ML}$, $\beta_{LE} = \beta_{EL}$, $\beta_{LTr} = \beta_{TrL}$, $\beta_{LK} = \beta_{KL}$, $\beta_{LO} = \beta_{OL}$, $\beta_{ME} = \beta_{EM}$, $\beta_{MTr} = \beta_{TrM}$, $\beta_{MK} = \beta_{KM}$, $\beta_{MO} = \beta_{OM}$, $\beta_{ETr} = \beta_{TrE}$, $\beta_{EK} = \beta_{KE}$, $\beta_{EO} = \beta_{OE}$, $\beta_{TrK} = \beta_{KTr}$, $\beta_{TrO} = \beta_{OTr}$ and $\beta_{KO} = \beta_{OK}$. Through equation (33), with symmetry imposed, the expression of $\partial \ln C / \partial \ln Y$ can be obtained as:

$$\begin{aligned} \frac{\partial \ln C}{\partial \ln Y} = & \beta_Y + \beta_{YY} \ln Y + \beta_{YL} \ln w_L + \beta_{YM} \ln w_M + \beta_{YE} \ln w_E + \beta_{YTr} \ln w_{Tr} \\ & + \beta_{YK} \ln w_K + \beta_{YO} \ln w_O + \beta_{YT} T \end{aligned} \quad (34)$$

Substituting equation (34) into (17) with the v term appended, imposing the homogeneity restriction of input prices ($\beta_{LY} + \beta_{MY} + \beta_{EY} + \beta_{TrY} + \beta_{KY} + \beta_{OY} = 0$), and $T = 1$ (as cross sectional data are used), the equilibrium condition is written as:

$$\begin{aligned} \frac{PY}{C} = & \beta_Y + \beta_{YY} \ln Y + \beta_{YL} \ln w_L + \beta_{YM} \ln w_M + \beta_{YE} \ln w_E + \beta_{YTr} \ln w_{Tr} \\ & + \beta_{YK} \ln w_K + \beta_{YO} \ln w_O + u + v \end{aligned} \quad (35)$$

Assume u is half-sided normal, i.e., $u \sim N^+(0, \sigma_u^2)$, and v is the usual two-sided normal, i.e., $v \sim N(0, \sigma_v^2)$. Equation 35 was estimated using the same maximum likelihood method used to estimate the stochastic cost frontier. The difference is in the interpretation of the one sided error term u . In estimating a stochastic cost frontier, the one-sided error term measures cost inefficiency. In estimating equation 35, the one-sided error term is the mark-up.

The relationship between the mark-up and the degree of market power is forthright. Kumbhakar et al., (2012) showed the market power as a function of mark-up (u). Using the estimated mark-up (\hat{u}), market power ($\hat{\theta}$) was obtained as:

$$\hat{\theta} = \frac{\hat{u}}{\frac{\partial \ln C}{\partial \ln Y}} \quad (36)$$

Equation (36) confirms that a firm's degree of market power rises, falls or remains constant when technology exhibits increasing return to scale ($\frac{\partial \ln C}{\partial \ln Y} < 1$), decreasing return to scale ($\frac{\partial \ln C}{\partial \ln Y} > 1$) or constant return to scale ($\frac{\partial \ln C}{\partial \ln Y} = 1$). The return to scale (RTS) and Lerner index (\mathcal{L}) were calculated as equations (37) and (38), respectively.

$$\widehat{\text{RTS}} = \frac{1}{\frac{\partial \ln C}{\partial \ln Y}} \quad (37)$$

$$\hat{\mathcal{L}} = \hat{\theta} / (1 + \hat{\theta}) \quad (38)$$

The degree of market power was also measured by Lerner Index. It is the deviation of marginal cost from the product price and as a portion of the product price.

$$\mathcal{L} = \frac{(P - MC)}{P} \quad (39)$$

The Lerner Index varies from 0 to 1. A Lerner Index closer to 1 denotes weak competitive market and the existence of market power. The mark-up can also be obtained by rearranging the Lerner Index:

$$P = \left(\frac{1}{1 - \mathcal{L}} \right) MC \quad (40)$$

Where $\left(\frac{1}{1 - \mathcal{L}} \right)$ is the mark-up factor. If the market is perfectly competitive ($P = MC$), there is no market power, Lerner Index is zero ($\mathcal{L} = 0$)

Limitations of the Study

The study has a number of limitations, namely:

1. The study tried to cover all the respective major rice markets for rice wholesalers and millers. However, the overall sample size was low compared to the population.
2. The study could not construct the sampling frame for the rice wholesalers. It randomly sampled the wholesalers, corresponding to the sampled millers in the respective rice markets.

CHAPTER V

RESULTS AND DISCUSSION

Overview of the Bangladesh Rice Market

Due to the market liberalization policies in 1980s and 1990s mentioned in the section 1.2 in this study, the control of the rice market became beyond the control of the government. The structure of the Bangladesh rice market changed into a free market system dominated by the private traders operating at all levels of the rice supply chain. Before discussing the structure of the Bangladesh rice market, this study provides a brief introduction of the marketing agents of the rice supply chain in this section.

Rice Supply Chain of Bangladesh

The supply chain describes a longer channel stretching from raw materials to components to final products that are carried to final buyers. The supply chain represents a value delivery system. Each company captures only a certain percentage of the total value generated by the supply chain. When a company acquires competitors or moves upstream or downstream, its aim is to capture a higher percentage of supply chain value (Raha et al., 2012). The rice supply chain of Bangladesh is shown in Figure 18.

The infrastructural condition of the paddy markets is very poor in Bangladesh. There are both similarities and dissimilarities existing in paddy markets all over the country. Most markets operate once or twice in a week. The farmers have to carry the paddy to the local markets. The paddy traders or wholesalers are not eager to go to the farm places to purchase paddy.

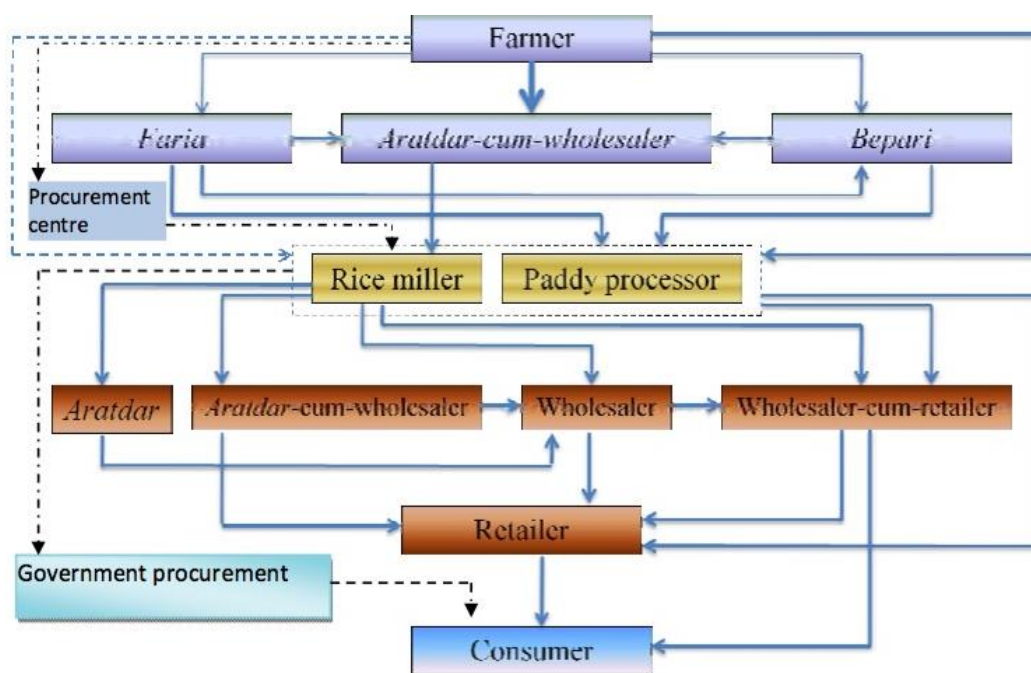


Figure 18. Typical marketing channels of paddy/ rice in Bangladesh (Raha et al., 2012)

Aratdar is a trader who possesses permanent establishment in market place and holds license for business. He does not buy product in his own account, i.e., he does not take title to the goods. But he takes the possession of the goods and makes arrangement to sell those, collects money from the buyers and sends remittances to suppliers (sellers) after deducting all costs incurred in completing the process of selling. The *aratdar* receives a fixed rate of commission on sales. In paddy market, the *aratdar* work for the millers. In many cases, the millers advanced funds for buying paddy to *aratdar* with guidelines about the quality of paddy, quantity and price range. The *aratdar* purchases paddy according to the direction of the millers along with his business experience. After building the sizeable lot, paddy is transported to miller's place. All tasks of bagging, weighing, sewing and loading is done by the *aratdar's* people. In most of the cases,

millers supply the bags. Transportation cost is born by the millers. *Aratdar* facilitates the transfer of paddy from local paddy trader/farmer to millers. When the *aratdar* acts as both *aratdar* and wholesaler, then he is called as *aratdar-cum-wholesaler*. Depending on the market situation, *aratdar* may act as *aratdar* as well as wholesaler.

A person who owns any type of rice mill is known as rice miller. He purchases paddy from various sources such as paddy traders (*bepari* and *aratdar*). Millers collect paddy from different areas/districts of the country. Small millers purchase paddy from the local market themselves mainly and through *aratdar*. Large millers purchase paddy through *aratdar* mainly from the distant and local markets.

A group of traders could be involved in paddy processing without having mill of their own. They purchase paddy from the *faria* and *bepari*. They use to hire milling facility that is husking mill, *chatal* (drying yard) and labor for processing paddy. In some places they also go for sorting and polishing the milled rice for quality improvement. They sell milled rice to wholesaler-cum-retailer and retailer.

The rice wholesalers are the *aratdar*, *aratdar-cum-wholesalers*. They purchase milled and processed rice from the millers and/or processors. The millers bear the transportation costs to transfer the rice to the wholesalers. The wholesalers get rice from the millers and/or processors without advanced payment. The payment is made after the rice is sold.

The rice retailers also have contact with the wholesalers/millers. They purchase rice from the wholesalers/millers/traders and sell to the consumers.

Rice Market Structure

Market structure refers to those organizational characteristics of a market, which determine the relations of (a) sellers in the market to each other, (b) buyers in the market to each other, (c) sellers to buyers, and (d) sellers established in the market to potential new firms that might enter it (Bain, 1968). Market structure means those characteristics of the organization of a market, which seem to exercise a strategic influence on the nature of competition and pricing within the market.

The structure of Bangladesh rice market can be examined and analyzed based on four criteria: 1) degree of seller and buyer concentration, 2) entry barriers, 3) assortment of product quality, and 4) distribution of market information (Raha et al., 2012). The study observed these criteria of Bangladesh rice market as follows:

- 1) Concentration: At the farm level, the paddy growers are numerous and individually produce a very small part of the total marketed surplus. Thus, the individual producers have no power to influence the market. So, seller concentration at farm level is very low. On the other hand, paddy-buyers' concentration in Bangladesh is high.
- 2) Entry barriers: The arrangement of sufficient capital is the major problem for the traders followed by suitable site for the shop and business risk. The established firms/traders also face problems at the time of entry to the business. The problems are insufficient capital, competition among traders and suitable site for shop.
- 3) Degree of product differentiation: The assortment of paddy measures the extent to which buyers differentiate or distinguish their specific preferences among competing types of paddy. In Bangladesh, different varieties of rice are grown in different

seasons. The paddy available in the market can be grouped according to production season, i.e., *Aus*, *Aman* and *Boro*. The paddy can be divided into aromatic and non-aromatic paddy, fine paddy and coarse paddy. The traders are not strictly confined in handling any particular paddy variety but the volume handled depends on the area and availability of paddy in that area along with the order of the buyers. However, the number of varieties of paddy handled by *faria* is less as compared to *bepari* and *aratdar-cum-wholesaler*. Though there are differences in paddy in terms of variety and quality, there is no deliberate effort to make the paddy differentiation in the market.

- 4) Distribution of market information: At the field level, there is no formal system of dissemination of market information on paddy marketing to paddy traders. But it was observed that the paddy traders collect market information from various sources. Generally *Faria* and *Bepari* collect market information by their own observation and also from fellow traders. Telephone is also used by the *bepari* for collection of market information from the potential buyers in other markets. *Aratdar-cum-wholesalers* mainly collect market information by telephone. It may be noted that the Department of Agricultural Marketing (DAM) disseminates market information especially on price of paddy in some selected markets of the country.

Table 6 can explain the plausible structure of the Bangladesh rice market. Rice millers are the key actors in Bangladesh rice supply chain. They have linkage and control both of the forward and backward levels. In the backward linkage, the suppliers (farmers) are so many and the demand side participants are a few (traders consisting of paddy wholesalers and millers). So, the backward linkage to millers' market follows the

oligopsony structure.

However, in the forward linkage, the suppliers (millers and rice wholesalers) are a few whereas the demand side participants are a huge number of consumers. The market structure in the forward linkage to millers is oligopoly. This study analyzed only the forward linkage market structure from the rice millers in Bangladesh. So, the market imperfection in this study is the oligopoly power exercised by the rice millers and wholesalers in the Bangladesh rice supply chain.

Table 6. Market structures

		SUPPLY SIDE FORM		
		Participants	MANY	FEW
DEMAND SIDE FORM	MANY	Perfect competition	Oligopoly	Monopoly
	FEW	Oligopsony	Bilateral oligopoly	Monopoly-oligopsony
	ONE	Monopsony	Oligopoly-monopsony	Bilateral monopoly

Source: Dobson et al., (1998)

Market Imperfection

Figure 19 can describe the scenario of market imperfection in the overview of the Bangladesh rice sector. The rice millers and/or wholesalers are practicing oligopoly power, which acts as the condition of the market for milled rice. The rice processing millers and/or wholesalers are operating collusively; hence the condition resembles an oligopoly in selling. The imperfect market situation enforces consumers to pay more (P^{oly}) for rice and the supply is less (Q^{oly}) than the perfect competition. The perfect competition is the point where the demand D^{PC} and the marginal cost (MC) curves of miller or wholesaler intersect each other and where supply is larger Q^{PC} and price is

lower at P^{pc} .

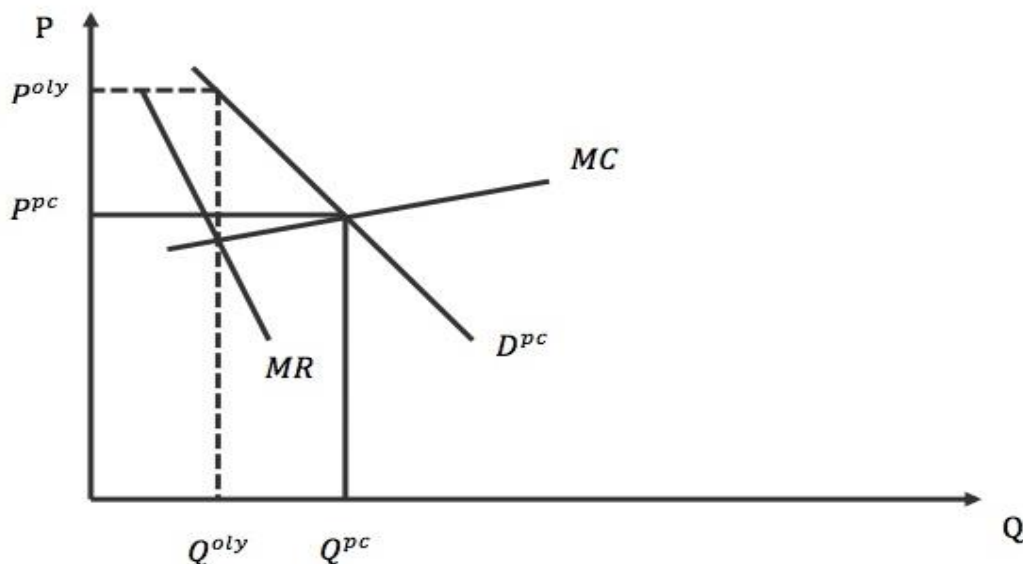


Figure 19. Bangladesh rice market under millers' and wholesalers' oligopoly power (Author's drawn)

Market Regulation

The rice millers are acting as speculative investors with a vast amount of money to capture the market. They are playing a fundamental role in paddy purchasing and selling procedures. They purchase an enormous amount of paddy at harvesting period and store the milled rice for year round selling. Mostly, the millers buy paddy through the commission agents (*aratdars*), who have well-known business in the regional/rural areas. The agents are getting advance money for their business from the millers with a contract to provide paddy to the rice mills. The millers decide the amount of paddy to be purchased as well as the price; commission agents have little freedom in such matters. The agents are bound to follow the instruction and regulation of the millers during purchasing paddy as the credit support is coming from millers. The rice farmers are the

loser in transferring product to the market. The traders are highly tied up and not following the government procured prices. Farmers are bound to carry their paddy to the local traders without any transportation charges. The advantages are going to the local traders and millers, as they are concentrated, whereas the farmers are producing and selling paddy individually. Neither the farmers' nor the government organization exists to empower farmers with a significant concentration.

Millers control the rice supply to maintain the price level with strong collusive and cooperative power. In the Bangladesh rice-marketing channel, millers and wholesalers are also working collusively. The wholesalers do not have to pay to the millers in advance. With a minimum payment, they can get rice from millers and full payment is made after selling. The wholesalers are also doing so with retailers. Therefore, the rice supply chain actors are supporting each other to gain much power and possibly capture higher margins. Although rice is the main political crop, the market regulation is beyond the control of the government. The government is trying to cope with the supply chain actors but is unable to control the strong cartels of rice millers.

Rice Price Transmission

Correlation of the Rice Price Series

The correlation analysis gives a picture of nature of the relationship among the variables. Correlation analysis was carried out to aid in identifying the degree and extent of co-linearity between the price series as well as determining the strength and direction of the relationship between the independent variables and the dependent variable. Table 7 presents a summary of the correlation coefficients among the price series variables. The

correlation results indicate that there is a strong and positive relationship among the price variables.

Table 7. Correlation coefficients of the price series

Items	Retail	Wholesale	Farm
Retail	1.0000		
Wholesale	0.9519	1.0000	
Farm	0.8682	0.9247	1.0000

Pattern and Trend of Rice Prices

Descriptive statistics of farm, wholesale and retail rice prices are presented in the Table 8. The price series cover 141 months. The mean of the farm, wholesale and retail prices are 24.44, 27.07 and 29.68 Tk./kg, respectively. All of the rice price series showed increasing trends (Figure 20).

Table 8. Descriptive statistics of rice prices

Particulars	Farm price	Wholesale price	Retail price
Count	141	141	141
Mean	24.43844	27.06546	29.68191
Standard Dev.	5.25397	5.82608	5.92989
Minimum	15.1	15.38	16
Maximum	36	39.5	43.33

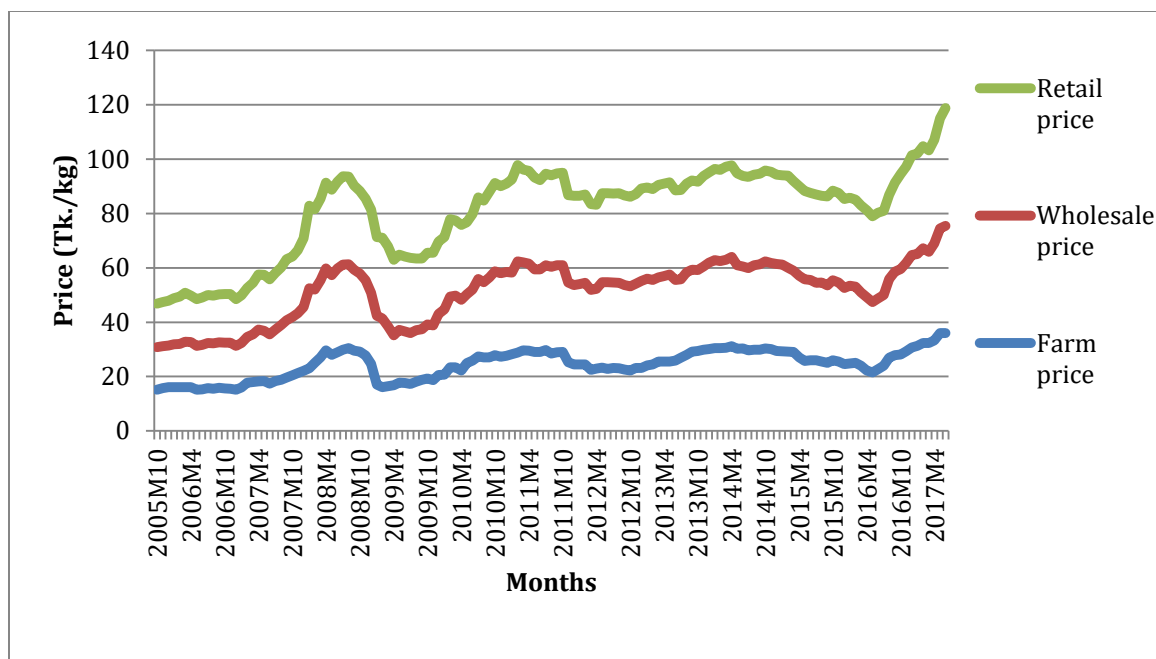


Figure 20. The farm, wholesale, and retail prices of the Bangladesh rice supply chain (DAM, 2018)

Unit Root Tests of Prices

The Augmented Dickey and Fuller Phillips-Perron (1988) tests were used to test for the stationarity of the variables in levels and first difference. The null hypothesis is that the variable under consideration has a unit root or is not stationary while the alternative hypothesis is that the variable of interest is stationary. The null hypothesis is rejected if the absolute value of the computed ADF or PP test exceeds the absolute critical value at 1 and 5 percent.

Table 9 presents the results of the unit root tests. The results suggest that prices along the rice supply chain have unit root in level, as the estimated values do not exceed the critical value. The price series become stationary after first difference I (1). The estimated values of all the price series exceed the critical value at 1 percent significant level. Results of the Augmented Dickey-Fuller and Phillips-Perron unit root tests for the

farm price are taken from Appendix C and Appendix D, respectively. Results of the Augmented Dickey-Fuller and Phillips-Perron unit root tests for the wholesale price are taken from Appendix E and Appendix F, respectively. Results of the Augmented Dickey-Fuller and Phillips-Perron unit root tests for the retail price are taken from Appendix G and Appendix H, respectively.

Table 9. Augmented Dickey-Fuller and Phillips-Perron unit root tests

Series	Augmented Dickey-Fuller	Phillips-Perron
Level		
fp	-1.8906	-1.9864
wp	-1.5423	-1.7858
rp	-1.9505	-1.9152
First difference		
Δ fp	-8.5015***	-8.5346***
Δ wp	-	-
Δ rp	10.1624***	10.4629***
	-9.8857***	-
		10.2020***

Note: Δ is the first difference operator. “***” denotes rejection of the null hypothesis of unit root at the 1% level. Here, fp, wp, and rp are the farm, wholesale, and retail price series.

Causal Markets Using Causality Test

An important issue in the empirical investigation of price transmission asymmetry is the selection of the so-called causal markets. This means the markets at which prices are established. It is usually assumed that the price is established at the farm level and it flows forward to the wholesale and then to the retail level (Gervais, 2011). A common explanation for the choice has been that supply shocks are more frequent than demand shocks and that seller adopts fixed mark-up pricing. Other researchers identify the casual market by employing some type of causality test.

In order to determine causal markets, the study used the Granger causality test (Granger, 1969). It used a Vector Auto Regressive (VAR) model in the Granger causality test with a total number of two lags selected using the Akaike Information Criterion and the Hannan Quinn Information Criterion. The (bi-variate) test has been applied to three pairs of prices, namely, (fp, wp), (fp, rp), and (wp, rp).

The pair-wise results of the Granger causality test are presented in Table 10. The results suggest that at 1 percent and 5 percent levels of significance, the causal order flows unidirectional forward from the farm to the wholesale and/or retail level and also from wholesale to retail level. The results with regard to the causal order therefore, shows that rice prices are likely to be established at the upward level of the supply chain and to flow to the downward levels. For example, in the wholesale and retail pair, wholesale price Granger caused retail price, but retail price did not cause the wholesale price. Likewise, the retail and farm pair showed the causality from farm price to the retail price. The farm and wholesale pair showed that the farm price caused the wholesale price, but the wholesale price did not cause the farm price (Table 10). The results of the pair-wise Granger causality test are taken from Appendix I.

Table 10. Results of the pair-wise Granger causality test

Null hypothesis	F-statistics	P-value	Decision
wp \neq > rp	5.5099**	0.0203	Unidirectional
rp \neq > wp	0.0067	0.9350	
fp \neq > rp	8.9554***	0.0033	Unidirectional
rp \neq > fp	0.1004	0.7518	
fp \neq > wp	11.8976***	0.0007	Unidirectional
wp \neq > fp	0.1991	0.6561	

Note: the symbol A \neq > B means A does not granger cause B. '***' and '**' denote rejection of the null hypothesis of at the 1% and 5% probability levels, respectively. fp, wp, and rp are the farm price, wholesale price, and retail price, respectively.

Co-integration of Prices Using Symmetric Auto Regressive Distributed Lagged (ARDL) Estimation

Based on the findings of the causality tests, the search of evidence for price transmission was confined to the following directions: farm to wholesale, wholesale to retail and farm to retail. This study considered the retail price as dependent variable. Farm and wholesale prices were the causal factors or explanatory variables. The appropriate and congenial method for testing for co-integration is the Auto Regressive Distributed Lagged (ARDL) bounds test as proposed by Pesaran et al., (2001). The main advantage of this approach is that it provides estimates of co-integration among the variables irrespective of whether they are integrated of the same order or not. The other advantage is that both short and long run dynamics are estimated simultaneously. The null hypothesis is that there is no co-integration of price series while the alternative hypothesis is that there is co-integration. The ARDL approach to co-integration provides two bounds: the lower and upper bounds. The null hypothesis of no co-integration is rejected if the computed F value exceeds the F critical value of the upper bound (Appendix J). On the other hand, the null hypothesis is not rejected if the computed F value is less than the F value of the lower bound. However, if the computed F value lies between the lower and upper bounds, the bounds test procedure for co-integration is inconclusive. In this case, other tests of co-integration such as trace statistics, maximum Eigen value test or Engle and Granger residual tests can be used to assess the existence of co-integration among the variables.

According to Table 11, the co-integration test (F_{PSS}) rejects the null hypothesis of no co-integrating relationship between the dependent (retail price) and explanatory

(wholesale, and farm) price series in the symmetric ARDL model. Furthermore, the normality test (JB) that tests the null hypothesis of normally distributed error term is rejected at the 10% significance level. The cumulative sum square (CUSUMQ) also does not satisfy the stability of the parameter. Since this finding implies a modeling problem, correctly specifying the long-run relationship is an important issue in the case of relationship between retail price and wholesale and farm prices. So, asymmetric ARDL modeling may be a more correct modeling strategy than linear ARDL approach. However, this study considered linear ARDL model to estimate the symmetric price transmission as a base price to measure the welfare impact of price transmission asymmetry.

Table 11. Results of the linear ARDL model estimation

Symmetric ARDL Model			
Variable	Coefficient	Standard error	t-statistic
C	0.2191*	0.1269	1.7270
rp_{t-1}	-0.8176***	0.2080	-3.9301
wp_{t-1}	0.2284***	0.0798	2.8631
fp_{t-1}	0.7048***	0.1694	4.1607
Δrp_{t-1}	0.0076*	0.0039	1.9816
Δwp	0.4655***	0.0476	9.7867
Δwp_{t-1}	0.0724**	0.0321	2.2553
Δfp_{t-1}	0.0837**	0.0401	2.0907
Diagnostics			
$F_{PSS} =$	5.1531**		
$ECT =$	-0.1040***	$JB =$	8.576*
$ARCH =$	1.7391	$LM =$	1.3811
$CUSUM =$	S	$AIC =$	-2.4386
$CUSUMQ =$	U	$SIC =$	-2.3335

Note: JB = Jarque-Bera test for normality, LM = LM test for serial correlation, ARCH = ARCH test for heteroscedasticity, S = Satisfied, U = Unsatisfied, ECT is the long run error correction term and F_{PSS} denotes the PSS F-statistic testing the null hypothesis $\rho = \theta_1 = \theta_2 = 0$. The critical values for F_{PSS} test, attained from Pesaran et al., 2001, lower bound and upper bound at 5% significant level. '***', '**' and '*' denote the significance at 1%, 5% and 10% levels, respectively.

Dynamics of Asymmetric Non-linear Auto Regressive Distributed Lagged (ARDL) Estimation

The estimated parameters of the lag price series in the ARDL or NARDL estimation do not directly indicate the effects of the lag price changes on the retail price change. Rather, the parameters' results have been provided for the further analysis and decision of the pattern of the price transmission and estimating long run coefficients. Table 12 presents the findings of asymmetric ARDL model estimation including both short- and long-term dynamics. The $WALD_{LR}$ is the Wald test that tests the null hypothesis of long run symmetry (i.e., $L_W^+ = L_W^- = L_F^+ = L_F^-$). The null hypothesis of $WALD_{SR}$ test is short run symmetry (i.e., $\sum \pi^+ = \sum \pi^- = \sum \eta^+ = \sum \eta^-$). The null hypotheses of long run and short run symmetry are rejected at 1% significance level by the Wald test. It means that there are short and long run asymmetric effects of wholesale and farm rice prices on retail price in Bangladesh. Furthermore, when the ARDL model is specified to asymmetric relation, the co-integration test (F_{PSS}) rejected the null hypothesis of no co-integrating relationship between farm, wholesale, and retail price series.

Table 12. Results of the asymmetric ARDL model estimation

Asymmetric ARDL Model			
Variable	Coefficient	Standard error	t-statistic
C	1.6387***	0.3193	5.1315
rp_{t-1}	-0.1825***	0.0352	5.1925
wp_{t-1}^+	0.1720***	0.0514	3.3449
wp_{t-1}^-	0.1281***	0.0429	2.9863
fm_{t-1}^+	0.1159*	0.0695	1.6684
fm_{t-1}^-	0.0813*	0.0415	1.9571
Δwp_t^+	0.6089***	0.0675	9.0164
Δwp_t^-	0.1842**	0.0828	2.2247
Δwp_{t-1}^-	-0.1347*	0.0794	-1.6973
Δwp_{t-2}^-	-0.1614**	0.0785	-2.0553
Δfm_{t-2}^+	0.2334**	0.1155	2.0214
$W_{PSS} = 9.1349***$		$L_W^+ = 0.9426**$	
$F_{PSS} = 5.2162**$		$L_W^- = 0.7020**$	
$L_F^+ = 0.6351*$		$L_F^- = 0.4452$	
$WALD_{SR} = 18.466***$		$WALD_{LR} = 9.282***$	
Diagnostics			
ECT = -0.1933***		JB = 6.90	
ARCH = 0.0091		LM = 1.9567	
CUSUM = S		AIC = -2.6034	
CUSUMQ = S		SIC = -2.3689	

Note: JB = Jarque-Bera test for normality, LM = The Breusch-Godfrey LM test for serial correlation, ARCH = ARCH test for heteroscedasticity, S = Satisfied, ECT is the long run error correction term and F_{PSS} denotes the PSS F-statistic testing the null hypothesis $\rho = \theta_1 = \theta_2 = 0$. The critical values for F_{PSS} test, attained from Pesaran, et al., 2001, lower bound and upper bound at 5% significant level. L_W is the long run coefficient for wholesale price and L_F is the long run coefficient for farm price. '***', '**' and '*' denote the significance at 1%, 5% and 10% levels, respectively.

NARDL Long Run Coefficients and Error Correction Term

From the results of the NARDL analysis, the long run equation can be written as:

$$\begin{aligned} \text{Retail} = & 0.9426 * \text{wholesale}_{\text{pos}} + 0.7020 * \text{wholesale}_{\text{neg}} + 0.6351 * \text{farm}_{\text{pos}} \\ & + 0.4452 * \text{farm}_{\text{neg}} \end{aligned} \quad (41)$$

The long-term coefficients of the NARDL model indicated that the effect of positive and negative changes in wholesale price (L_W^+ and L_W^-) on retail price were statistically significant at 5% level. But, the sizes of the coefficients were not similar to

each other. The long-term coefficient of the positive farm price change (L_F^+) was 0.635 and statistically significant at 10% level. The coefficient of negative farm price change (L_F^-) was neither as large as the coefficient of positive farm price change (L_F^+) nor significant. So, these findings indicated that optimal model for the price transmission from farm to retail through wholesale levels along the Bangladesh rice supply chain should include asymmetric relation both in the short run and long run.

The error correction term (ECT) was negative (-0.1933) and highly significant, meaning that there was a long run causality running from wholesale and farm prices to the retail price. It also confirmed that all the variables were co-integrated or had long run relationship. Result show that about 19.33 percent of the gap between long run equilibrium value and the actual value of the dependent variable (retail price) has been corrected monthly. It also can be said that speed of adjustment towards long run equilibrium was 19.33 percent monthly. This means that the price transmission system corrected its previous period disequilibrium at a speed of 19.33% monthly.

The dynamic multipliers also allowed tracing out the evolution of a price at a given level of the supply chain following a shock to a price at another level. Figure 21 presented the dynamic multipliers for the price transmission from the farm to the retail levels. The retail prices' response was not at the same rate in the short-run with an increases and decreases of the farm price. The equilibrium correction was achieved after nearly 20 months. The long-run effect, however, as depicted by the asymmetry line of a price increase at the farm level is larger than that of a price decrease. The behavior of the dynamic multiplier is consistent with both the short run and long run asymmetry.

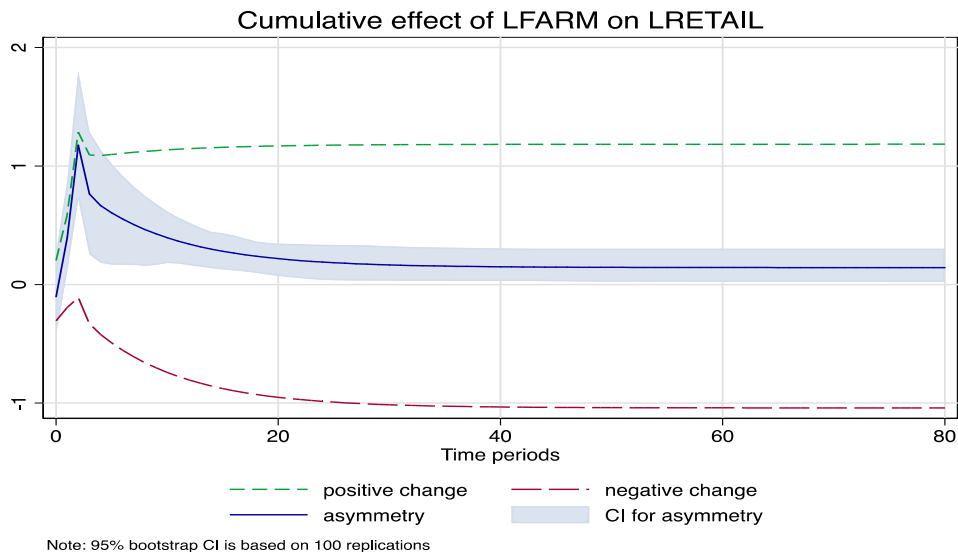


Figure 21. Dynamic multiplier farm to retail level

Figure 22 presented the dynamic multipliers for the price transmission from the wholesale to the retail levels. It shows that retail price response is not at the same rate with a positive and negative shock to wholesale price. The magnitude, however, of adjustment is larger for positive shocks with the equilibrium correction being achieved after nearly 20 months. Clearly, the effect of a positive shock in wholesale price dominates that of a negative one in both the short as well as in the long run. The behavior of dynamic multipliers is consistent with both short and long run asymmetry.

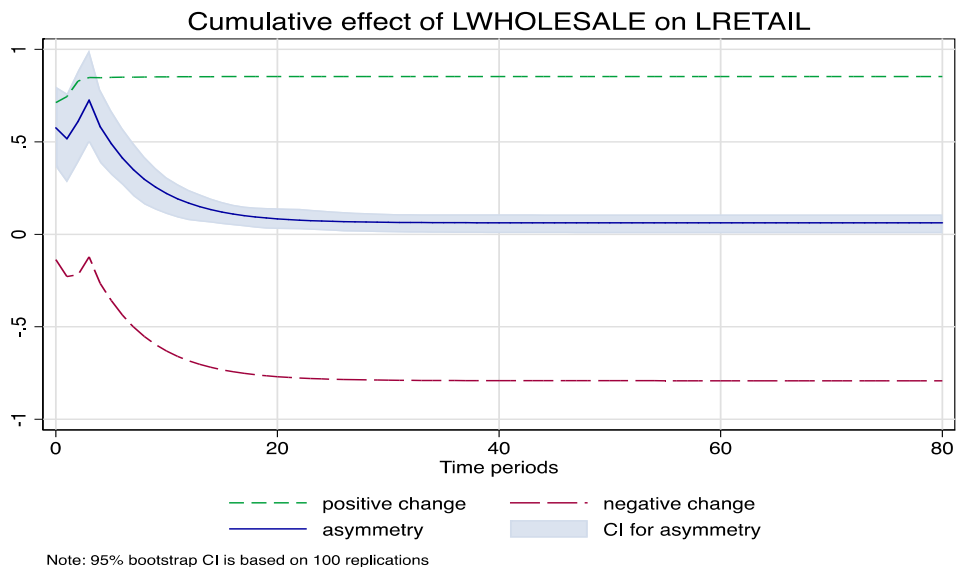


Figure 22. Dynamic multiplier wholesale to retail level

Post-estimation Diagnostic Tests of NARDL Model

The diagnostic tests results of the NARDL estimation are presented in Table 12. The test for autocorrelation was necessary since the estimated parameters may be inefficient and the standard errors wrongly estimated and biased downwards. The Breusch-Godfrey serial correlation LM test was used to test the null hypothesis of no autocorrelation against the alternative hypothesis of autocorrelation. The computed probability value statistic was found more than 5% implying that the null hypothesis is not rejected; hence the estimated model was free from autocorrelation. The estimated result of Breusch-Godfrey serial correlation LM test is in Appendix K.

The estimated parameters in the presence of heteroskedasticity are inefficient and have high standard errors thereby rendering the F and t statistics invalid. The null hypothesis was that the disturbance term was homoskedastic while the alternative

hypothesis was that the error term was heteroskedastic. Under the autoregressive conditional heteroskedasticity (ARCH) test, the probability value was implying that the null hypothesis was not rejected at 5% level; hence the disturbance term was homoskedastic. Result of ARCH test is in Appendix L.

The Jarque-Bera test was used to check if the residuals are normally distributed. The null hypothesis of the residuals being normally distributed was tested against the alternative hypothesis of the residuals not being normally distributed. The probability value indicates the insignificance of the computed Jarque-Bera test statistic. This means null hypothesis was not rejected; hence the residuals were normally distributed.

The Cumulative Sum of Recursive Residuals (CUSUM) and Cumulative Sum of Squares of Recursive Residuals (CUSUMSQ) were used to confirm the stability of the coefficients with the null hypothesis that the coefficients are stable against the alternative hypothesis that the coefficients are not stable. The plots showed that the coefficients are stable as the recursive residuals are within the 5 percent level of significance; hence the null hypothesis is not rejected (Figure 23). Therefore, the estimated coefficients are stable and consistent.

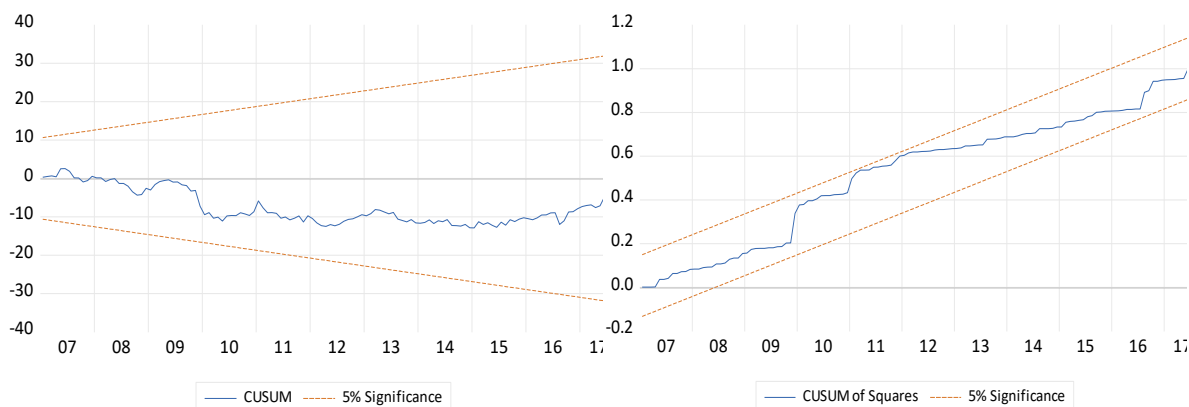


Figure 23. Cumulative sum (CUSUM) and cumulative sum square test on NARDL model with LR and SR asymmetry

Domestic Rice Demand

The estimated results of rice demand regression function for Bangladesh are shown in Table 13. The diagnostic check showed satisfactory results. The Durbin–Watson d statistic is 1.81. Given 44 observations and four regressors (including the constant term) in the model, the lower and upper 5% bounds are about 1.32 and 1.72. The computed d statistic is much greater than the upper bound. The null of no first-order serial correlation was accepted. It can be said that the errors are uncorrelated. The Breusch–Pagan–Godfrey Heteroskedasticity test was used with the null hypothesis of a homoskedastic disturbance term against the alternative hypothesis of heteroskedastic disturbance term. The result could not reject the null hypothesis, as the computed chi-square value is not significant at 5 percent level, implying that the residuals are homoskedastic.

Table 13. Estimated results of the domestic rice demand function

Variable	Coefficient	Standard Error	t-ratio	p-value
Intercept	-2850.708	1004.607	-2.84	0.004
P	-0.0242**	.0116	-2.085	0.014
GNI	0.0116**	.0053	2.188	0.011
POB	2.379 ^{ns}	1.680	1.416	0.108
R ² = 0.9820		Adj R ² =0.9806	F (3, 40)= 725.45***	DW= 1.81 (d _L =1.32, d _U =1.72)
χ _{BP} ² = 5.36 [p-value: 0.1215]		n=44		

Note: χ_{BP}² is the Breusch-Pagan test statistics for heteroskedasticity. ‘***’, ‘**’ denote the significance at 1% and 5% levels, respectively. ‘ns’ denotes not significant. d_L and d_U are the lower and upper bound values of Durbin-Watson table, respectively.

So, the domestic rice demand function was written in the following form:

$$\hat{D} = -2850.708 - 0.0242 P + 0.0116 \text{ GNI} + 2.379 \text{ POB}$$

Putting in its average value, multiplying with the estimated coefficient and adding the resultant figure to the intercept, removed the variable POB as:

$$\hat{D} = 28712.949 - 0.0242 P + 0.0116 \text{ GNI} \quad (42)$$

Equation (42) is the domestic rice demand function with price and income effects. The variable GNI was also removed and further condensed the demand function only with the price effect as:

$$\hat{D} = 37139.821 - 0.0242 P \quad (43)$$

Welfare Change of a Price Change

In order to calculate the compensated welfare effect (CV) of asymmetric price transmission along the rice supply chain of Bangladesh, the Vartia's algorithm was used. The predicted symmetric price from the linear ARDL illustrated model was treated as the initial price, and predicted asymmetric price from NARDL model was treated as the final price. The CV was calculated using the difference between the symmetric retail price and asymmetric retail price. The demand equation (42) with price and income effect and the Vartia's algorithm were used to calculate CV. Consequently, the change in consumer surplus (ΔCS) was calculated using the predicted symmetric and asymmetric price in equation (7) considering the demand equation (43). Thus,

$$\begin{aligned} \Delta CS &= - \int_{P_S=0.178}^{P_{AS}=1.385} (37139.821 - 0.0242 * P) dp \\ \Delta CS &= -\text{Tk. } 45985.324 \text{ thousand} \\ \Delta CS &= -\text{Tk. } 45.985 \text{ million} \end{aligned} \quad (44)$$

Table 14 represents the welfare measures of asymmetric price transmission in the rice supply chain of Bangladesh. With the 100 times convergence the CV does not differ from the change in CS. So, income does not have significant effect on the rice consumption in Bangladesh. The estimated results of the demand function in Table 5 also

support this, as the coefficient of GNI does not show significant effect on rice demand. The estimated welfare measure means that due to the rice price transmission asymmetry the consumers suffered losses in their consumer surplus (CS) of Tk. 45.985 million per month. The asymmetric price transmission resulted in dead weight losses amounting to Tk. 1.093 million per month (Figure 24). The total population of Bangladesh is about 162 million (www.Worldometers.info). So, a CS loss for the each rice consumer, on average, is about Tk. 0.284 per month.

Table 14. Estimated welfare measures associated with price transmission asymmetry (in thousand Tk)

Price Change		No. of Convergence	Vartia's Calculation		Demand and Price Calculation	
\hat{P}_{sy}	\hat{P}_{asy}		CV	DWL	ΔCS	DWL
		20	44312.158	2626.779		
0.178	1.385	50	45711.443	1247.085	45985.324	1093.216
		100	46177.872	787.187		

Note: P_{sy} = symmetric price, P_{asy} =asymmetric price, DWL= dead weight loss. 1 US\$= 80 TK.

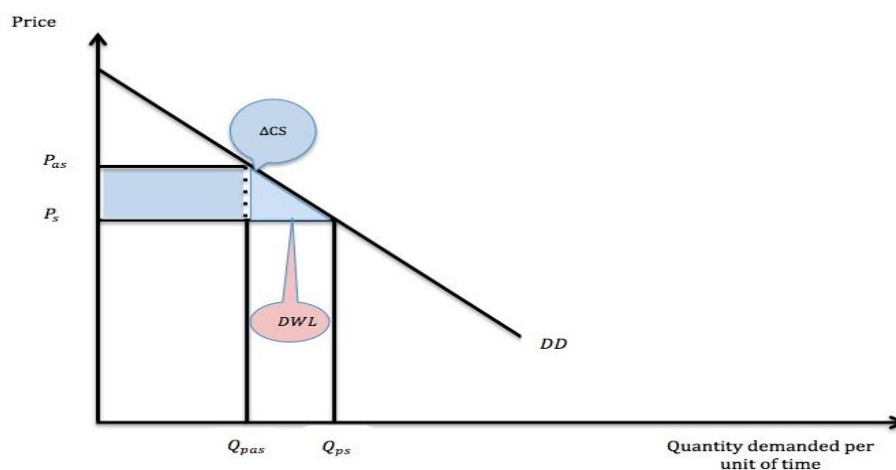


Figure 24. Change in consumer surplus and dead weight loss

Market Power as the Cause of Price Asymmetry

The collected data for the stochastic frontier analysis of the trans-log cost function for market power estimation requires some explanation. The data has been collected at the period June to August 2017. The output (Y) for the millers and wholesalers refers to the mills' output of rice and amount of rice sold in ton, respectively. The inputs employed at the rice processing stage are: raw materials (M, paddy), labor (L), capital (K), energy (E), other materials (O), and transportation (T). Price and quantity data on these inputs were collected through face-to-face interview.

Price of raw materials (w_M) is the amount of money spent by the miller per ton of paddy. In case of the wholesaler, it is the cost of per ton of purchased rice from the miller. Price of labor (w_L) is the daily salary of labor. Price of energy (w_E) is the cost of electricity per day for millers and per week for wholesalers and other materials (w_O), which were calculated weekly. Price of capital (w_K) is the bank interest rate. Price of the transportation (w_T) was collected weekly as well. However, in most cases, the wholesalers do not have to bear much transportation cost. The millers mainly bear the cost of transportation. Tables 15 and 16 represent the descriptive statistics of the input prices and output of millers and wholesalers, respectively.

Table 15. Descriptive statistics of rice millers

Variable	Mean	Std. dev.	Min	Max
Revenue share and output				
$(\frac{PY}{C})$	1.331	0.922	0.833	4.851
Y	22.315	15.804	1.40	71.5
Input prices				
w_M	25319.69	517.86	24000	27000
w_L	142.113	16.326	120	180
w_E	830.057	675.459	13.33	3000
w_O	3029.554	2672.564	571.429	12857.14
w_T	2939.518	2297.147	428.571	9142.86
w_K	12.606	1.122	10	15

Note: Y is the output, P is the price of output, and C is the total cost.

Table 16. Descriptive statistics of rice wholesalers

Variable	Mean	Std. dev.	Min	Max
Revenue share and output				
$(\frac{PY}{C})$	1.174	0.463	0.78	3.765
Y	17.645	32.557	0.64	240.0
Input prices				
w_M	41127.08	1945.248	36000	50000
w_L	228.667	74.552	80	500
w_E	164.156	167.728	25	1000
w_O	791.145	1098.12	25	6250
w_K	11.721	1.717	10	17

Note: Y is the output, P is the price of output, and C is the total cost.

Tables 17 and 18 denote the estimated mean and standard deviation of the mark-up component (\hat{u}), mark-up ($\hat{\theta}$), return to scale (RTS) and Lerner index (\mathcal{L}) that indicate the degree of market power being exerted by the rice millers and wholesalers in Bangladesh. The results revealed that the influence of mark-up is usually positive, representing the non-competitive behavior of rice markets. Both the half-normal and exponential distributions of the u term produce almost similar results. The estimated

mark-up ($\hat{\theta}$) for rice millers' is about 0.55 and that of wholesalers is about 0.49. These estimates suggest that, on average, rice millers are charging about 55% beyond the marginal processing cost, and the wholesalers are charging about 49% above the marginal business operating cost. The wholesalers are not bearing any processing cost; they are just maintaining the business operations and getting a relatively large margin.

The value of the Lerner Index (\mathcal{L}) is also significantly greater than zero (0.23 for millers and 0.27 for wholesalers). It indicates that the rice market is not perfectly competitive and the actors are exercising unfair market power. The results of the estimated parameters of the cost function for rice millers and wholesalers are presented in Appendix M and Appendix N, respectively.

Table 17. Mark-up and return to scale estimates of rice millers based on the cost function approach (n=160)

Variable	Mean	Std. Dev.	1st Quartile	Median	3rd Quartile
Half-normal distribution for the u term					
\hat{u}	0.4733	0.917	0.125	0.193	0.257
$\hat{\theta}$	0.5489	1.051	0.140	0.228	0.312
RTS	1.169	0.055	1.131	1.173	1.212
\mathcal{L}	0.229	0.197	0.122	0.185	0.238
Exponential distribution for the u term					
\hat{u}	0.4732	0.917	0.125	0.189	0.258
$\hat{\theta}$	0.5491	1.051	0.142	0.223	0.313
RTS	1.169	0.058	1.123	1.173	1.212
\mathcal{L}	0.229	0.198	0.124	0.182	0.238

Table 18. Mark-up and return to scale estimates of rice wholesalers based on the cost function approach (n=240)

Variable	Mean	Std. Dev.	1st Quartile	Median	3rd Quartile
Half-normal distribution for the u term					
\hat{u}	0.385	0.461	0.100	0.278	0.457
$\hat{\theta}$	0.488	0.578	0.122	0.350	0.586
RTS	1.269	0.046	1.240	1.267	1.297
\mathcal{L}	0.266	0.180	0.109	0.259	0.370
Exponential distribution for the u term					
\hat{u}	0.384	0.463	0.104	0.282	0.446
$\hat{\theta}$	0.486	0.583	0.133	0.353	0.575
RTS	1.266	0.025	1.250	1.266	1.284
\mathcal{L}	0.265	0.179	0.117	0.260	0.365

The above findings can be related to the studies that have been shown regarding the scale of market power in the food industries. Bhuyan and Lopez (1997) estimated the market power in the U.S. food market as 18%. Lopez (1984) estimated 19.2% market power practiced by the Canadian food processing industries. O'Donnell (2007) identified 13.6% market power of Australian wheat output markets. Bhuyan and Lopez (1998) also estimated 55% market power in the U.S. cereal breakfast industries.

Ward (2010) pointed out that even a minor degree of market power could convert into quite meaningful welfare effects. In this case, the Bangladesh rice supply chain is badly affected by millers' and wholesalers' oligopoly market power.

CHAPTER VI

SUMMARY, CONCLUSION, AND POLICY RECOMMENDATIONS

Summary and Conclusion

This study confirms the NARDL model as the appropriate model to analyze the price transmission asymmetry along the rice supply chain of Bangladesh. The study used retail price as the dependent variable and wholesale and farm prices as the explanatory variables. The monthly time series rice price data were used covering period October 2005 to June 2017. The following conclusions are based on the empirical results.

The rice price series are showing increasing trend as well as increasing margin between farm and retail. The millers are capturing maximum share of the marketing margin followed by the wholesaler (Figure 3). The series are stationary based on first difference analysis. This means that they are following the order $I(1)$ and thus, stationary. There is only unidirectional Granger causality between upstream and downstream rice prices. This means that the retail price is affected by the wholesale or farm prices; and wholesale price is affected by the farm price in Bangladesh.

There is a long run asymmetric relationship between retail price and wholesale and farm prices. The presence of asymmetry is in both speed and magnitude for the price levels retail, wholesale, and farm. This means that there are significant asymmetric effects in both long run and short run.

The empirical results suggest that processors (wholesalers/millers) enjoy a certain advantage over primary producers (farmers) and that retailers enjoy a certain advantage

over processors. Also, final consumers are more likely to experience a decrease in their surplus from a price increase rather than to experience an increase in their surplus from a price decrease at the upstream. The farmers do not have any power over the rice market of Bangladesh. The structure of the market is oligopoly involving millers and wholesalers. The adjustment of a positive shock takes almost 20 months to achieve equilibrium. The wholesalers and millers take the advantage of this period for capturing higher profit.

The statistical evidence indicates that price is asymmetrically transmitted along the Bangladesh rice supply chain and causes welfare loss for the consumers. Although the welfare (CS) loss for each consumer is very low (Tk. 0.284 per month), the aggregate welfare loss is much significant (Tk. 45.985 million per month). The social dead weight loss for the price transmission asymmetry is Tk. 1.093 million per month. The asymmetric price transmission is due to the market power. This could mean that the potential excess profit for the limited supply chain actors (miller, wholesaler and retailer) is very large.

The stochastic frontier estimation of market power shows the oligopolistic power employed by rice millers and wholesalers. The observed results of this study reveal that both the rice millers and wholesalers exert a high degree of market power. In case of the rice-milling sector, the estimated degree of market power denotes that, on average, the millers charge 55% beyond the marginal processing cost. In case of wholesalers, the estimated degree of market power implies that, on average, they charge 49% above the marginal business cost. The Lerner Index in both millers and wholesalers is significantly greater than zero. This means that the rice market is not operating in a competitive

manner. It also indicates the existence of market influence dominated by the supply chain actors. This result implies that a large proportion of the farm-to-retail price spread in the rice supply chain is being attributed to market power. Rice millers are the key actor causing this unfair high market power. Therefore, market power is one of the main causes of price transmission asymmetry in rice supply chain of Bangladesh.

The findings of the study supported the rice market structure in Bangladesh. The number of consumers is huge and rice is supplied by relatively limited numbers of millers and wholesalers. The millers and wholesalers are working collusively and charging much higher profit over the operating costs. So, the structure of the Bangladesh rice market is oligopolistic. The millers and wholesalers are practicing illegal oligopoly power. The market power results showed the presence of the significantly high oligopoly power of the rice millers and wholesalers.

The study showed that maximum margin of the farm to retail spread captured by the millers and wholesalers. The farmers are not getting much return, as the farmers' share of the margin was very little. The finding of this study showed that the millers and traders are capturing and controlling the market in all the supply chain levels. The actors of the market other than the consumers and farmers are strongly tied up. They are able to maintain oligopoly and oligopsony power in the Bangladesh rice market.

Policy Recommendations

The empirical results of this study provide strong evidence of systemic pricing inefficiencies within Bangladeshi rice markets. It provides policy makers with additional insights about the nature of pricing irregularities. The Bangladesh rice market is oligopsony in the farmers' to millers' stage and is oligopoly in the millers' to consumers' stage. This study also measures the exact welfare losses for the rice consumers as the impact of rice price asymmetry along the rice supply chain of Bangladesh. This finding can be useful for the policymaker to measure the magnitude of policy actions for addressing consumer welfare.

The study also measures the level of market power exercised by the rice miller and wholesaler along the rice supply chain of Bangladesh. The welfare loss related to price asymmetry and market power necessitates government intervention so that the systems can attain a more competitive or efficient manner. The findings of this study may help the policymakers to get intervention for a better management of rice supply chain.

The wholesalers in both paddy supply and rice supply stages are bound to the millers. Millers are providing credit to the paddy wholesalers with a product contract. The rice wholesalers or retailers buy rice from the mills with an agreement of payment after selling to the retailers or consumers. So, the millers control the rice market in the both stages. The wholesales are also organized and controlling the price in the local markets. All actors in the supply chain other than the consumers and farmers appear to operate collectively. The loss of the consumers and farmers are being captured by the relatively limited number of market actors with market power.

The government can take initiatives to establish farmers' organization (e.g.,

cooperatives) to enhance their negotiation power to get better price. The government can offer incentives to establish storage in the rural areas to enable farmers to choose a better selling period of their product. Farmers can be provided easy loan or input support for rice production so that they can avoid immediate selling of the product for the loan payment and next season cultivation.

The credit for paddy traders and rice wholesalers can reduce the procurement and controlling power of the rice millers. The existing government procurement and pricing policies (e.g., price floor and price ceiling) can be implemented more actively at the local markets. The government can even impose the antitrust laws. The antitrust laws can be used to foster competitive markets by controlling actions that limit competition such as mergers and acquisitions, price setting, and collusion pricing. There can be other solutions to bring the rice supply chain actors under government regulations. Patents, licenses and copyrights can be made obligatory for the rice millers, wholesalers and traders to maintain certain rules and qualities of the products.

The government can restart public purchasing and rationing systems targeted for the low-income group consumers (e.g., open market sell) in order to avoid huge fiscal costs. The establishment of a definite agency for the rice price regulation, procurement, and distributional decisions and actions can establish an efficient and competitive rice supply chain in Bangladesh.

Suggested Future Research

This study identified the price transmission asymmetry along the rice supply chain of Bangladesh. The findings of this study represent the pricing inefficiencies of the rice market and the welfare impact of asymmetric price transmission on the rice consumers. Further, this study focused on the estimation of market power as the cause of price transmission asymmetry along the rice supply chain.

This study analyzed the transmission scenario of the rice price at the different levels of supply chain. It did not bring under consideration of any structural change (e.g., sudden shock) or economic variable that can affect the specific price series. Further research can bring such factors under consideration to analyze the vertical price transmission.

The relevant future research can be the impact of asymmetric price transmission on producer welfare. Other future research can be the distribution of welfare losses across the range of consumers having different income levels. The approach of this study can be used to the regional markets to find out relatively symmetric/asymmetric price transmission markets.

The market power measure can be executed to the intermediaries of the paddy producer to miller (i.e., the oligopsony power). Identifying the causes of price transmission asymmetry other than the market power (such as menu costs, production lag and inventory management, search costs associated with asymmetric information etc.) can be a good scope of further research. The procedure of this study can be used to examine the welfare implications of asymmetric price transmission in other important products in the agricultural and industrial marketing channels.

LITERATURE CITED

- ABDULAI, A. 2002. Using Threshold Co-integration to Estimate Asymmetric Price Transmission in the Swiss Pork Market. *Applied Economics*. 34: 679-687.
- ABDULAI, A. 2000. Spatial Price Transmission and Asymmetry in the Ghanaian Maize Market. *Journal of Development Studies*. 63:327-349.
- AGUIAR, D. R. D. and Santana, J. A. 2002. Asymmetry in Farm to Retail Price Transmission: Evidence for Brazil. *Agribusiness*. 18(1):37-48.
- AHMED , R. and Bernard, A. (1989). Rice Price Fluctuation and an Approach to Price Stabilization in Bangladesh. Research Report 72. Washington D.C.: International Food Policy Research Institute. <http://www.ifpri.org/publication/rice-price-fluctuation-and-approach-price-stabilization-bangladesh>
- ALAM, M. J., McKenzie, A. M., Buysse, J., Begum, I. A., Wailes, E. J. and Van Huylenbroeck, G. 2012. Measuring Market Integration in the Presence of Threshold Effect: The Case of Bangladesh Rice Markets. Annual Meeting, Seattle, Washington 124435, Agricultural and Applied Economics Association. https://ageconsearch.umn.edu/bitstream/124435/2/AAEA2012_SeattleWA_Alam%20et%20al.pdf.
- ALAM, M. J., Mckenzie, A. M., Begum, I. A., Buysse, J., Wailes, E. J. and Huylenbroeck, G. V. 2016. Asymmetry Price Transmission in the Deregulated Rice Markets in Bangladesh: Asymmetric Error Correction Model. *Agribusiness*. 32 (4):498-511.
- ALAM, M. J. and Jha, R. 2016. Asymmetric Threshold Vertical Price Transmission in Wheat and Flour Markets in Dhaka (Bangladesh): Seemingly Unrelated

- Regression Analysis. ASARC Working Papers 2016-03, The Australian National University, Australia South Asia Research Centre.
https://crawford.anu.edu.au/acde/asarc/pdf/papers/2016/WP2016_03.pdf
- ALEXANDER, C. and Wyeth, J. 1994. Co-integration and Market Integration: An Application to the Indonesian Rice Market. *Journal of Development Studies*. 30(2): 303-328.
- AL-GUDHEA, S., Kenc, T. and Dibooglu, S. 2007. Do Retail Gasoline Prices Rise More Readily Than They Fall? A Threshold Co-integration Approach. *Journal of Economics and Business*. 59(6): 560-574.
- ALLOUI, R., Aïssa, M. S. B., Hammoudeh, S. and Nguyen, D. K. 2014. Dependence and Extreme Dependence of Crude Oil and Natural Gas Prices with Applications to Risk Management. *Energy Economics*. 42: 332-342.
- ANDERS, S. M. 2008. Imperfect Competition in German Food Retailing: Evidence from State Level Data. *Atlantic Economic Journal*. 36(4): 441–454.
- ARDENI, P.G. 1989. Does the Law of One Price Really Hold for Commodity Prices? *American Journal of Agricultural Economics*. 71(3):661-669.
- ARJAN Ruijs, 2009. Welfare and Distribution Effects of Water Pricing Policies. *Environmental and Resource Economics*. 43(2):161-182.
- ATIL, A., Lahiani, A. and Nguyen, D. K. 2014. Asymmetric and Nonlinear Pass-Through of Crude Oil Prices to Gasoline and Natural Gas Prices. *Energy Policy*. 65: 567- 573.

- AYSE Ulkuhan Demir, 2015. Three Essays on the Non-Linear Dynamics Of The Finance-Growth Nexus. PhDthesis submitted to the University of Leicester.
<https://lra.le.ac.uk/bitstream/2381/36300/1/2015DemirAUPhD.pdf>
- AZZAM, A. M. 1999. Asymmetry and Rigidity in Farm-Retail Price Transmission. *American Journal of Agricultural Economics*. 81: 525-533.
- AZZAM, A. M. 1998. Competition in the US Meatpacking Industry: Is It History? *Agricultural economics*. 18(2): 107–126.
- AZZAM, A. M. 1997. Measuring Market Power and Cost-Efficiency Effects of Industrial Concentration. *The Journal of Industrial Economics*. 45(4): 377–386.
- AZZAM, A. M. and Pagoulatos, E. 1990. Testing Oligopolistic and Oligopsonistic Behavior: An Application to the US Meat-Packing Industry. *Journal of Agricultural Economics*. 41(3): 362–370.
- BACHMEIER, L. J. and Griffin, J. M. 2003. New Evidence on Asymmetric Gasoline Price Responses. *The Review of Economics and Statistics*. 85(3): 772-776.
- BACON, R. W. 1991. Rockets and Feathers: the Asymmetric Speed of Adjustment of UK Retail Gasoline Prices to Cost Changes. *Energy Economics*. 13(3): 211-218.
- BADIANE, O. and Shively, G. E. 1998. Spatial Integration, Transport Costs and the Response of Local Prices to Policy Changes in Ghana. *Journal of Development Economics*. 56 (1998): 411-431.
- BAFFES, J. 1991. Some Further Evidence on the Law of One Price: The Law of One Price Still Holds. *American Journal of Agricultural Economics*. 73 (4):1264-1273.

- BAFFES, J. and Ajwad, M. I. 2001. Identifying Price Linkages: A Review of the Literature and an Application to the World Market of Cotton. *Applied Economics*. 33 (15): 1927-1941.
- BAHMANI-OSKOOEE, M., Harvey, H. and Niroomand, F. 2018. On the Impact of Policy Uncertainty on Oil Prices: An Asymmetry Analysis. *International Journal of Financial Studies*. 6(12): 1-11. doi:10.3390/ijfs6010012.
- BAILEY, D. V. and Brorsen, B.W. 1989. Price Asymmetry in Spatial Fed Cattle Markets. *Western Journal of Agricultural Economics*. 14: 246-252.
- BAIN, J. S. 1968. *Industrial organization*. University of California, John Wiley and Sons Inc. New York.
- BAKUCS, L. Z. and Fertő, I. 2005. Marketing Margins and Price Transmission on the Hungarian Pork Meat Market. *Agribusiness*. 21 (2): 273-286.
- BALCOMBE, K.G. and Morrison, J. 2002. *Commodity Price Transmission: A Critical Review of Techniques and an Application to Selected Export Commodities*. Report to the Food and Agriculture Organization of the United Nations.
- BALKE, N. S., Brown, S. P. A. and Yücel, M. K. 1998. Crude Oil and Gasoline Prices: An asymmetric Relationship?. *Federal Reserve Bank of Dallas, Economic Review*. First Quarter: 2-11.
- BALL, L. and Mankiw, N. G. 1994. Asymmetric Price Adjustment and Economic Fluctuations. *The Economic Journal*. 104: 247-261.
- BANGLADESH-RICEPEDIA. <http://ricepedia.org/bangladesh>.

- BARRETT, C. B. and Li, J. R. 2002. Distinguishing between Equilibrium and Integration in Spatial Price Analysis. *American Journal of Agricultural Economics*. 84 (2): 292-307.
- BART, M. and Steven, K. 2000. Retail Margins, Price Transmission and Price Asymmetry in Urban Food Markets: The Case of Kinshasa (Zaire). *Journal of African Economics*. 9 (1):1-23.
- BAULCH, B. 1997. Testing for Food Market Integration Revisited. *Journal of Development Studies*. 33 (4):512-534.
- BBS, 2016. Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.
- BBS, 2011. Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.
- BDNEWS24.COM. 2014. <http://bdnews24.com/economy/2014/05/24/rice-prices-go-up>.
- BEGUM, M. E. A. and D'Haese, L. 2010. Supply and Demand Situations for Major Crops and Food Items in Bangladesh. *Journal of Bangladesh Agricultural University*. 8(1): 91–102.
- BERMINGHAM, C. and O'Brien, D. 2010. Testing for Asymmetric Pricing Behaviour in Irish and UK Petrol and Diesel Markets. Central Bank and Financial Services Authority of Ireland (Research Technical Paper).
- BHUYAN, S. and Lopez, R. A. 1997. Oligopoly Power in the Food and Tobacco Industries. *American Journal of Agricultural Economics*. 79(3): 1035–1043.

- BHUYAN, S. and Lopez, R. A. 1998. Oligopoly Power and Allocative Efficiency in US Food and Tobacco Industries. *Journal of Agricultural Economics*. 49(3): 434–442.
- BLINDER, A. 1982. Inventories and Sticky Prices: More on the Micro-foundations of Macroeconomics. *American Economic Review*. 72 (3): 365-400.
- BORENSTEIN, S., Cameron, A. C. and Gilbert, R. 1997. Do Gasoline Prices Respond Asymmetrically to Crude Oil Price Changes? *The Quarterly Journal of Economics*. 112(1): 305-339.
- BOX, G. E. P and Jenkins, G. M. 1976. *Time Series Analysis: Forecasting and Control*. Holden-Day, San Francisco.
- BOYD, M. S. and Brorsen, B. W. 1988. Price Asymmetry in the US Pork Marketing Channel. *North Central Journal of Agricultural Economics*. 10 (1):103-109.
- BRESNAHAN, T. F. 1989. Empirical Studies of Industries with Market Power. In: R. Schmalensee and R. D. Willig (eds.), *Handbook of Industrial Organization*. 2: 1011–1057. Amsterdam: Elsevier Science BV.
- BROSEN, B. W., Chavas, J. P., Grant, W. R. and Schnake, L. D. 1985. Marketing Margins and Price Uncertainty: The Case of the US Wheat Market. *American Journal of Agricultural Economics*. 67(3): 521-528.
- BROWN, S. P. A. and Yucel, M. K. 2008. What Drives Natural Gas Prices? *Energy Journal*. 29: 45-60.
- BROWN, S.P.A. and Yücel, M. K. 2000. Gasoline and Crude Oil Prices: Why the Asymmetry? *Federal Reserve Bank of Dallas, Economic and Financial Review*. Q3: 23-29.
- BRRI, 2017. *Modern Rice Cultivation*. Bangladesh Rice Research Institute. 20th Edition,

- Gazipur-1701, Bangladesh.
- BRRI, 2011. Modern Rice Cultivation. Bangladesh Rice Research Institute. 18th Edition, Gazipur-1701, Bangladesh.
- CABRAL, L. and Fishman, A. 2012. A Consumer Search Theory of Sticky Prices and Asymmetric Price Adjustment. *International Journal of Industrial Organization*. 30(4): 371-376.
- CAPPS, Jr. O. and Sherwell, P. 2007. Alternative Approaches in Detecting Asymmetry in Farm-Retail Price Transmission of Fluid Milk. *Agribusiness*. 23 (3): 313-331.
- CARLO, D. N. and Dorosh, P. A. 2003. Public Policy, Markets and Household Coping Strategies in Bangladesh: Avoiding a Food Security Crisis Following the 1998 Floods. *World Development*. 31 (7): 1221-1238.
- CBECL BD. 2014. The Rice-Milling Sector in Bangladesh is Undergoing a Change. Report: China Bangla Engineers & Consultants Ltd, September 20.
- ČECHURA, L., Kroupová, Z. Z. and Hockmann, H. 2015. Market Power in the European Dairy Industry. *AGRIS on-line Papers in Economics and Informatics*. 7 (4): 39-47.
- CLERIDES, S. 2010. Retail Fuel Price Response to Oil Price Shocks in EU Countries. *Cyprus Economic Policy Review*. 4(1): 25-45.
- COUNTRY-REPORT-BANGLADESH.
<http://unapcaem.org/Activities%20Files/A07/Country%20paper-Bangladesh.pdf>
- CUTTS, M. and Kirsten, J. 2006. Asymmetric Price Transmission and Market Concentration: An Investigation into Four South African Agro-Food Industries. *South African Journal of Economics*. 74 (2):323-333.

- DAM, 2018. Department of Agricultural Marketing, Ministry of Agriculture, Government of the Peoples' Republic of Bangladesh. <http://www.dam.gov.bd>
- DAS, J., Zohir, S. and Baulch, B. 1997. The Spatial Integration and Pricing Efficiency of the Private Sector Grain Trade in Bangladesh. Report Prepared for DFID under RNRSS Crop Post-Harvest Programme jointly by BIDS, Dhaka, Bangladesh and IDS, University of Sussex, Brighton, UK.
- DAVIDS, T., Meyer, F. and Westhoff, P. 2017. Impact of Trade Controls on Price Transmission between Southern African Maize Markets. *Agrekon*. 56(3): 223-232. DOI: 10.1080/03031853.2017.1344133.
- DAWSON, P. J. and Dey, P. K. 2002. Testing for the Law of One Price: Rice Market Integration in Bangladesh. *Journal of International Development*. 14(4): 473-484. <https://doi.org/10.1002/jid.888>
- DEMIR, A. U. 2015. Three Essays on the Non-Linear Dynamics of the Finance-Growth Nexus. PhD thesis, Department of Economics, University of Leicester, United Kingdom. <http://hdl.handle.net/2381/36300>.
- DERCON, S. 1995. On Market Integration and Liberalization: Method and Application to Ethiopia. *Journal of Development Studies*. 32 (1):112-143.
- DE SALLES, A. A. 2014. Some Evidence on the Asymmetry Between Gasoline and Crude Oil Prices in Selected Countries. *International Journal of Energy Economics and Policy*. 4(4): 670-678.
- DICKEY, D. A. and Fuller, W. A. 1979. Distribution of the Estimators for Autoregressive Time Series with a Unit Root. *Journal of the American Statistical Association*. 74 (366):427-431.

- DICKEY, D. A., Hasza, D. P. and Fuller, W. A. 1984. Testing for Unit Roots in Seasonal Time Series. *Journal of the American Statistical Association*. 79 (386): 355-67.
- DOBSON, P., Waterson, M. and Chu, A. 1998. The Welfare Consequences of The Exercise of Buyer Power. London: Office of Fair Trading. Office of Fair Trading, Research Paper 16.
- DOLADO, J. J. and Lütkepohl, H. 1996. Making Wald Tests for Co-integrated VAR Systems. *Econometric Reviews*. 15 (4):369-386.
- DORNBUSCH, R. 1987. Exchange Rates and Prices. *American Economic Review*. 77 (1):93-106.
- EKANANDA, M and Suryanto, T. (2018). The Autoregressive Distributed Lag Model to Analyze Soybean Prices in Indonesia. *MATEC Web of Conferences*, 150 (05035). <https://doi.org/10.1051/mateconf/201815005035>.
- ENDERS, W. and Granger, C. W. J. 1998. Unit Root Tests and Asymmetric Adjustment with an Example Using the Term Structure of Interest Rates. *Journal of Business and Economic Statistics*. 16 (3): 304-311.
- ENGLE, R. F. and Granger, C. W. J. 1987. Co-Integration and Error Correction: Representation, Estimation and Testing. *Econometrica*. 55 (2):251-276.
- FACKLER, P. L. and Goodwin, B. K. 2002. Spatial Price Analysis. In B. L. Gardner and G. C. Rauser, eds. *Handbook of Agricultural Economics*. Amsterdam: Elsevier Science.
- FREY, G. and Manera, M. 2007. Econometric Models of Asymmetric Price Transmission. *Journal of Economic Surveys*. 21 (2): 349-415.

- FROOT, K. A. and Klemperer, P. 1989. Exchange Rate Pass- Through When Market Share Matters. *American Economic Review*. 79 (4): 637-654.
- GAFAROVA, G., Perekhozhuk, O. and Glauben, T. 2015. Price Discrimination and Pricing-to-Market Behavior of Black Sea Region Wheat Exporters. *Journal of Agricultural and Applied Economics*. 47(3): 287–316.
- GALEOTTI, M., Lanza, A. and Manera, M. 2003. Rockets and Feathers Revisited: An International Comparison on European Gasoline Markets. *Energy Economics*. 25(2): 175–190.
- GARDNER, B. L. 1975. The Farm-Retail Price Spread in a Competitive Food Industry. *American Journal of Agricultural Economics*. 59: 399-409.
- GARDNER, B. L. and Brooks, K. M. 1994. Food Prices and Market Integration in Russia: 1992-93. *American Journal of Agricultural Economics*. 76: 641-646.
- GERVAIS, J. P. 2011. Disentangling Nonlinearities in the Long- and the Short-run Price Relationships: An Application to the US Hog/Pork Supply Chain. *Applied Economics*. 43(12): 1497-1510.
- GHAFFAR, A. 2013. Probability Sampling Techniques.
<https://www.slideshare.net/azamghaffar/probability-sampling-techniques>.
- GOLETTI, F. and Babu, S. 1994. Market Liberalization and Integration of Maize Markets in Malawi. *Agricultural Economics*. 11 (2-3): 311-324.
- GOLETTI, F., Ahmed, R. and Farid, N. 1995. Structural Determinants of Market Integration: The Case of Rice Markets in Bangladesh. *The Developing Economies*. 33(2): 185-202. DOI: 10.1111/j.1746-1049.1995.tb00713.x
- GÓMEZ, M. I., Richards, T. J. and Lee, J. 2013. Trade Promotions and Consumer Search

- in Supermarket Retailing. *American Journal of Agricultural Economics*. 95 (5): 1209-1215.
- GOODWIN, B. K. and Harper, D. C. 2000. Price Transmission, Threshold Behavior and Asymmetric Adjustment in the U.S. Pork Sector. *Journal of Agricultural and Applied Economics*. 32: 543-553.
- GOODWIN, B. K. and Holt, M. T. 1999. Price Transmission and Asymmetric Adjustment in the US Beef Sector. *American Journal of Agricultural Economics*. 81(3): 630-637.
- GRANGER, C. W. J. 1969. Investigating Causal Relations by Econometric Models and Cross Spectral Methods. *Econometrica*. 37 (3): 424-438.
- GRANGER, C. W. J. 1988. Some Recent Development in a Concept of Causality. *Journal of Econometrics*. 39 (1-2): 199-211.
- GRANGER, C. W. J. and Lee, T. H. 1989. Investigation of Production, Sales and Inventory Relationships Using Multi co-integration and Non-Symmetric Error Correction Models. *Journal of Applied Econometrics*. 4:145-159.
- GRASSO, M. and Manera, M. 2007. Asymmetric Error Correction Models for the Oil-Gasoline Price Relationship. *Energy Policy*. 35(1):156-177.
- GRIGORIOS, V. 2016. Asymmetric Pass Through of Oil Prices to Gasoline and Natural Gas Prices. MS thesis, International Hellenic University, Greece. <https://repository.ihu.edu.gr/xmlui/handle/11544/15183>.
- GUJARATI, D. N. 2004. *Basic Econometrics*(4th ed.), Boston: McGraw-Hill.
- HAHN, W. F. 1990. Price Transmission Asymmetry in Pork and Beef Markets. *The Journal of Agricultural Economics Research*. 42(4): 21-30.

- HARRISS, B. 1979. There is Method in My Madness: or It Is Vice-Versa? Measuring Agricultural Market Performance. *Food Research Institute Studies*. 17(2): 197-218.
- HAUSMAN, J. A. 1981. Exact Consumer's Surplus and Deadweight Loss. *The American Economic Review*. 71(4): 662-676.
- HONARVAR, A. 2009. Asymmetry in Retail Gasoline and Crude Oil Price Movements in The United States: An Application of Hidden Co-integration Technique. *Energy Economics*. 31(3): 395-402.
- HOSSAIN, M. I. and Verbeke, W. 2010. Evaluation of Rice Markets Integration in Bangladesh. *The Lahore Journal of Economics*. 15(2): 77-96.
<http://hdl.handle.net/1854/LU-1101918>.
- HOUCK, J. P. 1977. An Approach to Specifying and Estimating Nonreversible Functions. *American Journal of Agricultural Economics*. 59 (3): 570-572.
- HUDA, F. A. 2014. Process of Global Shocks Transmission to Domestic Food Price Level: Case of Bangladesh. *International Journal of Food and Agricultural Economics*. 2(2): 97-112.
<https://ageconsearch.umn.edu/bitstream/168584/2/vol2.no2.pp97.pdf>
- HYDE, C. E. and Perloff, J. M. 1995. Can Market Power Be Estimated? Review of *Industrial Organization*. 10 (4): 465-485.
- IBRAHIM, M. H. 2015. Oil and Food Prices in Malaysia: A Nonlinear ARDL Analysis. *Agricultural and Food Economics*. 3(2): 1-14. <https://doi.org/10.1186/s40100-014-0020-3>.

- IQBAL, M. Z. and Babcock, B. A. 2016. Transmission of Global Commodity Prices to Domestic Producer Prices: A Comprehensive Analysis. Economics Presentations, Posters and Proceedings. 33. http://lib.dr.iastate.edu/econ_las_conf/33.
- JAYANTA, D., Sajjad, Z. and Baulch, B. 1997. The Spatial Integration and Pricing Efficiency of the Private Sector Grain Trade in Bangladesh. Report Prepared for DFID under RNRSS Crop Post-harvest Programme jointly by BIDS, Dhaka, Bangladesh and IDS, University of Sussex, Brighton, UK.
- JIMÉNEZ-RODRÍGUEZ, R. and Sánchez, M. 2004. Oil Price Shocks and Real GDP Growth: Empirical Evidence for Some OECD Countries. *Applied Economics*. 37(2): 201- 228.
- JOHANSEN, S. 1988. Statistical Analysis of Co-integration Vectors. *Journal of Economic Dynamics and Control*. 12: 231-254.
- JOHANSEN, S. and Juselius, K. 1990. Maximum Likelihood Estimation and Inference on Co-integration-with Applications to the Demand for Money. *Oxford Bulletin of Economics and Statistics*. 52 (2):169-210.
- JOHANSEN, S. 1991. Estimation and Hypothesis Testing of Co-integration Vectors in Gaussian Vector Autoregressive Models. *Econometrica*. 59(6): 1551-1580.
- JOHANSEN, S. 1995. Likelihood-Based Inference in Co-integrated Vector Autoregressive Models. In *Advanced Texts in Econometrics*, Oxford: Oxford University Press.
- KADITI, E. A. 2011. Market Dynamics in Supply Chains: The Impact of Globalization and Consolidation on Food Companies' Mark-Ups. LICOS Centre for Institutions and Economic Performance, discussion paper 273.

- KALANTZI, M. A. 2013. Measuring Market Power in the Greek Manufacturing Industry with Emphasis in the Food Industry. PhD thesis: Department of Business Administration of Food and Agricultural Enterprises, University of Patras, Greece.
- KARANTININIS, K., Katrakyliadis, K. and Persson, M. 2011. Price Transmission in the Swedish Pork Chain: Asymmetric Non Linear ARDL. <http://www.agro.auth.gr/etagro/12o-synedrio/19.pdf>.
- KARRENBROCK, J. D. 1991. The Behavior of Retail Gasoline Prices: Asymmetric or not? Federal Reserve Bank of St. Louis. 73: 19–29.
- KINNUCAN, H. W. and Forker, O. D. 1987. Asymmetry in Farm-Retail Price Transmission for Major Dairy Products. American Journal of Agricultural Economics. 69(2): 285-292.
- KOONTZ, S. R. and Garcia, P. 1997. Meat-Packer Conduct in Fed Cattle Pricing: Multiple-Market Oligopsony Power. Journal of Agricultural and Resource Economics. 22(1): 87–103.
- KOVENOCK, D. and Widdows, K. 1998. Price Leadership and Asymmetric Price Rigidity. European Journal of Political Economy. 14(1): 167-187.
- KRUGMAN, P. 1986. Pricing to Market When the Exchange Rate Changes. NBER Working Paper No. 1926.
- KUIPER, W.E., Lutz, C. and Van Tilburg, A. 2003. Vertical Price Leadership on Local Maize Markets in Benin. Journal of Development Economics. 71:417-433.

- KUMBHAKAR, S. C., Baardsen, S. and Lien, G. 2012. A New Method for Estimating Market Power with an Application to Norwegian Sawmilling. *Review of Industrial Organization*. 40(2): 109-129.
- LACHEHEB, M. and Sirag, A. 2016. Oil Price and Inflation in Algeria: A nonlinear ARDL Approach. *Topics in Middle Eastern and African Economies* 18 (2): 45-60. https://www.dohainstitute.edu.qa/MEEA2016/Downloads/Miloud%20Lacheheb_Final.pdf
- LANDES, W. and Posner, R. 1981. Market Power in Antitrust Cases. *Harvard Law Review*. 94: 937-996. <http://dx.doi.org/10.2307/1340687>.
- LEWIS, M. 2004. Asymmetric Price Adjustment and Consumer Search: An Examination of the Retail Gasoline Market. Competition Policy Center. <https://escholarship.org/uc/item/9pv2d9fn>
- L'OEILETT, G. and Lantz, F. 2009. Crude Oil Prices and Retail Prices: Is there an Asymmetric Transmission? Application for France and Germany. 10th IAEE European Conference Energy, Policies and Technologies for Sustainable Economies.
- LOPEZ, R. A., Zheng, H. and Azzam, A. 2015. Oligopoly Power in the Food Industries Revisited: A Stochastic Frontier Approach. Paper presented at the Agricultural & Applied Economics Association's 2015 AAEA & WAEA Joint Annual Meetings, San Francisco, California, 1-11.
- MACCINI, L. J. 1978. The Impact of Demand and Price Expectations on the Behavior of Prices. *The American Economic Review*. 68(1): 134-145.
- MEYER, J., and Von Cramon-Taubadel, S. 2004. Asymmetric Price Transmission: A

- Survey. *Journal of Agricultural Economics*. 55(3): 581-611.
- McNEW, K. 1996. Spatial Market Integration: Definition, Theory and Evidence. *Agricultural and Resource Economic Review*. 25(1): 1-11.
- McNEW, K. and Fackler, P. L. 1997. Testing Market Equilibrium: Is Co-integration Informative? *Journal of Agricultural and Resource Economics*. 22(2): 191-207.
- MOHANTY, S., Peterson, E. W. F. and Kruse, N. C. 1995. Price Asymmetry in the International Wheat Market. *Canadian Journal of Agricultural Economics*. 43(3): 355-366.
- MORRISON PAUL, C. J. 2001 Market and cost structure in the U.S. beef packing industry: a plant-level analysis. *American Journal of Agricultural Economics*. 83(1): 64-76.
- MOSCONI, R. and Giannini, C. 1992. Non-causality in Cointegrated Systems: Representation, Estimation and Testing. *Oxford Bulletin of Economics and Statistics*. 54(3): 399-417.
- MUNDLAK, Y. and Larson, D. F. 1992. On the Transmission of World Agricultural Prices. *The World Bank Economic Review*. 6: 399-422.
- MURSHID, K. A. S. and Yunus, M. 2016. Rice Prices and Growth and Poverty Reduction in Bangladesh. *Research Almanac, Bangladesh Institute of Development Studies*. http://bids.org.bd/uploads/events/TS_3_M%20Yunus.pdf.
- MUTH, M. K. and Wohlgenant, M. K. 1999. Measuring The Degree Of Oligopsony Power In The Beef Packing Industry In The Absence Of Marketing Input Quantity Data. *Journal of Agricultural and Resource Economics*. 24(2): 299-312. <https://ageconsearch.umn.edu/bitstream/30795/1/24020299.pdf>

- NEVO, A. 2001. Measuring Market Power in the Ready-to-Eat Cereal Industry. *Econometrica*. 69(2):307-342.
- NINNO, C. D., and Dorosh, P. and Smith, L.C. 2003. Public policy, Markets and Household Coping Strategies in Bangladesh: Avoiding a Food Security Crisis Following the 1998 Floods. *World Development*. 31 (7): 1221-1238.
- NSABIMANA, A. and Habimana, O. 2017. Asymmetric Effects of Rainfall on Food Crop Prices: Evidence from Rwanda. *Environmental Economics*. 8(3): 137-149. doi:10.21511/ee.08(3-1).2017.06
- O'DONNELL, C. J., Griffith, G. R., Nightingale, J. J. and Piggott, R. R. 2007. Testing for Market Power in the Australian Grains and Oilseeds Industries. *Agribusiness*. 23(3): 349–376.
- OHKAWA, K. 1956. Economic Growth and Agriculture. *Annals Hitotsubashi Academy*. 45-60.
- OSEI-ASARE, Y. B. and Eghan, M. 2013. Food Price Inflation and Consumer Welfare in Ghana. *International Journal of Food and Agricultural Economics*. 1(1): 27-39. <https://ageconsearch.umn.edu/bitstream/156140/2/27.pdf>
- PALASKAS, T. B. 1995. Statistical Analysis of Price Transmission in the European Union. *Journal of Agricultural Economics*. 46(1): 61-69.
- PALASKAS, T. B. and Harriss-white, B. 1993. Testing Market Integration: New Approaches with Case Material from the West Bengal Food Economy. *Journal of Development Studies*. 30(1):1-57.
- PALL, Z., Perekhozhuk, O., Glauben, T., Prehn, S. and Teuber, R. 2014. Residual Demand Measures of Market Power of Russian Wheat Exporters. *Agricultural*

- Economics. 45(3): 381–391.
- PANAGITOU, D. and Stavrakoudis, A. 2016. A Stochastic Frontier Estimator of the Aggregate Degree of Market Power Exerted by the U.S. Beef and Pork Packing Industries. Department Of Economics, University Of Ioannina. Mpra Paper No. 76136. <https://mpra.ub.uni-muenchen.de/76136/>.
- PAL, D. and Mitra, S. K. 2016. Asymmetric Oil Product Pricing in India: Evidence from A Multiple Threshold Nonlinear ARDL Model. *Economic Modelling*, 59(C): 314-328. DOI: 10.1016/j.econmod.2016.08.003.
- PAUL, C. J. M. 1999. Scale Effects and Mark-ups in the US Food and Fibre Industries: Capital Investment and Import Penetration Impacts. *Journal of Agricultural Economics*. 50(1): 64-82.
- PELTZMAN, S. 2000. Prices Rise Faster than They Fall. *Journal of Political Economy*. 108(3): 466-502.
- PERDIGUERO-GARCÍA, J. 2010. Symmetric or Asymmetric Gasoline Prices? A Meta-Analysis Approach. *Institut de Recerca en Economia Aplicada Regional i Pública*, 1-34. http://www.ub.edu/irea/working_papers/2010/201013.pdf
- PEREKHOZHUK, O., Hockmann, H., Ferto, I. and Bakucs, L. Z. 2013. Identification of Market Power in the Hungarian Dairy Industry: A Plant-Level Analysis. *Journal of Agricultural & Food Industrial Organization*. 11(1): 1–13.
- PEREKHOZHUK, O., Glauben, T., Teuber, R. and Grings, M. 2015. Regional-Level Analysis of Oligopsony Power in the Ukrainian Dairy Industry. *Canadian Journal of Agricultural Economics*. 63(1): 43–76.
- PEREKHOZHUK, O., Glauben, T., Grings, M. and Teuber, R. 2017. Approaches and

- Methods for the Econometric Analysis of Market Power: A Survey and Empirical Comparison. *Journal of Economic Surveys*. 31(1): 303–325.
- PESARAN, M. H., Shin, Y. and Smith, R. J. 2001. Bounds Testing Approaches to the Analysis of Level Relationships. *Journal of Applied Econometrics*. 16(3): 289-326.
- PESARAN, M. H. and Shin, Y. 1999. An Autoregressive Distributed Lag Modeling Approach to Co-integration Analysis. In S. Strøm (Ed.), *Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium*. Cambridge University Press, Cambridge.
- PHILLIPS, P. C. B. and Perron, P. 1988. Testing for a Unit Root in Time Series Regression. *Biometrika*. 75(2): 335-346.
- PRAKASH, A. 1998. The Transmission of Signals in a Decentralized Commodity Marketing System: The Case of the UK Pork Market. Unpublished Ph.D. Thesis, University of London.
- PRAKASH, A., Oliver IV, E. H. D'A. and Balcombe, K. 2001. Does Building New Roads Really Create Extra Traffic? Some New Evidence. *Applied Economics*. 33(12):1579-1585.
- QUAGRAINIE, K., Unterschultz, J., Veeman, M. and Scott, J. 2003. Testing for Processor Market Power in the Markets for Cattle and Hogs in Canada. *Canadian Journal of Agricultural Economics*. 51(3): 397–411.
- QUIROZ, J. A. and R. Soto 1996. International Price signals in agricultural markets: do governments care? Unpublished mimeo, GERENS and ILADES/Georgetown University.

- RADCHENKO, S. 2005a. Lags in the Response of Gasoline Prices to Changes in Crude Oil Prices: The Role of Short-Term and Long-Term Shocks. *Energy Economics*. 27(4): 573–602.
- RADCHENKO, S. 2005b. Oil Price Volatility and the Asymmetric Response of Gasoline Prices to Oil Price Increases and Decreases. *Energy Economics*. 27(5): 708-730.
- RAHA, S. K., Moniruzzaman, M., Alam, M. M. and Awal, M. A. 2012. Structure, Conduct and Performance of the Rice Market and the Impact of Technological Changes in Milling. Institute of Agribusiness and Development Studies (IADS) Bangladesh Agricultural University, Mymensingh.
- RAPSOMANIKIS, G. Hallam, D. and Conforti, P. 2006. Market Integration and Price Transmission in Selected Food and Cash Crop Markets of Developing Countries: Review and Application. Food and Agriculture Organization.
- RAVALLION, M. 1986. Testing market integration, *American Journal of Agricultural Economics*. 68(2): 292-307.
- REAGAN, P. B. and Weitzman, M. L. 1982. Asymmetries in Price and Quantity Adjustments by the Competitive Firm. *Journal of Economic Theory*. 27: 410- 420.
- REZITI, I. and Panagopoulos, Y. 2008. Asymmetric Price Transmission in the Greek Agri-Food Sector: Some Tests. *Agribusiness*.24(1): 16–30.
- RUIJS, A. 2009. Welfare and Distribution Effects of Water Pricing Policies. *Environmental and Resource Economics*. 43(2): 161-182. DOI: 10.1007/s10640-008-9228-6

- SABUR, S. A. 1990. Production and Price Behaviour of Vegetables in Bangladesh. Bangladesh Journal of Agricultural Economics. 13(2): 81-91.
http://ageconsearch.umn.edu/bitstream/207873/2/Resear_01%20Vol-XIII.pdf
- SABUR and Raha 2014. Impact of Automatic Rice Milling on Performance of Marketing System. Report: the Daily Star, November 09, 2014.
- SAID, S. E. and Dickey, D. A. 1984. Testing for Unit Roots in Autoregressive Moving Average Model of Unknown Order. Biometrika. 71(3): 599-607.
- SANTERAMO, F. G. and von Cramon-Taubadel, S. 2016. On Perishability and Vertical Price Transmission: Empirical Evidences from Italy. Bio-based and Applied Economics 5(2): 199-214. <http://dx.doi.org/10.13128/BAE-18043>
- SAPKOTA, P., Dey, M. M., Aam, M. F. and Singh, K. 2015. Price Transmission Relationships along the Seafood Value Chain in Bangladesh: Aquaculture and Capture Fisheries. Aquaculture Economics and Management. 19 (1): 82-103.
<https://doi.org/10.1080/13657305.2015.994237>
- SCHERER, F.M. and Ross, D. 1990. Industrial Market Structure and Economic Performance (3rd ed.). Boston: Houghton Mifflin.
- SCHROETER, J. R. 1988. Estimating the Degree of Market Power in the Beef Packing Industry. The Review of Economics and Statistics. 70(1): 158–162.
- SCHROETER, J. and Azzam, A. 1990. Measuring Market Power in Multi-Product Oligopolies: The US Meat Industry. Applied Economics. 22(10): 1365–1376.
- SCHROETER, J.R., and Azzam, A. 1991. Marketing Margins, Market Power, and Price Uncertainty. American Journal of Agricultural Economics. 73(4): 990-999.
- SERLETIS, A. and Rangel-Ruiz, R. 2004. Testing for Common Features in North

- American Energy Markets. *Energy Economics*, 26(3): 401-414.
- SEXTON, R. J., Kling, C.L. and Carman, H. F. 1991. Market Integration, Efficiency of Arbitrage and Imperfect Competition: Methodology and Application to US Celery. *American Journal of Agricultural Economics*. 73(3): 568-580.
- SHARMA, R. 2002. The Transmission of World Price Signals: Concepts, Issues and Some Evidence from Asian Cereal Markets. Paper Submitted to the OECD Global Forum on Agriculture, OECD CCNM/GF/AGR(2002)10.
- SHIN, D. 1994. Do Product Prices Respond Symmetrically to Changes in Crude Prices? *OPEC Review*. 18(2): 137–157.
- SHIN, H. S. 2009. Securitisation and Financial Stability. *The Economic Journal*. 119(536): 309-332.
- SHIN, Y., Yu, B. and Greenwood-Nimmo, M. 2014. Modelling Asymmetric Co-integration and Dynamic Multipliers in a Nonlinear ARDL Framework. In *Festschrift in honor of Peter Schmidt: Econometric methods and applications*, edited by W. C. Horrace and R. C. Sickles. New York: Springer Science and Business Media, 281-314.
- SHIN, Y., Yu, B. and Greenwood-Nimmo, M. 2013. Modelling Asymmetric Co-integration and Dynamic Multipliers in A Nonlinear ARDL Framework. *The Festschrift in Honor of Peter Schmidt*. 44(0): 1-35.
- STREATFIELD, P. K and Karar, Z. A. 2008. Population Challenges for Bangladesh in the Coming Decades. *Journal of Health Population and Nutrition*. 26(3): 261-272.
- TAPPATA, M. 2009. Rockets and Feathers: Understanding Asymmetric Pricing. *RAND Journal of Economics*. 40(4): 673-687.

- TASLIM, M. and Hossain, M. A. 2015. Asymmetric Transmission of International Price of Edible Oil in Bangladesh. *Bangladesh Development Studies*. 38(1): 33-54.
[http://bids.org.bd/uploads/publication/BDS/38/38-1 ... 20International-.pdf](http://bids.org.bd/uploads/publication/BDS/38/38-1...20International-.pdf)
- TIFFIN, R and Dawson, P. J. 2000. Structural Breaks, Cointegration and the Farm-retail Price Spread for Lamb. *Applied Economics*. 32(10):1281-1286.
- TOMEK, W. G., and Robinson, K. L. 1990. *Agricultural Product Prices*. Third edition, Ithaca, NY: Cornell University Press.
- VALADKHANI, A. 2013. Do Petrol Prices Rise Faster than They Fall When the Market Shows Significant Disequilibria? *Energy Economics*. 39: 66-80.
- VAN CAMPENHOUT, B. 2007. Modeling Trends in Food Market Integration: Method and Application to Tanzanian Maize Markets. *Food Policy*. 32(1): 112-127.
- VARTIA, Y.O. 1983. Efficient Methods of Measuring Welfare Change and Compensated Income in Terms of Ordinary Demand Functions. *Econometrica*. 51(1): 79-98.
- VAVRA, P. and Goodwin, B. K. 2005. Analysis of Price Transmission Along the Food Chain. *OECD Food, Agriculture, and Fisheries Working Papers No. 3*, OECD Publishing. doi:10.1787/752335872456.
- VILLAR, J. A. and Joutz, F. L. 2006. The Relationship Between Crude Oil and Natural Gas Prices. *Energy Information Administration*, 1-43.
http://www.uprm.edu/aceer/pdfs/CrudeOil_NaturalGas.pdf
- VON CRAMON-TAUBADEL, S., and Loy, J.P. 1996. Price Asymmetry in the International Wheat Market: Comment. *Canadian Journal of Agricultural Economics*. 44(3): 311-317.
- VON CRAMON-TAUBADEL, S. 1998. Estimating Asymmetric Price Response with the

- Error Correction Representation: An Application to the German Pork Market. *European Review of Agricultural Economics*. 25(1): 1-18.
- VON CRAMON-TAUBADEL, S. and Loy, J.P. 1999. The Identification of Asymmetric Price Transmission Processes with Integrated Time Series. *Jahrbücher für Nationalökonomie und Statistik*. 218(1): 86-106.
- VOUZAVALIS Grigorios, 2016. Asymmetric Pass Through of Oil Prices to Gasoline and Natural Gas Prices. MS thesis submitted to International Hellenic University, Greece.
- <https://repository.ihu.edu.gr/xmlui/bitstream/handle/11544/15183/G.%20Vouzavalis.pdf?sequence=1>
- WANN, J. J. and Sexton, R. J. 1992. Imperfect Competition in Multiproduct Food Industries with Application to Pear Processing. *American Journal of Agricultural Economics*. 74(4): 980-990.
- WARD, C. E. 2010. Assessing Competition in the US Beef Packing Industry. *Choices*. 25(2):1-14.
- WARD, R. W. 1982. Asymmetry in Retail, Wholesale and Shipping Point Pricing for fresh Vegetables. *American Journal of Agricultural Economics*. 62: 205-212.
- WELIWITA, A. and Azzam, A. 1996. Identifying Implicit Collusion Under Declining Output Demand. *Journal of Agricultural and Resource Economics*. 21(2): 235–246.
- WILLETT, L. S., Hansmire, M. R. and Bernard, J. C. 1997. Asymmetric Price Response Behavior of Red Delicious Apples. *Agribusiness*. 13(6): 649-658.

- WILLIG, R. D. 1976. Consumer's Surplus without Apology. *American Economic Review*. 66(4):589-597.
- WOHLGENANT, M. K. 1999. Product Heterogeneity and the Relationship between Retail and Farm Prices. *European Review of Agricultural Economics*. 26 (2):219-227.
- YAMANE, T. 1973. *Statistics: An Introductory Analysis* (3rd ed.). New York: Harper & Row.
- ZANIAS, G. P. 1993. Testing for Integration in European Community Agricultural Product Markets. *Journal of Agricultural Economics*. 44 (3):418-427.
- ZHANG, P., Fletcher, S. M. and Carley, D. H. 1995. Peanut Price Transmission Asymmetry in Peanut Butter. *Agribusiness*. 11(1):13-20.
- ZHENG, S. 2004. Measuring the Welfare Impact of Asymmetric Price Transmission on United States Food Consumers. PhD Thesis, Purdue University.
- ZHENG, S., Miller, D. J. and Fukuda, S. 2010. Measuring the Welfare Impact of Asymmetric Price Transmission. *Journal of the Faculty of Agriculture, Kyushu University*. 55(1): 181-189.
- ZULFIQAR, M., Waheed, A. and Chishti, A. F. 2012. Implications of Liberalization of Trade on Economic Welfare of Producers and Consumers of Basmati Rice. *Institutions and Economies*. 4(1):1-20.

APPENDICES

Appendix A: BIRRI released rice varieties in Bangladesh

Variety	Release Year	Season	Variety	Release Year	Season
BR1	1970	Aus/Boro	BIRRI Dhan45	2005	Boro
BR2	1971	Aus/Boro	BIRRI Dhan46	2007	Aman
BR3	1973	Aus/Aman/Boro	BIRRI Dhan47	2007	Boro
BR4	1975	Aman	BIRRI Dhan48	2008	Aus
BR5	1976	Aman	BIRRI Dhan49	2008	Aman
BR6	1977	Aus/Boro	BIRRI Dhan50	2008	Boro
BR7	1977	Aus/Boro	BIRRI Dhan51	2010	Aman
BR8	1978	Aus/Boro	BIRRI Dhan52	2010	Aman
BR9	1978	Aus/Boro	BIRRI Dhan53	2010	Aman
BR10	1980	Aman	BIRRI Dhan54	2010	Aman
BR11	1980	Aman	BIRRI Dhan55	2011	Aus/Boro
BR12	1983	Aus/Boro	BIRRI Dhan56	2011	Aman
BR14	1983	Aus/Boro	BIRRI Dhan57	2011	Aman
BR15	1983	Aus/Boro	BIRRI Dhan58	2012	Boro
BR16	1983	Aus/Boro	BIRRI Dhan59	2013	Boro
BR17	1985	Boro	BIRRI Dhan60	2013	Boro
BR18	1985	Boro	BIRRI Dhan61	2013	Boro
BR19	1985	Boro	BIRRI Dhan62	2013	Aman
BR20	1986	Aus	BIRRI Dhan63	2014	Boro
BR21	1986	Aus	BIRRI Dhan64	2014	Boro
BR22	1988	Aman	BIRRI Dhan65	2014	Aus
BR23	1988	Aman	BIRRI Dhan66	2014	Aman
BR24	1992	Aus	BIRRI Dhan67	2014	Boro
BR25	1992	Aman	BIRRI Dhan68	2014	Boro
BR26	1993	Aus	BIRRI Dhan69	2014	Boro
BIRRI Dhan27	1994	Aus	BIRRI Dhan70	2015	Aman
BIRRI Dhan28	1994	Boro	BIRRI Dhan71	2015	Aman
BIRRI Dhan29	1994	Boro	BIRRI Dhan72	2015	Aman
BIRRI Dhan30	1994	Aman	BIRRI Dhan73	2015	Aman
BIRRI Dhan31	1994	Aman	BIRRI Dhan74	2015	Boro
BIRRI Dhan32	1994	Aman	BIRRI Dhan75	2016	Aman
BIRRI Dhan33	1997	Aman	BIRRI Dhan76	2016	Aman
BIRRI Dhan34	1997	Aman	BIRRI Dhan77	2016	Aman
BIRRI Dhan35	1998	Boro	BIRRI dhan78	2016	Aman
BIRRI Dhan36	1998	Boro	BIRRI dhan79	2017	Aman
BIRRI Dhan37	1998	Aman	BIRRI dhan80	2017	Aman
BIRRI Dhan38	1998	Aman	BIRRI Hyb Dhan1	2001	Boro
BIRRI Dhan39	1999	Aman	BIRRI Hyb Dhan2	2008	Boro
BIRRI Dhan40	2003	Aman	BIRRI Hyb Dhan3	2009	Boro
BIRRI Dhan41	2003	Aman	BIRRI Hyb Dhan4	2010	Aman
BIRRI Dhan42	2004	Aus	BIRRI Hyb Dhan5	2016	Boro
BIRRI Dhan43	2004	Aus	BIRRI Hyb Dhan6	2017	Aman
BIRRI Dhan44	2005	Aman			

Note: Hyb=Hybrid

Source: Bangladesh Rice Research Institute (<http://www.brri.gov.bd>).

Appendix B: Rice area and production in Bangladesh

Year	Rice area (000' Ha)	Rice production (000' ton)	Year	Rice area (000' Ha)	Rice production (000' ton)
1972	9278.7	9774	1994	10073.5	18041.6
1973	9646.4	9901	1995	9921.46	16833.4
1974	10049.3	11720	1996	9941.82	17686.6
1975	9790.2	11109	1997	10177.37	18881
1976	10327.7	12560	1998	10262.89	18861.7
1977	9877.7	11569	1999	10116.43	19904.6
1978	10026.6	12764	2000	10708.08	23067
1979	10111.5	12645	2001	10797.03	25085.5
1980	10157.4	12539	2002	10660.74	24300
1981	10307	13883	2003	10770.67	25191.3
1982	10457.6	13631	2004	10823.69	26189.4
1983	10583.9	14129	2005	10368.39	25156.1
1984	10546.6	14415	2006	10529.09	26530.3
1985	10222.2	14622	2007	10571.43	27318
1986	10397	15041	2008	10574.67	28931
1987	10607.7	15407	2009	11279.64	31317
1988	10321.3	15414	2010	11353.71	31975
1989	10222.56	15544	2011	11528.51	33539.82
1990	10411.1	17710	2012	11528	33914
1991	10430.5	17785	2013	11423	33833
1992	10243.1	18255	2014	11371	34356.3
1993	10177.7	18341	2015	11421	34861.2

Source: BBS, 2016

Appendix C: ADF test results of farm price

Null Hypothesis: LFARM has a unit root

Exogenous: Constant

Lag Length: 1 (Automatic - based on SIC, maxlag=13)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.890634	0.3359
Test critical values: 1% level	-3.477835	

5% level	-2.882279
10% level	-2.577908

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(LFARM)

Method: Least Squares

Date: 03/25/18 Time: 12:43

Sample (adjusted): 2005M12 2017M06

Included observations: 139 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LFARM(-1)	-0.035296	0.018669	-1.890634	0.0608
D(LFARM(-1))	0.326705	0.080789	4.043939	0.0001
C	0.231736	0.118604	1.953865	0.0528
R-squared	0.119869	Mean dependent var		0.011950
Adjusted R-squared	0.106926	S.D. dependent var		0.104416
S.E. of regression	0.098676	Akaike info criterion		-1.772603
Sum squared resid	1.324226	Schwarz criterion		-1.709269
Log likelihood	126.1959	Hannan-Quinn criter.		-1.746866
F-statistic	9.261200	Durbin-Watson stat		2.036018
Prob(F-statistic)	0.000170			

Null Hypothesis: D(LFARM) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=13)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-8.501466	0.0000
Test critical values:		
1% level	-3.477835	
5% level	-2.882279	
10% level	-2.577908	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(LFARM,2)

Method: Least Squares

Date: 03/25/18 Time: 12:44

Sample (adjusted): 2005M12 2017M06

Included observations: 139 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LFARM(-1))	-0.689388	0.081091	-8.501466	0.0000
C	0.008067	0.008508	0.948067	0.3448

R-squared	0.345359	Mean dependent var	-0.000551
Adjusted R-squared	0.340580	S.D. dependent var	0.122652
S.E. of regression	0.099599	Akaike info criterion	-1.761048
Sum squared resid	1.359031	Schwarz criterion	-1.718825
Log likelihood	124.3928	Hannan-Quinn criter.	-1.743890
F-statistic	72.27492	Durbin-Watson stat	2.020479
Prob(F-statistic)	0.000000		

Appendix D: Phillips-Perron test result of Lfarm price

Null Hypothesis: LFARM has a unit root

Exogenous: Constant

Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.986433	0.2926
Test critical values:	1% level	-3.477487	
	5% level	-2.882127	
	10% level	-2.577827	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.010607
HAC corrected variance (Bartlett kernel)	0.020989

Phillips-Perron Test Equation

Dependent Variable: D(LFARM)

Method: Least Squares

Date: 03/25/18 Time: 12:46

Sample (adjusted): 2005M11 2017M06

Included observations: 140 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LFARM(-1)	-0.028580	0.019237	-1.485727	0.1396
C	0.193502	0.122201	1.583467	0.1156

R-squared	0.015744	Mean dependent var	0.012412
Adjusted R-squared	0.008611	S.D. dependent var	0.104184
S.E. of regression	0.103734	Akaike info criterion	-1.679791
Sum squared resid	1.484982	Schwarz criterion	-1.637768
Log likelihood	119.5854	Hannan-Quinn criter.	-1.662714
F-statistic	2.207386	Durbin-Watson stat	1.358793
Prob(F-statistic)	0.139632		

Null Hypothesis: D(LFARM) has a unit root

Exogenous: Constant

Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-8.534575	0.0000

Test critical values:	1% level	-3.477835
	5% level	-2.882279
	10% level	-2.577908

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.009777
HAC corrected variance (Bartlett kernel)	0.010016

Phillips-Perron Test Equation

Dependent Variable: D(LFARM,2)

Method: Least Squares

Date: 03/25/18 Time: 12:46

Sample (adjusted): 2005M12 2017M06

Included observations: 139 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LFARM(-1))	-0.689388	0.081091	-8.501466	0.0000
C	0.008067	0.008508	0.948067	0.3448
R-squared	0.345359	Mean dependent var		-0.000551
Adjusted R-squared	0.340580	S.D. dependent var		0.122652
S.E. of regression	0.099599	Akaike info criterion		-1.761048
Sum squared resid	1.359031	Schwarz criterion		-1.718825
Log likelihood	124.3928	Hannan-Quinn criter.		-1.743890
F-statistic	72.27492	Durbin-Watson stat		2.020479
Prob(F-statistic)	0.000000			

Appendix E: ADF test of Lwholesale price

Null Hypothesis: LWHOLESALE has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=13)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.542274	0.5094
Test critical values:		
	1% level	-3.477487
	5% level	-2.882127
	10% level	-2.577827

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(LWHOLESALE)

Method: Least Squares

Date: 03/25/18 Time: 12:47

Sample (adjusted): 2005M11 2017M06

Included observations: 140 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LWHOLESALE(-1)	-0.025003	0.016212	-1.542274	0.1253

C	0.269371	0.162044	1.662336	0.0987
R-squared	0.016944	Mean dependent var		0.020128
Adjusted R-squared	0.009821	S.D. dependent var		0.141284
S.E. of regression	0.140588	Akaike info criterion		-1.071780
Sum squared resid	2.727577	Schwarz criterion		-1.029757
Log likelihood	77.02463	Hannan-Quinn criter.		-1.054703
F-statistic	2.378608	Durbin-Watson stat		1.703810
Prob(F-statistic)	0.125297			

Null Hypothesis: D(LWHOLESALE) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-10.16235	0.0000
Test critical values:	1% level	-3.477835	
	5% level	-2.882279	
	10% level	-2.577908	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(LWHOLESALE,2)

Method: Least Squares

Date: 03/25/18 Time: 12:48

Sample (adjusted): 2005M12 2017M06

Included observations: 139 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LWHOLESALE(-1))	-0.859553	0.084582	-10.16235	0.0000
C	0.017767	0.012060	1.473241	0.1430
R-squared	0.429816	Mean dependent var		0.000796
Adjusted R-squared	0.425654	S.D. dependent var		0.185809
S.E. of regression	0.140816	Akaike info criterion		-1.068436
Sum squared resid	2.716608	Schwarz criterion		-1.026213
Log likelihood	76.25629	Hannan-Quinn criter.		-1.051278
F-statistic	103.2735	Durbin-Watson stat		2.012562
Prob(F-statistic)	0.000000			

Appendix F: Phillips-Perron test of Lwholesale price

Null Hypothesis: LWHOLESALE has a unit root

Exogenous: Constant

Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.785780	0.3863
Test critical values:	1% level	-3.477487	
	5% level	-2.882127	
	10% level	-2.577827	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)				0.019483
HAC corrected variance (Bartlett kernel)				0.033007
Phillips-Perron Test Equation				
Dependent Variable: D(LWHOLESALE)				
Method: Least Squares				
Date: 03/25/18 Time: 12:49				
Sample (adjusted): 2005M11 2017M06				
Included observations: 140 after adjustments				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LWHOLESALE(-1)	-0.025003	0.016212	-1.542274	0.1253
C	0.269371	0.162044	1.662336	0.0987
R-squared	0.016944	Mean dependent var		0.020128
Adjusted R-squared	0.009821	S.D. dependent var		0.141284
S.E. of regression	0.140588	Akaike info criterion		-1.071780
Sum squared resid	2.727577	Schwarz criterion		-1.029757
Log likelihood	77.02463	Hannan-Quinn criter.		-1.054703
F-statistic	2.378608	Durbin-Watson stat		1.703810
Prob(F-statistic)	0.125297			

Null Hypothesis: D(LWHOLESALE) has a unit root

Exogenous: Constant

Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-10.46290	0.0000
Test critical values:	1% level	-3.477835	
	5% level	-2.882279	
	10% level	-2.577908	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)				0.019544
HAC corrected variance (Bartlett kernel)				0.025661
Phillips-Perron Test Equation				
Dependent Variable: D(LWHOLESALE,2)				
Method: Least Squares				
Date: 03/25/18 Time: 12:50				
Sample (adjusted): 2005M12 2017M06				
Included observations: 139 after adjustments				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LWHOLESALE(-1))	-0.859553	0.084582	-10.16235	0.0000
C	0.017767	0.012060	1.473241	0.1430

R-squared	0.429816	Mean dependent var	0.000796
Adjusted R-squared	0.425654	S.D. dependent var	0.185809
S.E. of regression	0.140816	Akaike info criterion	-1.068436
Sum squared resid	2.716608	Schwarz criterion	-1.026213
Log likelihood	76.25629	Hannan-Quinn criter.	-1.051278
F-statistic	103.2735	Durbin-Watson stat	2.012562
Prob(F-statistic)	0.000000		

Appendix G: ADF test of Lretail price

Null Hypothesis: LRETAIL has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.950520	0.3085
Test critical values:	1% level	-3.477487	
	5% level	-2.882127	
	10% level	-2.577827	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(LRETAIL)

Method: Least Squares

Date: 03/25/18 Time: 12:50

Sample (adjusted): 2005M11 2017M06

Included observations: 140 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LRETAIL(-1)	-0.022065	0.011312	-1.950520	0.0531
C	0.258232	0.121089	2.132574	0.0347

R-squared	0.026829	Mean dependent var	0.022594
Adjusted R-squared	0.019777	S.D. dependent var	0.098609
S.E. of regression	0.097629	Akaike info criterion	-1.801097
Sum squared resid	1.315342	Schwarz criterion	-1.759074
Log likelihood	128.0768	Hannan-Quinn criter.	-1.784020
F-statistic	3.804530	Durbin-Watson stat	1.683821
Prob(F-statistic)	0.053141		

Null Hypothesis: D(LRETAIL) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-9.885651	0.0000
Test critical values:	1% level	-3.477835	
	5% level	-2.882279	
	10% level	-2.577908	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
 Dependent Variable: D(LRETAIL,2)
 Method: Least Squares
 Date: 03/25/18 Time: 12:51
 Sample (adjusted): 2005M12 2017M06
 Included observations: 139 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LRETAIL(-1))	-0.847263	0.085706	-9.885651	0.0000
C	0.019238	0.008523	2.257151	0.0256
R-squared	0.416341	Mean dependent var		0.001299
Adjusted R-squared	0.412081	S.D. dependent var		0.128051
S.E. of regression	0.098184	Akaike info criterion		-1.789656
Sum squared resid	1.320703	Schwarz criterion		-1.747433
Log likelihood	126.3811	Hannan-Quinn criter.		-1.772498
F-statistic	97.72609	Durbin-Watson stat		1.994056
Prob(F-statistic)	0.000000			

Appendix H: Phillips-Perron test of Lretail price

Null Hypothesis: LRETAIL has a unit root
 Exogenous: Constant
 Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-1.915162	0.3246
Test critical values:		
1% level	-3.477487	
5% level	-2.882127	
10% level	-2.577827	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.009395
HAC corrected variance (Bartlett kernel)	0.015117

Phillips-Perron Test Equation
 Dependent Variable: D(LRETAIL)
 Method: Least Squares
 Date: 03/25/18 Time: 12:51
 Sample (adjusted): 2005M11 2017M06
 Included observations: 140 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LRETAIL(-1)	-0.022065	0.011312	-1.950520	0.0531
C	0.258232	0.121089	2.132574	0.0347
R-squared	0.026829	Mean dependent var		0.022594

Adjusted R-squared	0.019777	S.D. dependent var	0.098609
S.E. of regression	0.097629	Akaike info criterion	-1.801097
Sum squared resid	1.315342	Schwarz criterion	-1.759074
Log likelihood	128.0768	Hannan-Quinn criter.	-1.784020
F-statistic	3.804530	Durbin-Watson stat	1.683821
Prob(F-statistic)	0.053141		

Null Hypothesis: D(LRETAIL) has a unit root
 Exogenous: Constant
 Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-10.20196	0.0000
Test critical values:		
1% level	-3.477835	
5% level	-2.882279	
10% level	-2.577908	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.009501
HAC corrected variance (Bartlett kernel)	0.012167

Phillips-Perron Test Equation

Dependent Variable: D(LRETAIL,2)

Method: Least Squares

Date: 03/25/18 Time: 12:52

Sample (adjusted): 2005M12 2017M06

Included observations: 139 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LRETAIL(-1))	-0.847263	0.085706	-9.885651	0.0000
C	0.019238	0.008523	2.257151	0.0256

R-squared	0.416341	Mean dependent var	0.001299
Adjusted R-squared	0.412081	S.D. dependent var	0.128051
S.E. of regression	0.098184	Akaike info criterion	-1.789656
Sum squared resid	1.320703	Schwarz criterion	-1.747433
Log likelihood	126.3811	Hannan-Quinn criter.	-1.772498
F-statistic	97.72609	Durbin-Watson stat	1.994056
Prob(F-statistic)	0.000000		

Appendix I: Pairwise Granger Causality test of Lfarm, Lwholesale and Lretail prices

Pairwise Granger Causality Tests

Date: 03/25/18 Time: 12:52

Sample: 2005M10 2017M06

Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
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LWHOLESALE does not Granger Cause LRETAIL	140	5.50992	0.0203
LRETAIL does not Granger Cause LWHOLESALE		0.00667	0.9350
<hr/>			
LFARM does not Granger Cause LRETAIL	140	8.95538	0.0033
LRETAIL does not Granger Cause LFARM		0.10042	0.7518
<hr/>			
LFARM does not Granger Cause LWHOLESALE	140	11.8976	0.0007
LWHOLESALE does not Granger Cause LFARM		0.19911	0.6561
<hr/>			

Appendix J: Pesaran, et al. (2001) Bound Test Table

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Table CI. Asymptotic critical value bounds for the F -statistic. Testing for the existence of a levels relationship^a

Table CI(i) Case I: No intercept and no trend

k	0.100		0.050		0.025		0.010		Mean		Variance	
	$I(0)$	$I(1)$	$I(0)$	$I(1)$	$I(0)$	$I(1)$	$I(0)$	$I(1)$	$I(0)$	$I(1)$	$I(0)$	$I(1)$
0	3.00	3.00	4.20	4.20	5.47	5.47	7.17	7.17	1.16	1.16	2.32	2.32
1	2.44	3.28	3.15	4.11	3.88	4.92	4.81	6.02	1.08	1.54	1.08	1.73
2	2.17	3.19	2.72	3.83	3.22	4.50	3.88	5.30	1.05	1.69	0.70	1.27
3	2.01	3.10	2.45	3.63	2.87	4.16	3.42	4.84	1.04	1.77	0.52	0.99
4	1.90	3.01	2.26	3.48	2.62	3.90	3.07	4.44	1.03	1.81	0.41	0.80
5	1.81	2.93	2.14	3.34	2.44	3.71	2.82	4.21	1.02	1.84	0.34	0.67
6	1.75	2.87	2.04	3.24	2.32	3.59	2.66	4.05	1.02	1.86	0.29	0.58
7	1.70	2.83	1.97	3.18	2.22	3.49	2.54	3.91	1.02	1.88	0.26	0.51
8	1.66	2.79	1.91	3.11	2.15	3.40	2.45	3.79	1.02	1.89	0.23	0.46
9	1.63	2.75	1.86	3.05	2.08	3.33	2.34	3.68	1.02	1.90	0.20	0.41
10	1.60	2.72	1.82	2.99	2.02	3.27	2.26	3.60	1.02	1.91	0.19	0.37

Table CI(ii) Case II: Restricted intercept and no trend

k	0.100		0.050		0.025		0.010		Mean		Variance	
	$I(0)$	$I(1)$	$I(0)$	$I(1)$	$I(0)$	$I(1)$	$I(0)$	$I(1)$	$I(0)$	$I(1)$	$I(0)$	$I(1)$
0	3.80	3.80	4.60	4.60	5.39	5.39	6.44	6.44	2.03	2.03	1.77	1.77
1	3.02	3.51	3.62	4.16	4.18	4.79	4.94	5.58	1.69	2.02	1.01	1.25
2	2.63	3.35	3.10	3.87	3.55	4.38	4.13	5.00	1.52	2.02	0.69	0.96
3	2.37	3.20	2.79	3.67	3.15	4.08	3.65	4.66	1.41	2.02	0.52	0.78
4	2.20	3.09	2.56	3.49	2.88	3.87	3.29	4.37	1.34	2.01	0.42	0.65
5	2.08	3.00	2.39	3.38	2.70	3.73	3.06	4.15	1.29	2.00	0.35	0.56
6	1.99	2.94	2.27	3.28	2.55	3.61	2.88	3.99	1.26	2.00	0.30	0.49
7	1.92	2.89	2.17	3.21	2.43	3.51	2.73	3.90	1.23	2.01	0.26	0.44
8	1.85	2.85	2.11	3.15	2.33	3.42	2.62	3.77	1.21	2.01	0.23	0.40
9	1.80	2.80	2.04	3.08	2.24	3.35	2.50	3.68	1.19	2.01	0.21	0.36
10	1.76	2.77	1.98	3.04	2.18	3.28	2.41	3.61	1.17	2.00	0.19	0.33

Table CI(iii) Case III: Unrestricted intercept and no trend

k	0.100		0.050		0.025		0.010		Mean		Variance	
	$I(0)$	$I(1)$	$I(0)$	$I(1)$	$I(0)$	$I(1)$	$I(0)$	$I(1)$	$I(0)$	$I(1)$	$I(0)$	$I(1)$
0	6.58	6.58	8.21	8.21	9.80	9.80	11.79	11.79	3.05	3.05	7.07	7.07
1	4.04	4.78	4.94	5.73	5.77	6.68	6.84	7.84	2.03	2.52	2.28	2.89
2	3.17	4.14	3.79	4.85	4.41	5.52	5.15	6.36	1.69	2.35	1.23	1.77
3	2.72	3.77	3.23	4.35	3.69	4.89	4.29	5.61	1.51	2.26	0.82	1.27
4	2.45	3.52	2.86	4.01	3.25	4.49	3.74	5.06	1.41	2.21	0.60	0.98
5	2.26	3.35	2.62	3.79	2.96	4.18	3.41	4.68	1.34	2.17	0.48	0.79
6	2.12	3.23	2.45	3.61	2.75	3.99	3.15	4.43	1.29	2.14	0.39	0.66
7	2.03	3.13	2.32	3.50	2.60	3.84	2.96	4.26	1.26	2.13	0.33	0.58
8	1.95	3.06	2.22	3.39	2.48	3.70	2.79	4.10	1.23	2.12	0.29	0.51
9	1.88	2.99	2.14	3.30	2.37	3.60	2.65	3.97	1.21	2.10	0.25	0.45
10	1.83	2.94	2.06	3.24	2.28	3.50	2.54	3.86	1.19	2.09	0.23	0.41

(Continued overleaf)

Appendix K: Breusch-Godfrey Serial Correlation LM Test of NARDL model

Breusch-Godfrey Serial Correlation LM Test:

Null hypothesis: No serial correlation at up to 1 lag

F-statistic	1.956645	Prob. F(1,125)	0.1643
Obs*R-squared	2.111433	Prob. Chi-Square(1)	0.1462

Test Equation:

Dependent Variable: RESID

Method: Least Squares

Date: 03/16/18 Time: 16:21

Sample: 2006M02 2017M06

Included observations: 137

Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.132484	0.331932	-0.399131	0.6905
LRETAIL(-1)	0.014389	0.036495	0.394282	0.6940
LWHOLESALE_P(-1)	-0.004171	0.051318	-0.081282	0.9353
LWHOLESALE_N(-1)	-0.016861	0.044409	-0.379673	0.7048
LFARM_P(-1)	-0.012676	0.069797	-0.181609	0.8562
LFARM_N(-1)	0.007455	0.041700	0.178767	0.8584
DLWHOLESALE_P	0.020298	0.068835	0.294874	0.7686
DLWHOLESALE_N	-0.008585	0.082720	-0.103782	0.9175
DLWHOLESALE_N(-3)	0.009388	0.078516	0.119564	0.9050
DLFARM_P(-2)	-0.008486	0.115205	-0.073659	0.9414
DLWHOLESALE_N(-2)	0.005972	0.079165	0.075443	0.9400
RESID(-1)	-0.139024	0.099388	-1.398801	0.1643
R-squared	0.015412	Mean dependent var		4.91E-16
Adjusted R-squared	-0.071232	S.D. dependent var		0.060976
S.E. of regression	0.063111	Akaike info criterion		-2.604335
Sum squared resid	0.497871	Schwarz criterion		-2.348570
Log likelihood	190.3970	Hannan-Quinn criter.		-2.500398
F-statistic	0.177877	Durbin-Watson stat		1.974691
Prob(F-statistic)	0.998458			

Appendix L: ARCH test of NARDL model

Heteroskedasticity Test: ARCH

F-statistic	0.009070	Prob. F(1,134)	0.9243
Obs*R-squared	0.009205	Prob. Chi-Square(1)	0.9236

Test Equation:

Dependent Variable: RESID^2

Method: Least Squares

Date: 03/16/18 Time: 16:22

Sample (adjusted): 2006M03 2017M06

Included observations: 136 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.003666	0.000645	5.685109	0.0000

RESID ² (-1)	0.008446	0.088681	0.095238	0.9243
R-squared	0.000068	Mean dependent var		0.003696
Adjusted R-squared	-0.007394	S.D. dependent var		0.006530
S.E. of regression	0.006554	Akaike info criterion		-7.202862
Sum squared resid	0.005756	Schwarz criterion		-7.160029
Log likelihood	491.7946	Hannan-Quinn criter.		-7.185456
F-statistic	0.009070	Durbin-Watson stat		1.948030
Prob(F-statistic)	0.924268			

Appendix M: Parameter estimates for the rice miller cost function

Parameter	Half-normal u distribution		Exponential u distribution	
	Estimate	Standard error	Estimate	Standard error
β_y	-8.3955	0.000000	-10.904	0.0013
β_{yy}	-0.0011	0.0002796	0.0005	0.0000001
β_{ym}	0.8567	0.0020049	1.0789	0.0001209
β_{yl}	0.2495	0.0030577	0.2769	0.0000131
β_{ye}	-0.0074	0.0003318	-0.0058	0.0000010
β_{yo}	-0.0059	0.0005849	-0.0065	0.0000016
β_{yt}	-0.0237	0.0010012	-0.0225	0.0000025
β_{yk}	-0.1542	0.0025591	-0.1142	0.0000211
σ_v	0.00002	0.0001354	0.00000004	0.0000007
σ_u	1.02949	0.0575496	0.47317	0.0374074

Appendix N: Parameter estimates for the cost function of wholesaler

Parameter	Half-normal u distribution		Exponential u distribution	
	Estimate	Standard error	Estimate	Standard error
β_y	-0.1630	0.005873	1.2704	0.000281
β_{yy}	0.0040	0.000005	0.0044	0.000028
β_{ym}	0.0891	0.000566	-0.0538	0.000002
β_{yl}	-0.0593	0.000033	-0.0213	0.000002
β_{ye}	-0.00008	0.000021	-0.0025	0.000001
β_{yo}	0.0026	0.000006	0.0005	0.000001
β_{yk}	0.1232	0.000033	0.0841	0.000008
σ_v	0.00000003	0.000002	0.000000006	0.000001
σ_u	0.600219	0.027396	0.384062	0.024791