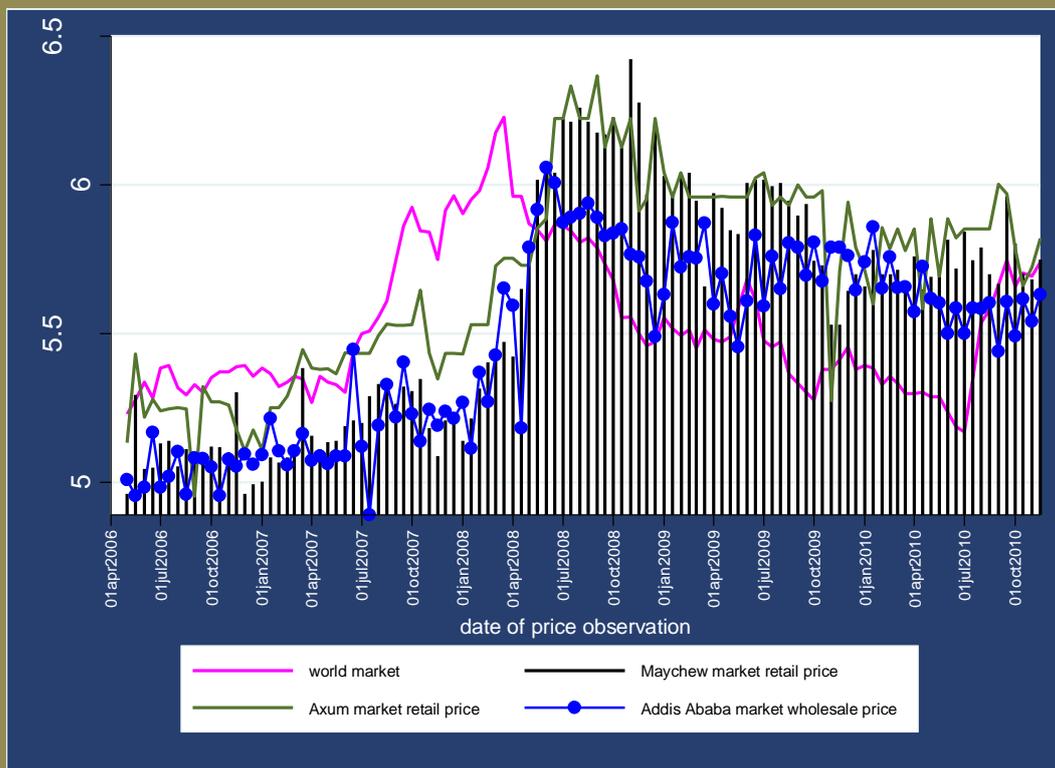# Wageningen University and Research Centre, Wageningen

Agricultural economics and Policy Group

Analyzing the relationship between world market prices and local prices of food in African markets: the case of wheat in Ethiopia

BY

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MARCH, 2012

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To

Nana Ama, Mame Bommo and Erzuah Ackah

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ABSTRACT

Prices of internationally traded commodities in local (retail) markets tend to share a relationship with the world market. Yet previous studies on market integration in Ethiopia have mainly concentrated on integration of regional markets. We analyze the relationship between world market wheat prices and retail wheat prices from the Tigray region of Northern Ethiopia, and including Addis Ababa. Tests for presence of unit roots using both structural and non-structural break approaches indicated all the market price variables contained unit roots, but were integrated of the order one. Through Johansen's approach we estimated five cointegration blocs of markets. Results from the vector error correction models show that world market wheat prices are cointegrated with prices of wheat in some local markets. Impulse response graphs revealed that an orthogonalized positive shock from the world market has both permanent and transitory effects. The Addis Ababa market is very sensitive and responsive in discovering price innovations. It is recommended that market access to all marketing centers is greatly improved, as it has the potential to ensure that the law-of-one-price holds among local markets.

Keywords: cointegration blocs, market integration, structural break, Tigray region of Ethiopia, vector error correction model, impulse response graphs.

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CHAPTER ONE

1.0 INTRODUCTION

Cereal grains are grown in large quantities due to their high energy content and calorific values. As a result they provide more food energy worldwide compared to any other type of crop. Most of them are staple foods in the diet of humans. They also serve as feed inputs in the production of meat products such as mutton, chicken, pork, veal. Moreover, in the last decade, the use of grains to produce biofuel has received much attention. Among the most important cereal grains are rice, wheat, maize, barley, oats, sorghum, millet, and rye. Wheat is one of the most important grain staples in the diet of Ethiopians due to the diversity of food products made from it. There is quite a substantial amount of locally produced wheat but this local supply is not always able to meet the nation's demand. Physical-climatic factors such as drought and poor market access, among others have all contributed to this limited supply. Consequently, much of the nation's supply comes from imports. Thus, world market prices can play an important role in determining wheat prices in local markets.

International trade is a good thing. Trade increases welfare because it paves way for specialization and specialization based on comparative advantage leads to economies of scale and welfare improvements. For centuries, countries have traded extensively internationally in terms of movement of physical goods and capital. Through trade, price development in one country tends to have impacts on the level and the extent to which prices develop in the trading partner. This process has been enhanced by the vast technological advancement that has made it possible for activities in one part of the world to be observed by outsiders. Some of these technological tools include the internet, telephones, televisions, radios and many others. The internet makes instant and almost unrestricted communication possible between people thousands of miles away, whereas jet transport allows quick physical access to all parts of the world. Many traders and producers observe price movements in other parts of the world and form expectations (temporal arbitrage). Based on these expectations, they fix new prices for their goods and services. This way, local prices of goods and services are not only determined by the market forces of demand and supply within that country, but also partly by the movements in prices elsewhere. In such circumstances, prices are said to be transmitted from one region or country to the other. Price transmission between two spatially separated regions means that price levels of commodities in one country have tremendous influence on price levels of similar or related commodities in other countries, especially where these countries are connected through trade. Thus, despite the importance of price transmission within each country, cross-country effects may also play a key role in determining local market prices.

Recently, there has been a loud hue and cry about increasing world food prices. Over the last decade, prices of food throughout the world have risen rapidly, and this phenomenon even led to an acute global food crisis in the period 2007-2008 economic year. Recent developments in food markets worldwide indicate a possible resurgence of this phenomenon. Lately, price developments of agricultural products provide partial evidence, as there has been a tendency for world real prices of agricultural products to increase, and therefore reverse from their long-term trend of declining world prices (Banse, van Meijl et al. 2008). Increasing price uncertainty has unfavorable effects on consumers and producers and makes long-term planning difficult. This has generated serious concerns among policymakers about the adverse impacts of food prices, particularly on the poor in developing countries, who channel more than half of their income into food consumption expenditure on the average, (De Janvry and Sadoulet (2010), Ivanic and Martin (2008)). On the demand side, increases in food prices at the world market leads to income transfer from net-importing countries to net-exporting countries of food commodities. In the face of declining incomes, rational consumers may have to decrease their consumption expenditure and possibly substitute commodities. This event has mixed ramifications for the aggregate demand and supply of any country that is a net importer of food. Hence, it is important to assess the relationship that local market prices within a country have with world prices of similar commodities. The correlation of local prices with world market prices can be particularly noticeable in developing countries. Most developing countries rely heavily on imported cereal grains, chiefly wheat and rice for their food supplies, as these cereal grains are their main staple foods. This strong dependence on food imports, coupled with severe absence of acceptable and reliable storage facilities clearly shows that a majority of (developing) countries that are import-dependent are highly exposed to and can be adversely affected by world market price fluctuations (Cudjoe, Breisinger et al. 2010)

Studies that investigate empirically how the rising world market prices have practical implications for local markets in developing countries are limited. Most studies have concentrated on price transmission between regional markets within the country. Other studies have investigated the effects of globalization and international trade on income or wealth distributions within countries and also across rich and poor nations, across urban and rural regions, and across high- and low-skilled workers (Robbins 1996); (O'Connor and Lunati 1999) and (Verma, Hertel et al. 2011).

In Ethiopia, studies on grain market integration have mainly focused on how the regional market prices are cointegrated to the central grain market price in Addis Ababa (Asfaw, Jayne et al. 1998) Dercon (2002); Getnet (2007). Again, a number of attempts have been made in trying to examine how local markets are cointegrated and adjusting to price shocks in their immediate

markets or to their immediate regional markets. But only few studies have examined whether changes in world market prices affect price development in local markets of developing countries. Such analysis is helpful in identifying the level of integration of local markets with the external world market and to assess how local market actors form expectations based on this relationship. The subject of our study, therefore, is to assess a possible long term equilibrium relationship between world market prices and food crop prices in Ethiopian local markets. We consider this study relevant because prices in local markets tend to respond differently to increases in global price shocks, thus generating price asymmetry in markets. Fundamentally, price asymmetry violates the theory of market efficiency. From a policy point of view, asymmetric pricing provides an authentic scenario for government intervention to improve welfare. Moreover, prices in local markets are more likely to have direct impact on the welfare of the poor than average country prices as is normally used in similar studies. Many producers and traders in developing countries use the so-called world market prices as a yardstick upon which to base their pricing decisions (Minot 2011). In this way it may turn out that local market prices are (partly) determined by the world market prices, which may lead to a long-run equilibrium relationship between world market prices and local market prices.

1.1 RESEARCH OBJECTIVE

Producers base their production and marketing decisions on market price information. Traders also observe prices in nearby markets or international markets to make adjustments to their prices. When markets are integrated, price movements in one market certainly have impacts on other markets. In our modern global world where there is connection in price movements across countries and between markets, knowledge of the mechanisms by which prices are equalized and how expectations are formed becomes imperative.

The main objective of this research is to evaluate long-run relationships and causality between local food prices and world food prices by assessing the relationship between local wheat prices in Ethiopia and world market wheat prices.

1.2 RESEARCH QUESTIONS

Do local food prices in Ethiopia depend on world market prices? To be able to provide an answer to this broad question, we decompose it into four specific research questions.

1. What were the general trends of wheat price levels in Ethiopia within the period 2006-2010?
2. How does bi-weekly (i.e. period of two weeks) wheat price variation in world market influence local market prices in Ethiopia in the short- and long-term?

3. How do past trends in world market prices determine current local market prices of wheat?
4. What are the short- and long-term relationships between prices of wheat in different local markets?

1.3 ORGANIZATION OF THE REST OF STUDY

The rest of the study is organized into four main chapters. Chapter two thoroughly reviews the general trends in world food prices, the theories related to market integration and past studies carried out in our area of investigations that focus on market integration and cointegration. Chapter three contains the methodological design. In this chapter, we explicitly outline the sources and nature of data, describe the trends of prices and also discuss the econometric methods employed in our analysis. Chapter four provides the estimation results, including thorough discussions and/or interpretation. Finally, chapter five summarizes the findings, concludes and makes recommendations based on the findings.

CHAPTER TWO

2.0 LITERATURE REVIEW

This chapter presents the theoretical framework used in this study and reviews past research conducted in our area of investigation. There are three main sections, each dealing with a specific subject related to this study. Section 2.1 looks at the general trends in agricultural commodities prices. Section 2.2 presents an overview of theories associated with market integration and section 2.3 outlines a review of past studies related to integration and cointegration.

2.1 TRENDS IN WORLD FOOD PRICES

The last century has been characterized by dramatic fluctuations in the prices of agricultural commodities within and across countries worldwide. Until the last decade, the general trend had been a continuous decline in the prices of agricultural food commodities. Technological development that increases productivity of agricultural inputs could be one of the causes of the declining prices. Recently, however, food prices have generally been upward trending and this has varying implications in domestic as well as internationally traded commodity markets. While producers might readily welcome this price upsurge, consumers cry out loud due to the increasing proportion of income that must be channeled into food consumption. Generally, a buoyant global economic growth which creates increased demand for food commodities (with limited supply) has the tendency to induce higher commodity prices. Figure 2.1 reveals the trend of some important staple food commodities from January, 2000 till September, 2011. We also include the prices of crude oil to observe how the commodity prices tend to move with crude oil prices.
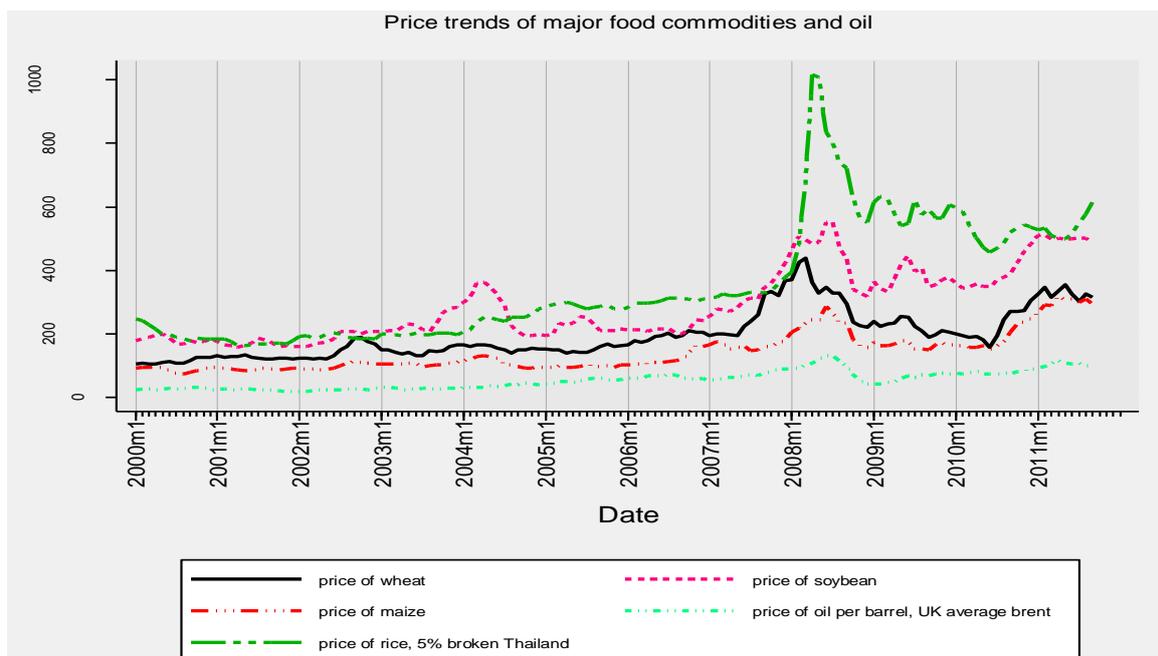
Figure 2.1 General Price trends of selected food commodities and oil

Source: Generated by author from IMF price database

On the whole, commodity prices have experienced remarkable increase, particularly in the last five years. In late 2006 prices began to rise but 2007 and 2008 were characterized by dramatic increases. Even though there was a slight decline in 2009, the level has remained relatively high compared to early years.

Several studies have been carried out to ascertain the prime movers of this upward price surge. A review by the European Commission (2008) identified three main groups of factors responsible for the current surging trends of food commodity prices. First, they assert that dramatic changes have taken place in agricultural production and trade, which affects the supply side of the economy; secondly, changes have occurred in the macroeconomic environment and these have varying impacts on both aggregate demand and aggregate supply; thirdly, a variety of policies such as agricultural and trade policies have been implemented that tremendously influence supply and demand. Headey and Fan (2008) reviewed a number of factors that are important determinants of current price fluctuations. They explicitly quote the depreciation of the United States dollar, the implementation of policies (e.g. EU biofuel policy) that catalyzed the large scale production of biofuels, continuous increase of world crude oil prices, trade restrictive measures such as tariffs and quotas, as well as speculations of market activities and investment as important determinants. Earlier on, Mitchell (2008) and Rosegrant (2008) had individually identified biofuel policies as the leading driving force. These policies further enhanced increased production of biofuels using cereals and oilseeds. According to

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Mitchell's investigations, grains led the rapid rise in prices of food commodities. Within the period from 2002 to 2008, the depreciation of the United States dollar was close to 35 percent. The negative impact of this dollar depreciation is the increase in the prices of commodities traded in dollars. Furthermore, a mathematical computation by Collins (2008) indicate that approximately 60 percent of the increase in prices of maize within the period 2006-2008 could be attributed to the increased use of maize for ethanol production.

Normally, price fluctuations in developing countries are more pronounced than those in developed countries. This observation might be attributed to effective price stabilization policies implemented by developed country governments. In large parts of Africa, stabilization policies are grossly lacking. As a consequence, huge disturbances such as the 2007-2008 global food crises severely affected the domestic markets in developing countries. Particularly in landlocked countries such as Ethiopia, cereal prices show marked volatility in price developments. For example, Meijerink, Roza et al. (2009) established that price levels of cereals continued to increase even when the world prices of cereals declined after the global shock. Their investigations identified a strong correlation of cereal prices within the corridor of eastern African countries rather than with world market prices. In Ethiopia, the year 2008 was characterized by a severe drought which led to poor yields. As a result, food prices escalated due to the fact that the world market also experienced a crisis at that time. Tadesse and Guttormsen (2011) quote that speculative activities engaged in by some traders are the main culprits for the continuous increase of price instability of grains in Ethiopia.

2.2 MARKET INTEGRATION

When prices in two spatially separated markets or locations follow similar patterns over a long period of time the markets are said to be integrated. Basically, market integration has been considered to relate to the flow of goods and information between markets or regions that are distantly situated. Thus, in discussing market integration the prerequisite is the existence of two or more separate regions or countries, each of which is characterized by its own supplies and demands for a range of commodities under autarkic conditions. González-Rivera and Helfand (2001) offer a very appealing and intuitive definition of integrated market as the set of locations that share the same or related traded commodities and the same long-run information or innovations. Prices are considered to be transmitted from one market (upstream/wholesale market) to another (downstream/retail market), such that by accounting for transportation and other transaction costs, the law-of-one-price should hold in these two integrated markets.

Three types of price transmission mechanisms, namely spatial, vertical and cross-commodity, give rise to three types of integration: spatial integration, vertical integration and cross-

commodity integration. In spatial integration, prices of the same commodity in two spatially distant markets do affect each other. In vertical integration, prices of a commodity and its product, e.g. wheat and flour, do have a relationship with one another, whereas in cross-commodity integration the price of one commodity, say wheat, affects the price of another commodity, say rice. Our focus in this study is on spatial market integration. Among studies that look into spatial price transmission mechanisms are papers by Minot (2011), Conforti (2004), Abdulai (2000) and Baffes and Gardner (2003). Their findings indicate that the degree of price transmission within countries varies widely and is critical in determining local prices, particularly in more remote parts of a country.

Market integration is considered to be a desirable phenomenon because it improves welfare by fostering competition, improving security of supply and providing better signals for consumers and producers to make optimal decisions. Through these processes, market integration influences economic growth, induces structural change and has the potential to change the location of economic transactions (Vollrath and Hallahan 2006).

Theoretical Overview of Price Transmission and Spatial Market Integration

Theoretically, many economists have based their analysis of market integration on the law-of-one-price. Earlier examples were provided by Ravallion (1986), Goodwin and Schroeder (1991) among others. In its basic form the law-of-one-price states that the same commodity in two or more spatially separated markets should exhibit the same price, and should differ only by transfer (transportation) costs. An important factor that influences market integration is the cost and risks associated with trade between the markets. It is hypothesized that as the magnitude of costs and risks enlarges, trade tends to decline and markets become less integrated. Transportation costs are usually used as proxy to capture costs and risks associated with trade between markets. Minot (2011) asserts that price transmission is not likely to occur between two markets within or across countries where transportation costs are prohibitively high. He attributes high transportation costs to wide distance between the markets, poor transportation infrastructure, high trade barriers and risks associated with trading. Lack of market integration characterized by incomplete price transmission may be an indication of inefficient market operations. Hence, market and price information may be deficient.

We denote the price in market A by P_a and that in market B by P_b. Then, if the assumptions backing the law-of-one-price hold, we have

$$P_a - P_b = t, \tag{2.1}$$

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We attribute the difference to transfer costs, t. Thus, the two markets should be in equilibrium and thus should not provide any opportunity for arbitrage. But without arbitrage, it may be difficult for integration between markets to be achieved. A less strict form of equation (2.1) is represented by

$$P_a - P_b \leq t, \tag{2.2}$$

This inequality makes room for arbitrage opportunities or commercialization, which closely approximates characteristics of agricultural and food markets.

Other economists try adopting a framework that tends to relax the assumptions backing the law-of-one-price and looks at the degree to which spatially distant markets are connected with one another. The connectedness consists of the transmission of price innovations or shocks in two dimensions, temporal and spatial. We follow similar theoretical considerations by looking at how connected is world market with local markets in terms of transmission of price innovations.

An appropriate measure to evaluate whether two markets are integrated is to explore if a possible cointegrating relationship exists between them. In a cointegration framework, sharing long-run information is an important prerequisite. The long-run information means there exists one and the only integrating factor that may be common to all price series. In analyzing market integration, great advances have been made in methodology from the use of simple correlation coefficients to more sophisticated econometric approaches, such as bivariate models, cointegration and error correction models. Our focus will be confined to cointegration and error correction models.

2.3 REVIEW OF PAST STUDIES ON COINTEGRATION IN AGRICULTURAL MARKETS

Granger (1986) provided sound arguments that cointegration is one of the most attractive procedures for analyzing price relations among spatially separated but linked markets. He stipulates that cointegration explicitly accommodates short-run divergences among two or more time series of data; nonetheless it requires the series to converge together in equilibrium in the long run. In ordinary regression models, due to the non-stationary nature of many economic time series variables, classical asymptotic theory tends to fail and the assumptions backing such theory become invalid. Hence, spurious regressions may result and inferences based on such estimation techniques become unreliable. Thus, cointegration has proven to be a useful econometric estimation technique which overcomes such fallacies.

Bessler and Fuller (1993) critically explored a cointegration relationship among several US wheat markets. They made use of the two-step procedure suggested by Engle and Granger (1987) and the maximum likelihood procedure suggested by Johansen (1991). In their analysis, they tried to compare forecasts from an error correction specification and vector autoregression in levels, to forecasts from univariate autoregressions in first differences. The results from the forecasts comparison indicated that the vector autoregression in levels had higher forecast-error bias, but lower error variance, relative to the error correction specification.

Conforti (2004) investigated cointegration relationships between agricultural food commodity prices in some selected African countries and world market prices using error correction models. He found that four out of sixteen commodity prices showed long run equilibrium relationships with world markets. Rapsomanikis and Mugera (2011) reviewed a number of articles that assessed possible long-run relationship between world market prices and domestic market prices of commodities in selected countries. Their analysis revealed, particularly for the Ethiopian wheat market that there was a cointegration with the world market. However, they mentioned that the speed of adjustment was rather slow (only about 0.06%).

Alexander and Wyeth (1994) used Granger causality tests within the context of cointegration to evaluate spatial integration for Indonesian rice markets. Their results revealed patterns of causality in terms of lead and lag relationships among several spatially separated markets. Goodwin, Grennes et al. (1999) used Granger causality tests within the context of multivariate cointegrated systems to evaluate spatial linkages among regional food markets in the Federation of Russia after the reform. Their findings identified significant dynamic patterns in the adjustment of prices to shocks in other regions.

Fackler and Goodwin (2001) identify a number of limitations associated with Granger causality tests. According to their review, Granger causality tests are unable to make known the exact nature of the relationship, but only indicate whether a relationship among contemporaneous and lagged prices is statistically and significantly different from zero. Additionally, they emphasize that Granger causality tests are sensitive to omitted variables biases.

CHAPTER THREE

3.0 METHODOLOGICAL DESIGN

This chapter consists of two main sections. Section 3.1 describes the nature and sources of the data used for the analysis. We also outline the principal trends followed by the price series over the period under study. Section 3.2 is composed of five sub-sections, each one outlining a specific method of data analysis in great detail.

3.1 STUDY DESIGN AND DATA

The study design adopted in this research is an econometric study (using multivariate time-series techniques). We try to discover the past trends in wheat prices and based on our results we ascertain causality between the series of prices (that is, world market prices and local market prices of wheat).

3.1.1 Variables

The two broad variables of interest in our research are local market prices and world market prices of wheat. The data stems from a secondary source that relates to wheat prices. The local retail price is bi-weekly wheat price data collected at 15-day intervals, on the 1st and 16th of every month from May 2006 to November 2010. The main reason limiting our time span of data was the availability of data. We had data available for 2006 to 2010, hence our choice for this time frame. Our data should have resulted in 110 observations, but some months were not recorded and there were missing observations for some of the local markets. We therefore solved for those missing values using multiple imputation methods as outlined in section 3.1.2. The prices were converted from Ethiopian Birr per quintal to US dollar per tonne using the exchange rate. The local markets from which price information were collected are mostly from the Tigray region of Northern Ethiopia. The price information was collected by the Tigray Agricultural Marketing Promotion Agency (TAMPA). They include retail markets in Alamata, Maychew, Abi-Adi, Mek'ele, Hawzen, Adigrat, and Aksum. Since Addis Ababa is the capital city and also hosts the central grain market, we included both the wholesale and retail prices from these markets. The world market price was obtained from the FAO database on wheat prices within the same period (i.e. 2006-2010). The local markets are geographically dispersed in different towns and/or cities; therefore they may have different pricing methods and/or trading volumes.

3.1.2 Solving for missing observations using multiple imputation

In trying to overcome the problem of missing data, we used the method of multiple imputations (MI). The primary intention of multiple imputations is to generate plausible values in place

where actual data are missing. In doing this the imputation technique ensures that the parameter estimates are unbiased and the uncertainties in the parameter estimation in the missing data case are estimated in a reasonable way (Graham 2009).

This method was implemented in STATA using the 'ICE' (imputation by chained equations) command. The multiple imputation technique is most desirable where the observations are missing at random. The imputation method consists of three basic steps;

- We specified the 'ice' command followed by the variables which missing values were to be predicted, and also included variables with non-missing values (in our case it was the world market price). Options exist for selecting the type of model to use for the prediction/imputation. We used the regression model in the imputation since our variables are continuous. A number of datasets is generated depending on the number of imputations (m) specified.
- The datasets generated have all missing values imputed/filled which can be used for further analysis.
- We then pooled estimates of the different datasets and got one representative set of estimates (like an average for all datasets) for our discussion.

In our analysis, we specified m=300, based on recommendations by Graham, Olchowski et al. (2007). According to Graham, Olchowski et al. (2007), larger number of imputations results in better estimates of the parameters. In the end, we generated 300 datasets that were pooled to obtain the summary statistics used in our discussion.

3.1.3 Summary statistics of wheat prices

Table 3.1 reveals that the mean values for the price of wheat for the different markets within the period under study showed quite remarkable variation, especially among local markets. Addis Ababa (approximately US$ 249/ton) had the lowest mean retail price while Mek'ele (approximately US$ 326/ton) experienced the highest average retail price. It is reasonable to observe that among retail prices Addis Ababa market experienced the lowest value over the time span of data. In most African countries, capital cities tend to serve as the point of concentration of most commodities produced in the countryside or production centers. In the process of concentration, the prices of goods become depressed because of excess supply over demand. Moreover, Addis Ababa is the capital city which serves as the first point of entry for imported wheat. Therefore, prices can generally be lower than retail markets located outside this city because transportation and other arbitrage costs add to the final retail price in the rest of the markets. Generally, the average retail prices of wheat in the local Ethiopian markets were higher than the average world market price except in the Addis Ababa local markets.

Table 3.1 Summary statistics of prices in different markets

Variable	Observation	Mean	Std. Dev.	Minimum	Maximum
Addis Ababa price wholesale	110	249.34	68.33	131.70	427.61
Addis Ababa price retail	110	256.14	65.59	155.10	398.51
Maychew price	110	289.75	114.42	142.81	616.03
Alamata price	110	316.29	119.40	151.62	532.03
Mek'ele price	110	325.96	113.13	155.18	530.86
Abi-Adi price	110	302.98	98.60	163.34	571.11
Hawzen price	110	263.12	87.60	136.51	460.86
Adigrat price	110	300.23	92.23	165.81	490.03
Axum price	110	312.57	102.05	141.64	582.78
World market price	110	261.13	68.81	176.00	507.00

Source: Computed from research data

The standard deviation for most of the price series is a bit high, thus showing significant spread in prices within the period under study.
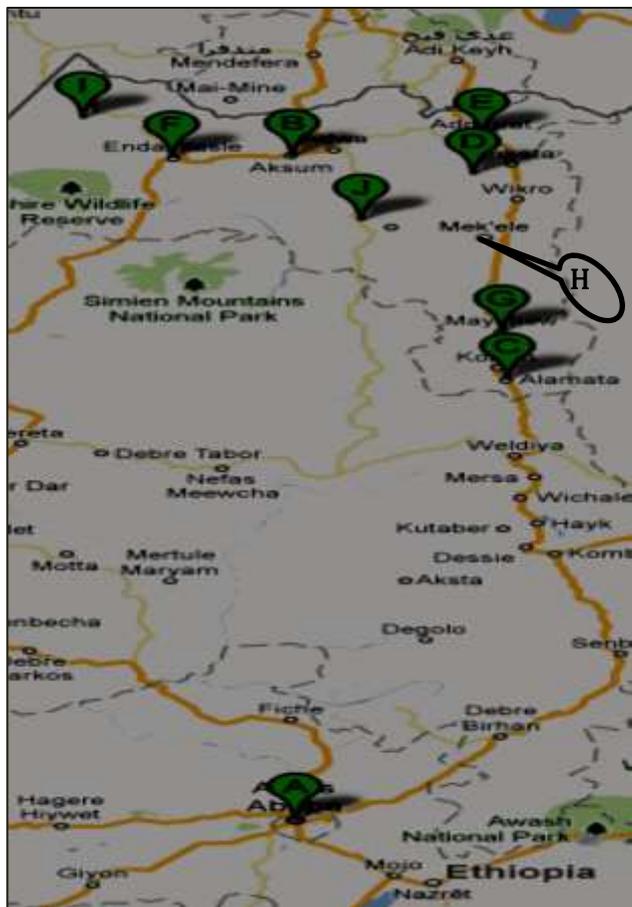
Key

A. Addis-Ababa

B. Axum

C. Alamata

D. Hawzen

E. Adigrat

G. Maychew

H. Mek'ele

J. Abi-Adi

Figure 3.1 Map of Northern Ethiopia indicating local markets studied
Source: Generated by author from Google maps

3.1.4 Evolution of prices in different local markets and the world market

Figures 3.2-3.4 plots the world market price and the local Ethiopian market prices in a graph. At a glance, the figures reveal that the variability of the wheat price in all local markets as well as the world market is not constant. Moreover, the general observation is that local prices tend to move closely together, thus raising the suspicion of possible cointegration. In general, wheat prices in all local markets tend to fluctuate a lot within the period 2006 -2010 compared to the world market prices. The level of prices was quite stable in the months of 2006 and early 2007. However, beginning July 2007 prices began to surge upwards. The trend continued for the ensuing months until the end of October 2007. Later there was a brief period of declining prices, but thereafter, prices started to escalate. Of course, this scenario (escalation of prices) which continued until approximately January 2009 coincides with the advent of the global food shocks that occurred during 2007-2008. The period from October 2009 onwards, however showed much less variation, even though the trend was still present.
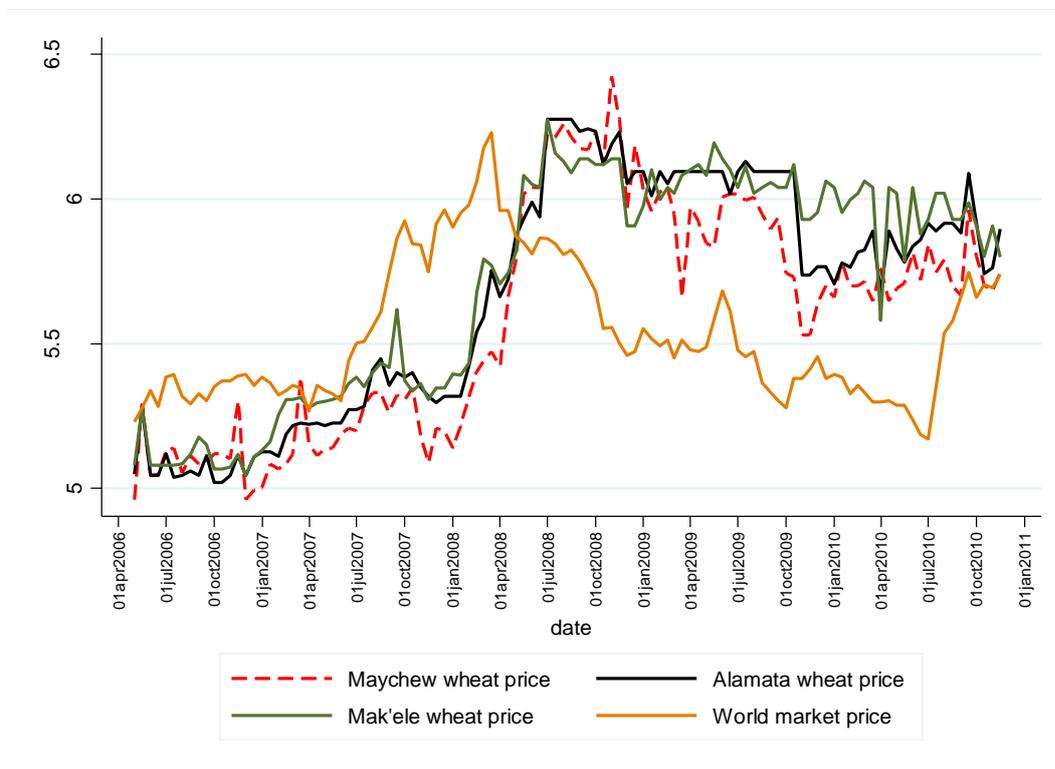
Figure 3.2 Time series plot of world market, Alamata, Mek'ele and Maychew local markets from May 2006-November 2010

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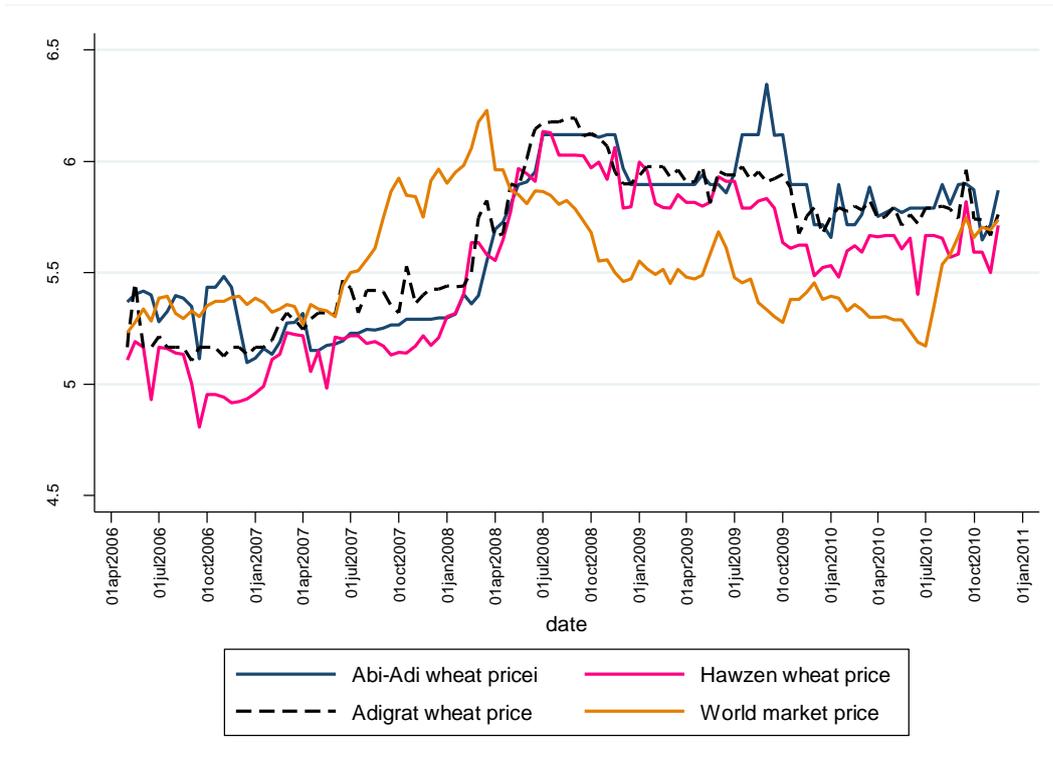
Figure 3.3 Time series plot of world market, Abi-adi, Hawzen and Adigrat local markets from May 2006-November 2010
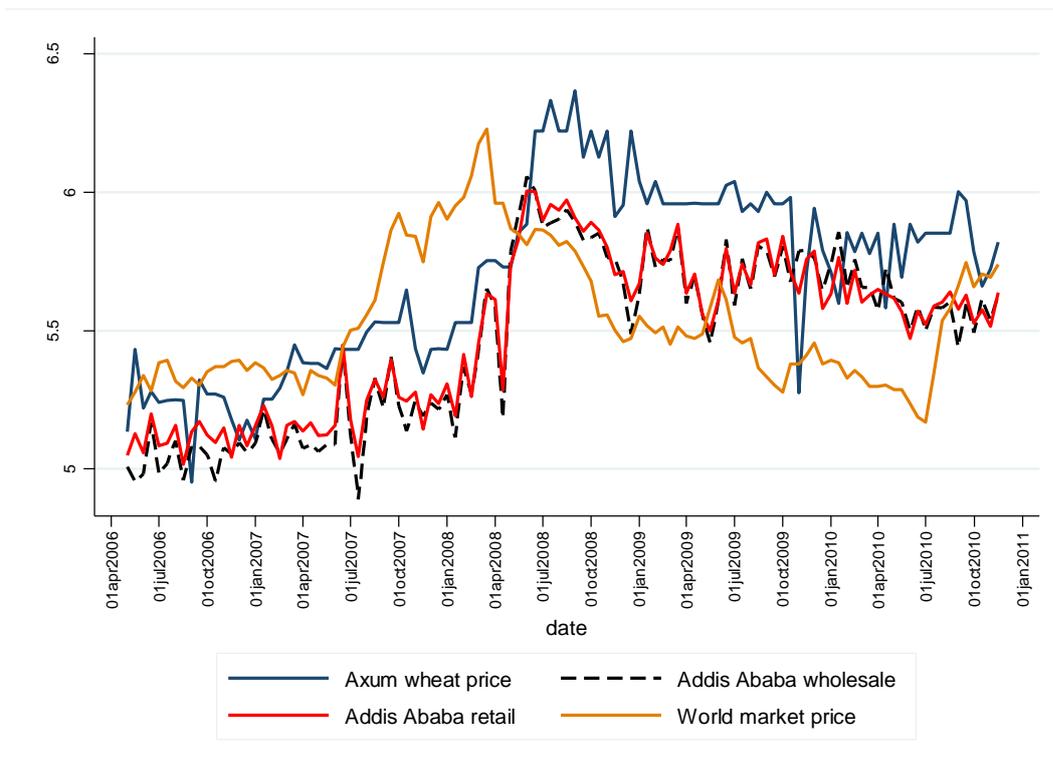
Figure 3.4 Time series plot of world market, Axum and Addis Ababa local markets from May 2006-November 2010

Comparatively, prices of wheat in almost all local markets were generally lower than the corresponding world market prices from May 2006 to May 2008. However, the trend was reversed and local retail prices attained higher levels than world market prices after May 2008, and this trend was sustained until approximately October, 2010. Interestingly, the graph reveals that after January 2008, the local market prices continued to increase even when the world market prices were declining. This might have resulted from the crop failure caused by severe drought and pest infestation that occurred around the same time (2008) in most wheat growing regions of Ethiopia (Meijerink, Roza et al. 2009). Moreover, the same period marks the culmination of the global food crisis which caused instability in food markets of most countries, especially in the developing world. According to Meijerink, Roza et al. (2009) the government embarked on certain policy measures with the intention to mitigate the effect of rising food prices, but this rather aggravated the already fragile situation and prices remained high after April, 2008.

3.2 DATA ANALYSIS

Econometric time series and multiple regression methods were adopted for our analysis. The influence of world market prices on local market price conditions is investigated using multiple linear regressions. Consider W_t to be the (natural) log of world market price and L_t to be the (natural) log of local market price. Then we specify the model

$$L_t = \alpha_1 + \alpha_2 W_t + \alpha_3 G p_t + \varepsilon_t. \tag{3.1}$$

Where $t =$ index of time, $G_p =$ policy variables

The coefficient α_2 is the elasticity that measures the percentage change in local market price due to a one percentage change in world market price.

3.2.1 Tests for Stationarity and Unit Roots

Most econometric theory is built upon the assumption of stationarity in the data. If this assumption holds, then equation 3.1 can conveniently be estimated with ordinary least squares regression. But one problem with this regression is that, non-stationarity in one or more variables generally lead to spurious regression. A regression is said to be spurious when the model has a very high R-squared in combination with Durbin-Watson statistic close to 0 or 4, but none of the (alpha) coefficients of the independent variable(s) are significant. In reality, many economic series such as prices usually exhibit trends, implying that they are non-stationary. In this case, equation 3.1 cannot be estimated efficiently with ordinary least squares regression. So, we can model such time series variables as being trend stationary or difference stationary. Stationarity of a stochastic process requires that the variances and autocovariances

are finite and independent of time. On the other hand, a non-stationary series has no tendency to return to a long term deterministic mean function; hence the mean, variances and autocovariances are time-dependent. However, pairs of non-stationary time series could have a long term relationship between them.

Non-stationarity means presence of unit roots. In testing for the presence of unit roots, several methodological options are available. Prominent among them are the (augmented) Dickey-Fuller (ADF) tests, Phillips-Perron tests, and KPSS tests. Some differences exist among these three types of unit root tests. Basically, while the ADF test uses a parametric autoregression to approximate the ARMA structure of the errors in the test regression, the Phillips-Perron test ignores any serial correlation in the test regression. The Phillips-Perron and ADF tests specify the null hypothesis that a time series Y_t is non-stationary (i.e. unit root is present), while the KPSS test has stationarity as the null hypothesis. In small finite samples, the general observation is that the Augmented Dickey-Fuller and Phillips-Perron tests have low power. In other words, these tests may be unable to differentiate between stationary and non-stationary processes. More so, the power of these tests reduces when deterministic terms are accommodated in the test regressions. For these reasons (Ng and Perron 2001) suggest an efficient test that has higher power than the ADF or Phillips-Perron tests. The Elliot-Rothenberg-Stock test is an example of such efficient tests. The Elliot-Rothenberg-Stock test is implemented as the Dickey-Fuller GLS (DF-GLS). Perron and Rodríguez (2003) emphasize that efficient tests have much smaller size distortions and are more robust compared to the first generation unit root tests. Earlier on, Pagan and Schwert (1990) had noted through Monte Carlo investigations that the tests developed by Dickey and Fuller were sensitive to the assumptions that data is generated through a pure autoregressive process. This observation was also made by Perron (1989). In the presence of a moving average component in the series and structural breaks, the ADF tests could produce misleading inferences. Pagan and Schwert (1990) concludes that before one can specify a correct form of the ARIMA model one needs to test for unit roots in the autoregressive polynomials. For our test for unit roots we fall back on the KPSS and DF-GLS test because of their superiority over the first generation tests (which include ADF and Phillips-Perron tests).

Structural breaks or regime shifts do occur in most time series, especially in periods of economic booms and busts, but also through government policy changes, e.g. the variable Gp in equation 3.1. Failure to account for such shifts or breaks can lead to wrong inferences in the unit root tests. Adachi and Liu (2009) emphasize that the outcome of unit root tests based on the assumption of no structural break is not comparable to the outcome in the presence of a break. According to Beyer, Haug et al. (2009), a structural break presents false unit root behaviour and this leads to wrong conclusions. Gregory and Hansen (1996) and Hatemi-J (2008) among others

identify structural breaks as important sources of misspecification of test statistics that can cause the residual based tests to have low power. For these reasons we also employ unit root tests that account for structural breaks.

Our preliminary time series graphs give a hint, based on visual examination, that structural breaks in the local price series might be significant. It is justifiable to anticipate such regime shifts since policy makers do implement measures that can interfere with the normal trends of price series. The presence of structural breaks in time series tends to entertain a wider rejection region in the unit root test such that it becomes difficult to reject the null hypothesis of non-stationarity (Perron 1989). Therefore, it is worthwhile to investigate if there were structural breaks within the period under study and to ascertain the sources of the breaks.

To do this, we adopt a methodology developed by Zivot and Andrews (1992). This procedure allows only one regime shift. The null hypothesis of the Zivot-Andrews test states that the series contains unit roots without any exogenous structural break while the alternative specifies a stationary process with a one-time break at an endogenous break date. This test proves to be more useful and flexible as it does not require *a priori* knowledge of the break point as is required by the Phillips-Perron and other regime shift unit root tests.

3.2.2 Tests for Cointegration

Several methodological options exist for evaluating spatial market linkages. Some of them have been developed within the foundations of cointegration tests by Engle and Granger (1987), and Engle and Yoo (1987). Univariate as well as multivariate cointegration techniques have been used extensively for the obvious reasons that they are able to capture long run relationships among a set of variables. The general cointegration procedures presume that deviations from equilibrium conditions for two or more economic variables, which individually are not stationary, should be stationary in the long run. The intuition is that economic forces should not allow long-run deviations to persist from equilibrium conditions, although significant short-run deviations may be observed. An important implication is that, while individual economic variables such as prices may fluctuate extensively, certain pairs of such variables should not diverge extensively from one another in the long run.

An ordinary regression involving two non-stationary series often leads to a spurious regression. However, a possible linear combination of variables with the same order of integration may exist that is stationary. Defining cointegration as proposed by Engle and Granger (1987), we denote the two series of economic variables, L_{it} (local market $i's$ wheat retail price) and W_t (world market wheat price). Here, each of the series by itself is assumed to be non-stationary

and requires a transformation through first differencing to achieve stationarity. In this case, a linear combination of the two series,

$$L_{it} - \alpha - \beta W_t = \varepsilon_t \tag{3.2}$$

produces a residual series ε_t, which may be stationary. When this is the case, the series L_{it} and W_t are said to be cointegrated. More precisely, if the residuals turn out to be stationary, then L_{it} and W_t are co-integrated of order one, $I(1)$ and the parameter vector $[1, -\beta]$ is the cointegrating vector. The cointegrating vector removes the common trend. Cointegration implies a long-run equilibrium relationship between Li_t and W_t (Verbeek 2010, pp. 338-345).

To test for cointegration, we first have to test whether the price series have the same order of integration using unit-root tests. If both price series have the same order of integration, e.g. I (1) we proceed to test for cointegration among the variables. For this cointegration test we use one of the two approaches based on the outcome of the preliminary unit root tests. If the hypothesis of structural breaks is rejected, then we adopt Johansen's maximum Eigen-value or trace test (Johansen and Juselius 1990; Johansen 1991). However, if the hypothesis for structural break is not rejected, then we adopt Gregory and Hansen (1996) procedure which readily accommodates a single endogenous structural break.

3.2.4 VECM / VAR Test

If the test results prove that there is cointegration, we can specify and estimate a Vector Error Correction Model for all local markets in order to explore price dynamics that may exist among these markets, under the cointegrating constraints and derive the impulse response functions and adjustment parameters from the estimates. These error correction models are specified in the form

$$\Delta L_{it} = c + \alpha_i \left(L_{it-1} - \beta_1 W_{t-1} - \sum_{j=2}^{9} \beta_j L_{jt-1} \right) + \sum_{p=1}^{p} \delta_p \Delta W_{t-p} + \sum_{j=1}^{9} \sum_{p=1}^{p} \gamma_{j,p} \Delta L_{jt-p} + \varepsilon_t \tag{3.3}$$

$$\Delta L_{it} = c + \alpha_i \left(L_{it-1} - \sum_{j=2}^{9} \beta_j L_{jt-1} \right) + \sum_{j=1}^{9} \sum_{p=1}^{p} \gamma_{j,p} \Delta L_{jt-p} + \varepsilon_t \tag{3.4}$$

$\alpha_i \beta_i = \pi_i$ is the impact or pi matrix that measure the long-run effect of shocks to one market on another market.

Equations 3.3 and 3.4 investigate the dynamic relationships among the various prices. We have Δ = first-difference operator, L = local market retail price of wheat, W = world market price of wheat, α = error correction term that measures the speed of adjustment at which short-

run deviations from the long-run equilibrium are corrected in the next period; δ and γ measure the short run elasticity of transmission, β measures the long run elasticity of transmission, p is the number of lags and

$$\left(L_{it-1} - \beta_1 W_{t-1} - \sum_{j=2}^{9} \beta_j L_{jt-1} \right)$$

is the error correction term derived from the cointegrating equation and represents the long-run equilibrium relationship, ε_t is a residual or random component that follows a white noise process.

If our tests show non-cointegration, then we can use a vector autoregressions (VAR) model to generate the impulse response functions. The impulse response function traces the effect and persistence of one market's shock to other markets, and this gives us an indication of how fast information transmits across the markets. We envisage a local market leader (especially the Addis Ababa central grain market) which captures information from the world market and then transmission to other local markets is accomplished. Thus, we can measure how rapidly information is transmitted across different markets. The adjustment parameter coefficients also tell us the speed with which short run deviations return to the long-run equilibrium.

3.2.5 Granger Causality Tests

The concept of Granger causality is based on the principle that two variables W and L can have effects on one another. The intuition is that if W causes L, (or equivalently if L_i causes L_j), then changes in W should lead to later changes in L, or vice versa. Granger causality is assumed to exist between two time series of data L_{it} and W_t if the variance of the error of prediction associated with L_{it} is reduced by including the series W_t. The concept of Granger causality implies that if W_t causes L_{it}, then changes in W_t should precede changes in L_{it}.

In the VAR model our causality equation is as follows:

$$L_{it} = \beta_0 + \beta_1 L_{it-1} + \ldots\ldots + \beta_k L_{it-k} + \varepsilon_t \tag{3.5}$$

$$L_{it} = \beta_0 + \beta_1 L_{it-1} + \ldots\ldots + \beta_k L_{it-k} + \gamma_1 W_{t-1} + \ldots\ldots + \gamma_k W_{t-k} + \varepsilon_t \tag{3.6}$$

L_i is the local market $i's$ retail price of wheat, W is the world market price of wheat, the $\beta's$ and $\gamma's$ are parameters. We test for the significance of the $\gamma's$ and if they are jointly significant, then we conclude that W Granger causes L_i.

In the VECM model, the causality equation can be represented in the form:

$$\Delta L_{it} = c + \alpha_i \left(L_{it-1} - \beta_1 W_{t-1} - \sum_{j=2}^{9} \beta_j L_{jt-1} \right) + \sum_{p=1}^{p} \delta_p \Delta W_{t-p} + \sum_{j=1}^{9} \sum_{p=1}^{p} \gamma_{j,p} \, \Delta L_{jt-p} + \varepsilon_t \qquad (3.7)$$

The variable W_t does not Granger cause L_{it} if its lagged values are not included in equation 3.7. Thus, there is no causal relationship from W_t to L_{it} if $\alpha_i = 0$ and $\delta_p = 0$ are valid. If $\alpha_i \neq 0$ and $\delta = 0$ holds, there is only long-run causality. On the other hand, if $\delta_p \neq 0$ but $\alpha_i = 0$, there is only short-run causality. However, if both $\alpha_i \neq 0$ and $\delta_p \neq 0$, then, there is strong unidirectional Granger causality running from the world market to the local market i. This extends to the other $L_{j's}$.

The Granger causality test can give a good indication of causal relationships among prices of wheat in local markets on the one hand, and between local market prices and world market prices on the other hand. We will use linear Granger causality tests to explore the dynamic relationship between the bi-weekly local prices of wheat in Ethiopian markets and the world market prices.

These causality tests can provide useful information on whether knowledge of past world market price levels and movements in these prices improves short-run forecasts of current and future levels and/or movements in local market prices of wheat. We do not anticipate the reverse causality because it is assumed that the Ethiopian market is too small to have any noticeable effect on world market prices. It could also provide useful information about causality among local retail or wholesale markets. Specific knowledge may exist that enable producers and traders to form expectations and therefore make the necessary adjustments to their pricing decisions. The output obtained from the impulse response functions together with the Granger causality tests provide better insights into the nature of the price linkages compared to that normally provided by standard regression estimations.

CHAPTER FOUR

4.0 EMPIRICAL RESULTS AND DISCUSSION

In this chapter, we present the results from our empirical analysis. The chapter consists of three main sections. Section 4.1 presents and discusses the results from the stationarity tests using different techniques. In Section 4.2 we present the results for the cointegration tests and also discuss the outcomes. Section 4.3 consists of the results and discussion for the error correction model.

4.1 RESULTS FOR UNIT ROOT TESTS

We employed two non-structural break tests and one structural break unit root test to investigate the stationarity of the various price variables. Before carrying out any of these tests, the prices were first converted into natural logarithmic values.

4.1.1 Unit root tests without structural breaks

Table 4.1 presents the outcome of the unit root tests that do not allow for structural breaks. Preliminary investigations were carried out using the DF-GLS and KPSS tests. We first included trend and constant terms but the output indicated that both the trend and constant terms were not significant and so these were dropped from subsequent tests. In the DF-GLS tests, the maximum number of lags included was 4, by the Ng-Perron sequential t method. The results indicated that under the no-break assumption, the null hypothesis of non-stationarity for the DF-GLS could not be rejected at 1% critical level for all price series.

Table 4.1 Results for unit root tests in levels and first differences

Price variable	KPSS test (1%:0.739, 5%: 0.463)		DF-GLS (1%:-2.598, 5%: -1.950)	
	Levels	First difference	Levels	First difference
Maychew	1.38	.168	-0.496	-4.868
Alamata	1.60	.178	-0.119	-3.710
Mak'ele	1.78	.237	-0.293	-8.780
Abi − Adi	1.43	.088	-0.939	-2.557
Hawzen	1.39	.132	-0.679	-1.983
Addigrat	1.52	.154	-0.227	-3.704
Aksum	1.48	.250	-0.580	-9.319
Addis Ababa (wholesale)	1.59	.075	-0.657	-4.763
Addis Ababa (retail)	1.51	.117	-0.429	-6.921
World market	.278	.114	-1.111	-5.951

The output presented in table 4.1 reveals some interesting points. We can immediately see that at the 1% level of significance, the null hypothesis of stationary price series of the KPSS test was rejected for all of the price variables except the world market price. The maximum lag length selected by the Schwert criterion for this test was pegged at 12 lags. However, at lower lag lengths (e.g. with only 4 lags included), the null of stationarity was rejected for the world market price as well. Based on the above tests, the general conclusion was that price series were non-stationary, hence further tests based on first differences was necessary.

Considering the tests based on the first differences, it is evident both tests verified that the various price series attained stationarity after first differencing. All the test statistics were statistically significant at 1% critical level. Hence, we can conveniently conclude based on the results above that all price variables were integrated of the order one, $I(1)$ allowing for potential cointegration among these prices which needs to be investigated. But before we move so fast, we first account for potential structural breaks.

4.1.2 Unit root tests incorporating structural breaks

As discussed in the previous chapter, the presence of one or more structural breaks can overturn the conclusions based on the conventional unit root tests that do not incorporate structural breaks. Therefore, we investigated the presence of unit roots in our price series using tests that admit one break in the series. For this we used the Zivot-Andrews test that allows for a change in trend, which is most relevant for our data. The outcome is presented in table 4.2. The null hypothesis for this test is the presence of unit root without exogenous structural break while the alternative specifies trend stationary series with one endogenous structural break at an unknown break point. Failing to reject the null hypothesis implies that a structural break is not significant; hence the indicated breakpoint is irrelevant.

Table 4.2 Results for univariate unit root tests with one structural break (prices in levels)

Price variable	Zivot-Andrews statistic	Break date
Maychew	-2.803	16/07/2008
Alamata	-3.102	16/07/2008
Mak'ele	-3.416	16/08/2008
Abi − Adi	-2.510	16/08/2008
Hawzen	-2.874	16/07/2008
Addigrat	-3.239	01/07/2008
Aksum	-3.421	01/08/2008
Addis Ababa (wholesale)	-3.733	01/07/2008
Addis Ababa (retail)	-3.236	16/06/2008
World market	-2.011	01/05/2010

Critical values: 1%: -4.93; 5%: -4.42

The observation from the results is that most of the series suffered non-significant structural breaks within the third quarter of 2008. Specifically, the break date generated from the undifferenced Alamata, Maychew and Hawzen price series was on 16th of July, 2008. The test statistics are all lower than the 5% critical values; hence we cannot reject the null hypothesis of non-stationary series vs. the alternative of a stationary series with a structural break. Since these breaks are non-significant, we do not discuss them further. We conclude based on this result, that our price series are truly non-stationary; therefore we proceed to investigate possible cointegration among them.

4.2 TESTS FOR COINTEGRATION

According to the stationarity tests, we found all price series to be integrated of the order one from the tests that do not accommodate structural breaks. We could also not reject the null hypothesis of non-stationarity vs. a structural break from the Zivot-Andrew test. Therefore, our next task was to investigate possible cointegration based on Johansen's approach.

We decided to perform cointegration tests as a system among all the market price variables with the Johansen's approach to investigate the dynamic relationships that exist among them. The maximum optimal lag length was chosen to be two based on the AIC (-23.40198), SBIC (-18.80759) and HQIC (-21.53912). The results are presented in table 4.3. We strongly reject the null hypothesis of no cointegration but could not reject the null hypothesis that $r \leq r_0$ at $r_0 = 5$ for both 1% and 5% critical levels. We conclude that there are at most five cointegrating relationships among the ten wheat market prices.

Table 4.3 Results for Johansen cointegration test among market prices

Rank	Parameters	Eigenvalues	Trace statistic	5% critical value	1% critical value
0	120		372.70	233.13	247.18
1	139	0.504	291.26	192.89	204.95
2	156	0.474	216.68	156.00	168.36
3	171	0.400	157.43	124.24	133.57
4	184	0.355	106.61	94.15	103.18
5	195	0.284	67.80***	68.52	76.07
6	204	0.198	42.16	47.21	54.46
7	211	0.124	26.86	29.68	35.65
8	216	0.111	13.19	15.41	20.04
9	219	0.070	4.77	3.76	6.65
10	220	0.040			

*** indicates significance at 1% critical level

4.3 VECTOR ERROR CORRECTION MODELS (VECM)

The primary function of error correction models is to model stationary relationships among multivariate time series that have unit roots. We established from the Johansen's trace and eigenvalue tests that there were five cointegrating relationships among the ten price variables. Hence, a VECM model for the cointegrated price series is more appropriate than a VAR model.

We estimated the model presented in equation (3.3) for each local market i, to explore causality and dynamic relationship between the world market price and local market retail prices. Hence, we have nine equations to be estimated for all the local markets. The tenth equation, which is the equation for the world market, is not of particular interest to us because of our initial assumptions that Ethiopia is a small country in terms of wheat production and trade.

For the purposes of explaining the various parameter coefficients, we state the estimated model for the Maychew retail market.

$$\Delta L_{1t} = -.098 * (L_{1t-1} - .14W_{t-1} + 1.64L_{6t-1} - 2.12L_{7t-1} + .92L_{8t-1} - 1.88L_{9t-1}) +$$
$$\quad (.111)$$

$$\quad -.453 * (L_{2t-1} - 2.55L_{6t-1} + .87L_{7t-1} + .97L_{8t-1}) +$$
$$\quad (.216)$$

$$\quad .239 * (L_{3t-1} + .14W_{t-1} - 2.61L_{6t-1} + 1.12L_{7t-1} - 1.47L_{8t-1} + 1.9L_{9t-1}) +$$
$$\quad (.196)$$

$$\quad -.048 * (L_{4t-1} + .22W_{t-1} - 2.07L_{6t-1} + 2.25L_{7t-1} + 4.12L_{8t-1} - 6.11L_{9t-1}) +$$
$$\quad (.086)$$

$$\quad .353 * (L_{5t-1} + .12W_{t-1} - 2.21L_{6t-1} + .65L_{7t-1} + 1.81L_{8t-1} - 1.36L_{9t-1})$$
$$\quad (.126)$$

$$\quad -.34\Delta L_{1t-1} + \varepsilon_t \quad\quad\quad\quad\quad\quad\quad\quad\quad (4.1)$$
$$\quad (.130)$$

NB: standard errors of adjustment $(\alpha_{ij,s})$ and short-run parameters in parenthesis.

$L_1 =$ Maychew, $L_2 =$ Alamata, $L_3 =$ Mek'ele, $L_4 =$ Abi-Adi, $L_5 =$ Hawen, $L_6 =$ Adigrat, $L_7 =$ Axum, $L_8 =$ Addis Ababa wholesale, $L_9 =$ Addis Ababa retail, $W =$ World market

The coefficients in front of the error-correction terms are the adjustment parameters for each error correction term. E.g. -0.098 is the adjustment parameter for the first error correction term. If $i = 1$, we refer to the first model (i.e. Maychew equation) and i starts from 1 to 9. If $j = 1$, then we are referring to the first error correction term or long-run relationship and j starts from 1 to 5.

4.3.1 Model fit statistics for the Vector Error Correction Models

The model fit statistics of the cointegration equations are summarized and presented in the table 4.4. From the results, each equation fits pretty well with very significant chi-square values for all the equations except the one for the world market price and the Hawzen market price which are not significant. The statistics for the world market are in accordance with our expectations. The Aksum and Addis Ababa markets have good R-square values, while the rest of the equations have modest R-squares.

Table 4.4 Model fit statistics for vector error correction equations

Equation	R-square	Chi-square	P-value (Chi)
ΔMaychew	0.2885	36.49	0.0025
ΔAlamata	0.3137	41.14	0.0005
ΔMek'ele	0.2602	31.65	0.0111
ΔAbi − Adi	0.2294	26.80	0.0438
ΔHawen	0.2025	22.85	0.1179
ΔAdigrat	0.4092	62.34	0.0000
ΔAxum	0.5468	108.59	0.0000
ΔAddis Ababa wholesale	0.4268	67.01	0.0000
ΔAddis Ababa retail	0.4493	73.43	0.0000
ΔWorld market	0.1626	17.48	0.3553

4.3.2 Short-run coefficients of transmission elasticity

From equation 4.1, the short-run parameter coefficient for Maychew is –.34, and is significantly different from zero at 1%. The world market price, as well as the rest of the local market prices, has no short-run effects on the price of wheat in the Maychew market. The coefficients on these market prices are all insignificant, suggesting that the current retail price of wheat in Maychew adjust to the short-term changes in its previous price only. The output in table 4.5 represents the short run parameters for the nine error correction models we estimated. These parameters measure the elasticity of transmission of price changes from one market to the other. More specifically, it measures the percentage change in the price of wheat in one market caused by one percent change in another market. The general observation is that most of these short run parameters are not statistically significant. In the Maychew model for instance, we realize that only the lagged first-differenced price of Maychew has a significant impact on the current price of wheat in the Maychew market. So, in the Maychew equation, a one percent increase in the average price of wheat in the Maychew market in the previous period leads to 0.34% fall in the current average wheat price in this market. Average prices in the Mek'ele market also respond to changes in its previous prices. The rest of the local markets behave differently. The Addis Ababa wholesale market responds to short-term changes in the prices of Abi-Adi and Hawzen.

The only market that tends to respond to the short-term changes in the prices of many markets is the Abi-Adi market. Thus, within the scope and span of our data, the results provide evidence that local retail market price adjustment to world price shocks in the short-run remains very weak or even zero.

Table 4.5 short-run parameters coefficients for VECM

Model (dependent variable)									
	ΔMaychew	ΔAlamata	ΔMek'ele	ΔAbi-Adi	ΔHawen	ΔAdigrat	ΔAxum	ΔAddis Ababa wholesale	ΔAddis Ababa retail
Independent variable									
Maychew	-.34***		.20*				-.44***		
Alamata									
Mak'ele			-.30**	-.22*					
Abi − Adi							.40***	-.31**	
Hawzen		-.19**					-.24*	.43***	.258**
Adigrat									
Axum				.24*					
Addis Ababa wholesale				.85***					
Addis Ababa retail				-1.04***					
World market									
Intercept									

*** Significant at 1%; ** significant at 5%; * significant at 10%

NB: empty spaces indicate that the parameters are non-significant at 10% level, hence omitted.

4.3.3 Cointegrating vectors and error correction equations

There are five long run equilibrium relationships, given by the error correction equations, among the ten market prices. From our equation 4.1, the error correction term for the first bloc of cointegrating markets is given by

$$z_{1t} = (L_{1t-1} - .14W_{t-1} + 1.64L_{6t-1} - 2.12L_{7t-1} + .92L_{8t-1} - 1.88L_{9t-1}) \qquad (4.2)$$

This combination of prices is stationary and means that this set of prices tend to move in the same direction in the long-run. The issue is whether all of these markets adjust when the long-run equilibrium is disturbed by a random shock.

We categorize these long-run relationships into cointegration blocs for the purposes of our discussion. Each error correction equation, consisting of a bloc of cointegrating markets, signifies the interdependence among those markets. Most of the cointegrating vector parameters are statistically significant at the 1% critical level. The first cointegration bloc exists between the average retail price of Maychew market and the average retail prices of Adigrat, Axum, Addis Ababa and world wheat markets as demonstrated in equation 4.2. The second bloc of cointegrating markets occurs between average retail prices of Alamata, Adigrat, Axum and Addis Ababa wholesale markets. The rest of the blocs are:

Bloc 3: Mek'ele, Adigrat, Axum, Addis Ababa and world market prices

Bloc 4: Abi-Adi, Adigrat, Axum, Addis Ababa and world market prices

Bloc 5: Hawzen, Adigrat, Axum, Addis Ababa and world market prices

Table 4.6 summarizes the set of markets that compose each of the five cointegration relationships or error correction terms. Most local markets cointegrate with the world market and thus share a long-run relationship. Trade is the fundamental element of market integration, and since wheat is an imported cereal in Ethiopia, it is not surprising that local markets have a long-run equilibrium relationship with the world market. It is also interesting to see that most local markets cointegrate among themselves. Our result of cointegration is in conformity with the findings of Rapsomanikis and Mugera (2011), who concluded that the world market wheat price cointegrates with local prices in Ethiopia. Again, different local markets cointegrate, especially with the Addis Ababa markets as found by Getnet (2007).

Table 4.6 Cointegrating vectors for VECM

	Maychew	Alamata	Mek'ele	Abi-Adi	Hawzen	Adigrat	Axum	Addis Ababa wholesale	Addis Ababa retail	World market
	Cointegrating Vectors									
_ce1	1					1.63***	-2.12***	.92*	-1.88***	.14*
_ce2		1				-2.55***	0.87***	.97**		
_ce3			1			-2.61***	1.16***	-1.47***	1.90***	.14**
_ce4				1		-2.07***	2.25***	4.42***	-6.11***	.22**
_ce5					1	-2.21***	.64***	1.81***	-1.35***	.12***

*** Significant at 1%; ** significant at 5%; * significant at 10%

NB: empty spaces indicate that the parameters are non-significant at 10% level, hence omitted.

4.3.6 Adjustment parameters (Long-run coefficients of transmission elasticity)

With reference to equation 4.1, the coefficient $\alpha_{12} = -0.45$ represents the adjustment parameter for Maychew in the second error correction term. The adjustment parameter measures the speed with which markets adjust when the long run equilibrium is disturbed. The figure -0.45 means that when the second cointegrating equation is out of equilibrium due to a 1% shock, the price in Maychew falls with a speed of 0.45% every two weeks in order to restore equilibrium once again. Thus, the Maychew market significantly adjusts to deviations in the second error correction term. With reference to equation 4.2, it is seen that Maychew is not significantly reacting to deviations from equilibrium in the first, third and fourth error correction terms. The coefficient estimates of the adjustment parameters have the correct signs, especially for those markets which prices were normalized to one during estimation. Such variables are expected to have negative coefficients because when their prices are above the equilibrium price, it is expected that they fall back to the equilibrium level. In table 4.8 the coefficients for the adjustment parameters in all the cointegration equations are presented.

Table 4.8 Adjustment parameters

Dependent variable (ΔP_i)	CE1	CE2	CE3	CE4	CE5
ΔMaychew		-.45			.35
ΔAlamata		-.46			.35
ΔMek'ele	-.23				
ΔAbi − Adi		-.39	-.38		
ΔHawen					
ΔAdigrat	.16		.31		.36
ΔAxum	.46			-.28	.40
ΔAddis Ababa wholesale	.41	-.68	.78		
ΔAddis Ababa retail	.42	-.46	.50		
ΔWorld market		.23			

NB: empty spaces indicate that the parameters are non-significant at 10% level, hence omitted.

Generally, we notice that most markets adjust whenever any of the cointegrating equations is out of balance. Specifically, the Addis Ababa wholesale price significantly adjusts to disequilibrium in cointegration blocs 1, 2 and 3 at least at 5% critical level. Adigrat also significantly adjusts to cointegrating equations 1, 3 and 5 whiles Axum adjusts to equations 1, 4

and 5. When the first cointegrating equation is out of balance from the long-run trend, the Addis Ababa market prices surge upward at the rate of approximately 0.41% every two weeks. Mek'ele adjusts only to shocks from the second cointegration bloc.

The Hawzen markets as well as the world markets are not significantly reacting to disequilibrium in any error correction term. These variables are said to be weakly exogenous. Weak exogeneity makes such variables affect other variables but are themselves not affected by any variable. In the case of Hawzen, the location of this town a bit far from the main highway may explain why it tends to be weakly exogenous. If access to this market is poor, it becomes very difficult to integrate with the rest of the marketing centers since transport of goods between markets becomes costly and risky. This makes transactions cost become unnecessarily prohibitive which may prevent trade. In this case, the Hawzen wheat price appears to be a random walk. A variable is said to be a random walk if it is influenced only by the error component. Thus, we can represent prices in Hawzen as

$$\Delta L_{5t} = \varepsilon_t$$

Pricing in this market tends to be random and does not follow any special kind of mechanism.

Among all the markets under consideration, the Addis Ababa wholesale market tends to react strongest (with a speed of 0.78% every two weeks) in the third long-run relationship, whereas Adigrat price reacts slowest to disequilibrium conditions in the first cointegrating bloc. This means the Addis Ababa market leads all other local markets in discovering price innovations. This is clearly in line with our a priori expectations.

4.3.4 Impact parameters (pi matrix)[1] of the VECM

The impact parameters measure the long-run effect of price changes in one market on the price levels in the other market. Our main interest lies in the effects of world market price on local markets. Table 4.7 presents these parameters. From this result, we see that the world market price has significant long-run impact on the price levels in Mek'ele, Adigrat, Axum and Addis Ababa markets. It is interesting to find that in the long-run, a 1% change in the world market price of wheat leads to 0.11% change in the average price level in both the wholesale and retail markets in Addis Ababa.

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[1] $\pi = \alpha\beta'$ represents the $\mathrm{long-run}$ effect of the independent variables on the dependent variable

Table 4.7 Impact parameter coefficients of the vector error correction models

Model (dependent variable)									
Lagged independent variable	ΔMaychew	ΔAlamata	ΔMek'ele	ΔAbi-Adi	ΔHawen	ΔAdigrat	ΔAxum	ΔAddis Ababa wholesale	ΔAddis Ababa retail
Maychew			-.23**			.16**	-.46***	.41***	.42***
Alamata	-.45**	-.46***		-.39**				-.68***	-.46**
Mak'ele				.37**		.31**		.78***	.50***
Abi − Adi							-.28***		.13*
Hawzen	.35***	.35***				.36***	.40***		
Adigrat						-1.1***			
Axum							-1.1***		-.43**
Addis Ababa wholesale				1.22**				-1.1**	
Addis Ababa retail				-1.04**					
World market			-.06**			.09***	.08***	.11***	.11***

*** Significant at 1%; ** significant at 5%; * significant at 10%

NB: empty spaces indicate that the parameters are non-significant even at 10% level, hence omitted.

The greatest long-run impact of world market is on the Addis Ababa market, which is reasonably intuitive. Being the capital city of Ethiopia, we expect Addis Ababa to be the market leader that receives price information from the world market and then transmission to other local retail markets is accomplished. The fact that the world market price has impact on the four identified markets further highlights the importance of transportation or accessibility in market integration. There are airports in three of these markets, which imply that there is a direct access to the world market. We also infer from the table that in the long-run, local market prices have impacts upon one other, except the Hawzen market which appears non-responsive to changes in any other market. The Addis Ababa market responds to long-run price changes in more markets compared to the others.

4.3.7 Results for Granger Causality

As outlined in equation (3.7) of section 3.2.5, we test for the significance of the short-run (δ) and long-run (α) coefficients when testing for Granger causality. The output in tables 4.5 and 4.6 indicate that most parameters, especially the short-run parameters are non-significant. Particularly for the world market price, none of the short-run coefficients is significantly different from zero in the local market equations. Hence, the possibility of strong unidirectional Granger causality running from world to local markets is ruled out. So, in the short-run the null hypothesis that world market does not Granger cause any of the local markets cannot be rejected. The implication is that world market price changes in the short-run (two weeks) are not immediately transmitted to local markets. In the long-run, however, world market price changes do Granger cause local market prices. The null hypothesis of non-Granger causality cannot be rejected for four of the local markets. The (α) coefficients (from the impact matrix) of the world market price are significantly different from zero at 5%. Thus, in the long-run there is unidirectional Granger causality running from the world market to local markets. This is quite reasonable and intuitive. Two weeks may be too short a time to experience immediate changes from the world market at the local level, but in the long-run expectations of producers and traders can imply that prices in local markets adjusts and follow the paths exhibited at the international market.

4.3.7 Impulse Response Functions

We further examine the dynamics between the world market–local market wheat price relationships with the impulse response functions (IRF[2]). Twelve-period (about six months) IRFs for the estimated error correction models are presented in figure 4.1. The impulse here is a one standard deviation positive shock from the world market and the response relates to the

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[2] IRF measures how and for how long an innovation or shock from the independent variable persists on the dependent variable

price(s) affected by the shock. The IRFs indicate that at 5% level of significance, an orthogonalized positive shock to the average world market price has both transitory and permanent effects on the various local markets. A transitory shock is one whose effect dies out immediately or shortly after one or few periods, whereas a permanent shock has effects that persist for a longer time horizon.
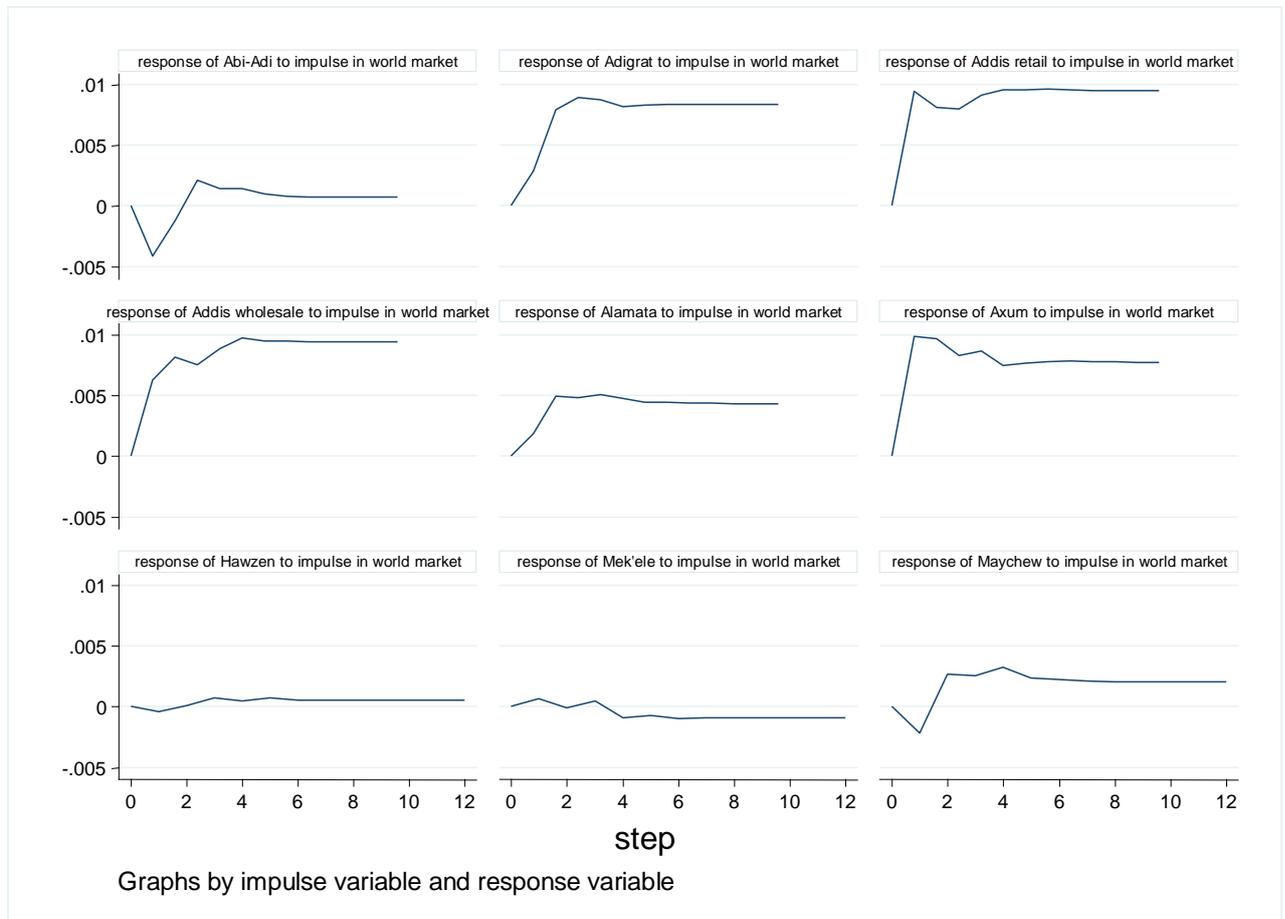
Figure 4.1 Impulse response graphs showing impulse to world market and responses from local markets

Specifically, we find that in the short-term (e.g. within two weeks) the local market wheat price in Abi-Adi, Hawzen and Maychew negatively responds to a given (one-standard-deviation) positive shock in the world market. After two periods (one month), the response from these local markets become positive and then stabilizes. In the Mek'ele market a one-time shock in world market has only a transitory effect. The shock dies out immediately after three periods (six weeks). In the rest of the local markets, shocks from the world market tend to cause an initial rise and fall before attaining stability, but still remain positive. Hence, in the long-run shocks from the world market leads to permanent increase in the average prices in eight local markets. The IRF also shows that the Addis Ababa and Adigrat markets have the largest response to shocks in the world market. Thus, according to our estimated models, in the long-run unexpected shocks that are local to the world market wheat price will have a permanent

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effect on average prices in the Ethiopian local markets. However, there is asymmetric response to those shocks from the world market. This leads to the conclusion that market efficiency in local wheat markets in Ethiopia is yet to be achieved.

CHAPTER FIVE

5.0 SUMMARY AND CONCLUSIONS, RECOMMENDATIONS AND CRITICAL REFLECTION

In this chapter we summarize the main findings from the study and conclude based on the findings. The conclusions are critically examined to arrive at recommendations. Finally, we take stock of the challenges and limitations we had to face in undertaking this research.

5.1 SUMMARY

This study was designed to investigate the short- and long-term price dynamics between world market and local market wheat prices. Effort was extended to discover the relationships among wheat prices in local markets in developing countries. To achieve this goal, we used wheat price data on Addis Ababa market, seven local markets collected from Tigray region of Northern Ethiopia and world market wheat prices taken from a FAO dataset over the period May, 2006 to November, 2010. During the period under study, we discovered that price levels in local markets showed marked variation in contrast to world market prices. Initially, local market price levels stayed below that of the world market but later rose far above world prices and remained high.

We employed multivariate time series techniques to explore the dynamic relationships that existed among the market prices. Preliminary tests for unit roots using both conventional and structural break unit root tests showed that all price series were non-stationary but were all integrated of order one, thus providing scope for possible cointegration. The Johansen's cointegration tests predicted at most five long-run relationships among the ten price variables.

We then fitted a vector error correction model for all ten price series as a system. The overall model fit was good for all equations estimated with moderate R-square values and very significant chi-squares except the Hawzen and world markets. Results indicated that local markets shared long run relationships with world market as well as with one another. Short term effects were not clear-cut, though few of the short run elasticity of transmission coefficients were significant. Specifically, the short-run effects of world market on all local markets under consideration were not significant, implying that within a period of two weeks, shocks to world market are not immediately transmitted to local markets in Ethiopia.

The five error correction models were found to consist of blocs of cointegrated markets, namely,

Bloc 1: Maychew, Adigrat, Axum and Addis Ababa and world market prices
Bloc 2: Alamata, Adigrat and Axum and Addis Ababa wholesale
Bloc 3: Mak'ele, Adigrat, Axum, Addis Ababa and world market

Bloc 4: Abi-Adi, Adigrat, Axum, Addis Ababa and world market

Bloc 5: Hawzen, Adigrat, Axum, Addis Ababa and world market

The cointegrating vector for each variable in the outlined error correction model was statistically significant. Generally, markets within a particular bloc adjust when the long run equilibrium is disturbed by any stochastic force in order to restore equilibrium once more. The speed of adjustment varies per market but most of the estimated parameters were moderate to high. We found that most of the local markets adjust to the Addis Ababa market prices because of its central role in domestic grain price determination and information processing. The exceptional revelation was the case of Hawzen wheat market, located some distance off the main highway, which seemed reluctant to adjust to any disequilibrium condition. The Hawzen market price thus followed a random walk. Markets along the corridor of the main highway have pretty high and significant estimates of adjustment coefficients, thus suggesting that good market access are key elements of market integration.

5.2 CONCLUSIONS BASED ON FINDINGS

We conclude based on our findings that

1. With reference to the price trends within the period under study, price levels in Ethiopian local markets had a different pattern than world market. Whiles local prices were initially below world prices, it later rose and stayed high after 2008.

2. In the short-term the bi-weekly world market price of wheat has no significant effect on local market retail wheat prices in Ethiopia. However, in the long-run, world market price is cointegrated with some local market wheat prices. The implication is that price developments in those local markets move in the same direction as the world market because they share a long-run equilibrium relationship.

3. Granger causality tests, which shows how past trends in world market determine local market prices of wheat, indicate that the world market price does not Granger cause local market prices in the short-run due to the relatively short time dimension. However, in the long-run there is unidirectional causality from the world to local markets, possibly because producers and traders have more time flexibility to adjust their production and marketing decisions.

4. In the long-run the world market has significant impacts on the local markets. An innovation in the world market tends to be transmitted asymmetrically to the various local markets in Ethiopia. Addis Ababa market is the most sensitive and responsive in capturing price innovations from the world market.

5. A group of local markets also share both short- and long-run relationships with each other. A key feature of such cointegrated market prices is the proximity to each other or/and importantly, presence of good market access. Most markets are cointegrated with the central grain market, Addis Ababa which plays a central role in grain price determination.

5.3 POLICY IMPLICATIONS AND RECOMMENDATION

Good market access ensures free and easy flow of goods and services between markets. Good market accessibility has the tendency to remove price distortions and results in efficient pricing within a particular country. This guarantees that an isolated market does not suffer so much price hikes or distortions, and thus becomes integrated with other markets. Hence, it is important to improve roads and other infrastructure that will make possible free movement of goods across regions and between markets. Also essential is the flow of information across the markets so that through arbitrage, the law-of-one-price exists among local markets. When this is accomplished, asymmetric pricing which leads to market inefficiencies will be removed. This calls for the establishment of adequate price information systems that are mandated to transmit commodity price and stock information across markets.

Our analysis revealed that scope exists for looking into more local markets and across regions with world market. If reliable data can be obtained on more internationally traded commodities, it would be interesting to look into price dynamics with the world market in a general equilibrium framework. Moreover, our results showed that local markets responded differently to the same shock from the world market. This resulted in asymmetric pricing. We find future research to be worth investigating how producers and retailers respond to this price asymmetry in the different markets, and how it helps them to form expectations of price changes and subsequent effect on the level of these prices.

5.3 CRITICAL REFLECTION

In this study there were practical challenges and limitations that were encountered along the way. The first is the issue of missing data. The data for the study was collected by the Tigray Agricultural Marketing Promotion Agency (TAMPA) and several observations on specific dates were not collected. It was a real challenge to come up with values for such missing data since the time series regression technique used does not permit missing observations. Techniques for handling missing observations in time series are not common and require more than the normal way of dealing with missing data. It was thus a real challenge to come up with a better way of solving this problem. But in the end, great lessons have been learnt from that challenge. Again, applied time series econometrics is an interesting subject area to work. The usual vector error correction models that most authors estimate and interpret normally have few variables. But

this work involved ten variables, hence more than 100 parameters to estimate and interpret. To come up with plausible explanation and/or interpretation, it required much time and great effort. Nonetheless, it is always satisfying to learn much from these challenges. It is believed that such challenges are worthy prerequisites and have the potential to prepare a person adequately for future research, professional life and career.

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APPENDIX

A1. Stata output from vector error correction models

```
Vector error-correction model

Sample:  3 - 110                              No. of obs   =        108
                                              AIC          = -23.40198
Log likelihood =  1448.707                    HQIC         = -21.53912
Det(Sigma_ml)  =  1.06e-24                    SBIC         = -18.80759

Equation          Parms      RMSE     R-sq      chi2     P>chi2
```

Equation	Parms	RMSE	R-sq	chi2	P>chi2
D_l_may	16	.107974	0.2885	36.49354	0.0025
D_l_ala	16	.077884	0.3137	41.13705	0.0005
D_l_mak	16	.100219	0.2602	31.65079	0.0111
D_l_abi	16	.086215	0.2294	26.79872	0.0438
D_l_haw	16	.098669	0.2025	22.84788	0.1179
D_l_adi	16	.068552	0.4092	62.34259	0.0000
D_l_axum	16	.103539	0.5468	108.5932	0.0000
D_l_adw	16	.118711	0.4268	67.01466	0.0000
D_l_adr	16	.09633	0.4493	73.43518	0.0000
D_l_wmp	16	.067544	0.1626	17.47924	0.3553

A1.1 VECM statistics for the Maychew retail market price model

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
D_l_may						
_ce1						
L1.	-.0984768	.1110323	-0.89	0.375	-.3160961	.1191425
_ce2						
L1.	-.4532345	.215933	-2.10	0.036	-.8764554	-.0300137
_ce3						
L1.	.2391685	.1960379	1.22	0.222	-.1450588	.6233957
_ce4						
L1.	-.0478452	.0861436	-0.56	0.579	-.2166835	.120993
_ce5						
L1.	.3535596	.1261475	2.80	0.005	.1063151	.6008041
l_may						
LD.	-.3366592	.1296946	-2.60	0.009	-.590856	-.0824624
l_ala						
LD.	-.015654	.2158609	-0.07	0.942	-.4387336	.4074257
l_mak						
LD.	-.0320931	.16195	-0.20	0.843	-.3495092	.285323
l_abi						
LD.	.2329004	.1421848	1.64	0.101	-.0457767	.5115775
l_haw						
LD.	-.1578562	.1391085	-1.13	0.256	-.4305038	.1147914
l_adi						
LD.	.1976135	.2516339	0.79	0.432	-.2955799	.6908069
l_axum						
LD.	-.0060211	.1702978	-0.04	0.972	-.3397986	.3277564
l_adw						
LD.	.0374299	.3530276	0.11	0.916	-.6544915	.7293513
l_adr						
LD.	-.0660931	.4232122	-0.16	0.876	-.8955739	.7633876
l_wmp						
LD.	-.0458032	.1735534	-0.26	0.792	-.3859617	.2943553
_cons	.0001991	.0106926	0.02	0.985	-.0207579	.0211562

A1.2 VECM statistics for the Alamata retail market price model

D_l_ala							
_ce1						
L1.	−.0175109	.08009	−0.22	0.827	−.1744845	.1394627
_ce2						
L1.	−.4644686	.1557572	−2.98	0.003	−.7697472	−.1591901
_ce3						
L1.	.217276	.1414065	1.54	0.124	−.0598756	.4944276
_ce4						
L1.	.0163906	.0621373	0.26	0.792	−.1053962	.1381774
_ce5						
L1.	.3544248	.0909929	3.90	0.000	.1760818	.5327677
l_may						
LD.	.0076794	.0935516	0.08	0.935	−.1756784	.1910372
l_ala						
LD.	−.1795531	.1557053	−1.15	0.249	−.4847298	.1256237
l_mak						
LD.	−.0797817	.1168181	−0.68	0.495	−.308741	.1491776
l_abi						
LD.	.0965458	.1025611	0.94	0.347	−.1044702	.2975618
l_haw						
LD.	−.1922812	.100342	−1.92	0.055	−.3889479	.0043856
l_adi						
LD.	.0811771	.1815091	0.45	0.655	−.2745742	.4369284
l_axum						
LD.	.0475725	.1228395	0.39	0.699	−.1931885	.2883336
l_adw						
LD.	−.0653817	.2546466	−0.26	0.797	−.5644799	.4337165
l_adr						
LD.	.069709	.3052723	0.23	0.819	−.5286138	.6680318
l_wmp						
LD.	−.0020667	.1251879	−0.02	0.987	−.2474306	.2432971
_cons	.0015914	.0077128	0.21	0.837	−.0135254	.0167082

A1.3 VECM statistics for the Mek'ele retail market price model

D_l_mak							
_ce1						
L1.	−.2331851	.1030578	−2.26	0.024	−.4351748	−.0311955
_ce2						
L1.	.0047827	.2004244	0.02	0.981	−.3880419	.3976074
_ce3						
L1.	−.2730248	.1819582	−1.50	0.133	−.6296564	.0836068
_ce4						
L1.	−.0602907	.0799566	−0.75	0.451	−.2170028	.0964214
_ce5						
L1.	.1873833	.1170874	1.60	0.110	−.0421038	.4168703
l_may						
LD.	.2021092	.1203798	1.68	0.093	−.0338309	.4380493
l_ala						
LD.	−.0629572	.2003576	−0.31	0.753	−.4556508	.3297364
l_mak						
LD.	−.3051848	.1503185	−2.03	0.042	−.5998037	−.0105659
l_abi						
LD.	−.1164384	.1319729	−0.88	0.378	−.3751006	.1422238
l_haw						
LD.	.0857185	.1291175	0.66	0.507	−.1673473	.3387842
l_adi						
LD.	.0201316	.2335613	0.09	0.931	−.43764	.4779033
l_axum						
LD.	−.0678531	.1580668	−0.43	0.668	−.3776582	.2419521
l_adw						
LD.	−.0180745	.3276728	−0.06	0.956	−.6603013	.6241523
l_adr						
LD.	−.0335712	.3928166	−0.09	0.932	−.8034777	.7363352
l_wmp						
LD.	.0712859	.1610886	0.44	0.658	−.244442	.3870138
_cons	.0063524	.0099246	0.64	0.522	−.0130995	.0258043

A1.4 VECM statistics for the Abi-Adi retail market price model

D_l_abi							
_ce1							
L1.	.0669839	.0886568	0.76	0.450	-.1067804	.2407481
_ce2							
L1.	-.3933639	.1724178	-2.28	0.023	-.7312965	-.0554314
_ce3							
L1.	.3756405	.156532	2.40	0.016	.0688434	.6824375
_ce4							
L1.	-.0996864	.0687837	-1.45	0.147	-.2345001	.0351272
_ce5							
L1.	.1467111	.100726	1.46	0.145	-.0507082	.3441304
l_may							
LD.	-.0358111	.1035583	-0.35	0.729	-.2387817	.1671595
l_ala							
LD.	.0753332	.1723602	0.44	0.662	-.2624867	.413153
l_mak							
LD.	-.218286	.1293135	-1.69	0.091	-.4717358	.0351638
l_abi							
LD.	-.1135991	.1135315	-1.00	0.317	-.3361167	.1089185
l_haw							
LD.	-.0125084	.1110751	-0.11	0.910	-.2302116	.2051947
l_adi							
LD.	.2311718	.2009242	1.15	0.250	-.1626323	.624976
l_axum							
LD.	.2446454	.135979	1.80	0.072	-.0218687	.5111594
l_adw							
LD.	.8526088	.2818848	3.02	0.002	.3001247	1.405093
l_adr							
LD.	-1.036897	.3379257	-3.07	0.002	-1.699219	-.3745749
l_wmp							
LD.	-.0873834	.1385786	-0.63	0.528	-.3589926	.1842257
_cons	-.0003762	.0085378	-0.04	0.965	-.0171099	.0163576

A1.5 VECM statistics for the Hawzen retail market price model

D_l_haw							
_ce1							
L1.	-.0748694	.1014638	-0.74	0.461	-.2737348	.1239959
_ce2							
L1.	.2830134	.1973243	1.43	0.151	-.1037352	.669762
_ce3							
L1.	-.1547007	.1791438	-0.86	0.388	-.505816	.1964147
_ce4							
L1.	-.0237482	.0787199	-0.30	0.763	-.1780364	.1305399
_ce5							
L1.	-.139834	.1152763	-1.21	0.225	-.3657715	.0861035
l_may							
LD.	.1883009	.1185178	1.59	0.112	-.0439898	.4205916
l_ala							
LD.	-.0033117	.1972585	-0.02	0.987	-.3899312	.3833079
l_mak							
LD.	.0323117	.1479935	0.22	0.827	-.2577502	.3223736
l_abi							
LD.	.1590711	.1299316	1.22	0.221	-.0955902	.4137325
l_haw							
LD.	-.2086358	.1271204	-1.64	0.101	-.4577873	.0405156
l_adi							
LD.	-.1424211	.2299487	-0.62	0.536	-.5931122	.30827
l_axum							
LD.	.1143048	.1556219	0.73	0.463	-.1907085	.4193181
l_adw							
LD.	-.0058971	.3226045	-0.02	0.985	-.6381902	.6263961
l_adr							
LD.	.0611696	.3867407	0.16	0.874	-.6968283	.8191675
l_wmp							
LD.	.0211525	.158597	0.13	0.894	-.2896919	.3319969
_cons	.0061834	.0097711	0.63	0.527	-.0129676	.0253344

A1.6 VECM statistics for the Adigrat retail market price model

D_l_adi							
_ce1						
L1.	.1564846	.0704938	2.22	0.026	.0183192	.29465
_ce2						
L1.	-.0246818	.1370948	-0.18	0.857	-.2933826	.244019
_ce3						
L1.	.3087431	.1244635	2.48	0.013	.0647991	.5526871
_ce4						
L1.	-.0853772	.0546921	-1.56	0.119	-.1925718	.0218174
_ce5						
L1.	.3590171	.0800904	4.48	0.000	.2020429	.5159914
l_may						
LD.	-.1065425	.0823425	-1.29	0.196	-.2679308	.0548458
l_ala						
LD.	.0335712	.137049	0.24	0.806	-.2350399	.3021824
l_mak						
LD.	-.1431793	.1028212	-1.39	0.164	-.3447053	.0583466
l_abi						
LD.	.0896587	.0902724	0.99	0.321	-.087272	.2665894
l_haw						
LD.	-.0628126	.0883193	-0.71	0.477	-.2359153	.11029
l_adi						
LD.	.14807	.1597611	0.93	0.354	-.1650561	.461196
l_axum						
LD.	.0041274	.1081212	0.04	0.970	-.2077862	.2160411
l_adw						
LD.	-.0749214	.2241355	-0.33	0.738	-.5142189	.364376
l_adr						
LD.	-.0617318	.2686953	-0.23	0.818	-.588365	.4649013
l_wmp						
LD.	-.0423857	.1101882	-0.38	0.700	-.2583506	.1735793
_cons	-.0004284	.0067887	-0.06	0.950	-.013734	.0128771

A1.7 VECM statistics for the Axum retail market price model

D_l_axum							
_ce1						
L1.	.4594616	.1064714	4.32	0.000	.2507814	.6681418
_ce2						
L1.	.0847063	.2070631	0.41	0.682	-.32113	.4905426
_ce3						
L1.	.1713896	.1879853	0.91	0.362	-.1970548	.5398341
_ce4						
L1.	-.2839373	.0826051	-3.44	0.001	-.4458402	-.1220343
_ce5						
L1.	.4042268	.1209657	3.34	0.001	.1671383	.6413152
l_may						
LD.	-.4408751	.1243672	-3.54	0.000	-.6846304	-.1971199
l_ala						
LD.	.1447861	.2069941	0.70	0.484	-.2609148	.5504871
l_mak						
LD.	-.1399763	.1552976	-0.90	0.367	-.444354	.1644014
l_abi						
LD.	.4005839	.1363443	2.94	0.003	.133354	.6678139
l_haw						
LD.	-.2451001	.1333944	-1.84	0.066	-.5065482	.0163481
l_adi						
LD.	.2256309	.2412976	0.94	0.350	-.2473037	.6985655
l_axum						
LD.	.0714205	.1633025	0.44	0.662	-.2486465	.3914874
l_adw						
LD.	-.185264	.3385264	-0.55	0.584	-.8487635	.4782355
l_adr						
LD.	.0899185	.405828	0.22	0.825	-.7054898	.8853269
l_wmp						
LD.	.072921	.1664244	0.44	0.661	-.2532649	.3991069
_cons	.000681	.0102534	0.07	0.947	-.0194152	.0207772

A1.8 VECM statistics for the Addis Ababa wholesale price model

D_l_adw						
_ce1						
L1.	.4094716	.1220729	3.35	0.001	.170213	.6487302
_ce2						
L1.	-.6843854	.2374046	-2.88	0.004	-1.14969	-.2190809
_ce3						
L1.	.7848067	.2155312	3.64	0.000	.3623732	1.20724
_ce4						
L1.	.1338287	.0947094	1.41	0.158	-.0517982	.3194556
_ce5						
L1.	-.1773822	.1386911	-1.28	0.201	-.4492117	.0944474
l_may						
LD.	.0068992	.142591	0.05	0.961	-.272574	.2863725
l_ala						
LD.	.05423	.2373254	0.23	0.819	-.4109192	.5193792
l_mak						
LD.	-.241984	.1780537	-1.36	0.174	-.5909628	.1069949
l_abi						
LD.	-.3107177	.1563232	-1.99	0.047	-.6171055	-.0043299
l_haw						
LD.	.4292824	.1529409	2.81	0.005	.1295237	.7290412
l_adi						
LD.	-.1459545	.2766555	-0.53	0.598	-.6881893	.3962803
l_axum						
LD.	.1146555	.1872316	0.61	0.540	-.2523116	.4816226
l_adw						
LD.	.0863377	.3881314	0.22	0.824	-.6743859	.8470613
l_adr						
LD.	-.1073435	.4652949	-0.23	0.818	-1.019305	.8046178
l_wmp						
LD.	-.0112598	.190811	-0.06	0.953	-.3852425	.3627229
_cons	.002435	.0117558	0.21	0.836	-.020606	.0254759

A1.9 VECM statistics for the Addis Ababa retail price model

D_l_adr						
_ce1						
L1.	.4207384	.0990579	4.25	0.000	.2265885	.6148883
_ce2						
L1.	-.4613155	.1926455	-2.39	0.017	-.8388937	-.0837373
_ce3						
L1.	.5050679	.174896	2.89	0.004	.162278	.8478578
_ce4						
L1.	.1399839	.0768533	1.82	0.069	-.0106458	.2906137
_ce5						
L1.	-.0283476	.112543	-0.25	0.801	-.2489278	.1922325
l_may						
LD.	-.1243215	.1157076	-1.07	0.283	-.3511042	.1024612
l_ala						
LD.	.0622744	.1925812	0.32	0.746	-.3151778	.4397267
l_mak						
LD.	-.1611489	.1444843	-1.12	0.265	-.444333	.1220352
l_abi						
LD.	-.1574048	.1268508	-1.24	0.215	-.4060277	.0912182
l_haw						
LD.	.2586083	.1241062	2.08	0.037	.0153647	.501852
l_adi						
LD.	.0052923	.2244962	0.02	0.981	-.4347122	.4452968
l_axum						
LD.	.160678	.1519318	1.06	0.290	-.137103	.4584589
l_adw						
LD.	.0608505	.314955	0.19	0.847	-.5564501	.678151
l_adr						
LD.	-.1876027	.3775705	-0.50	0.619	-.9276274	.5524219
l_wmp						
LD.	.0362234	.1548364	0.23	0.815	-.2672504	.3396972
_cons	.0016533	.0095394	0.17	0.862	-.0170436	.0203502

A1.10 VECM statistics for the World market price model

D_l_wmp						
_ce1						
L1.	.0143056	.0694569	0.21	0.837	-.1218274	.1504386
_ce2						
L1.	.2302869	.1350781	1.70	0.088	-.0344613	.4950352
_ce3						
L1.	-.0532118	.1226326	-0.43	0.664	-.2935674	.1871437
_ce4						
L1.	.0137354	.0538876	0.25	0.799	-.0918824	.1193531
_ce5						
L1.	-.0999332	.0789123	-1.27	0.205	-.2545984	.054732
l_may						
LD.	-.0956582	.0811312	-1.18	0.238	-.2546725	.0633561
l_ala						
LD.	-.22543	.1350331	-1.67	0.095	-.49009	.0392299
l_mak						
LD.	.1911723	.1013087	1.89	0.059	-.0073892	.3897337
l_abi						
LD.	.0014279	.0889445	0.02	0.987	-.1729002	.175756
l_haw						
LD.	.0901898	.0870201	1.04	0.300	-.0803665	.2607461
l_adi						
LD.	.1804899	.157411	1.15	0.252	-.1280301	.4890099
l_axum						
LD.	-.0061866	.1065307	-0.06	0.954	-.214983	.2026099
l_adw						
LD.	-.3093557	.2208385	-1.40	0.161	-.7421911	.1234798
l_adr						
LD.	.3015406	.2647429	1.14	0.255	-.2173459	.820427
l_wmp						
LD.	.0979676	.1085674	0.90	0.367	-.1148205	.3107558
_cons	.00548	.0066888	0.82	0.413	-.0076299	.0185898

A2. Stata output for cointegrating equations

```
Cointegrating equations

Equation          Parms     chi2     P>chi2
_ce1                  5    604.7731   0.0000
_ce2                  5    951.7454   0.0000
_ce3                  5    658.9764   0.0000
_ce4                  5    203.6248   0.0000
_ce5                  5    1062.795   0.0000
```

```
Identification:  beta is exactly identified
                 Johansen normalization restrictions imposed
```

beta	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
_ce1						
l_may	1	.	.	.	.	.
l_ala	2.78e-17	.	.	.	.	.
l_mak	-6.25e-17	.	.	.	.	.
l_abi	-3.62e-17	.	.	.	.	.
l_haw	-6.94e-17	.	.	.	.	.
l_adi	1.635231	.3968414	4.12	0.000	.8574364	2.413026
l_axum	-2.124663	.3156439	-6.73	0.000	-2.743314	-1.506013
l_adw	.9192704	.5491913	1.67	0.094	-.1571249	1.995666
l_adr	-1.884339	.6962327	-2.71	0.007	-3.24893	-.5197478
l_wmp	.1418208	.0753022	1.88	0.060	-.0057687	.2894103
_cons	1.802856	.	.	.	.	.
_ce2						
l_may	5.55e-17	.	.	.	.	.
l_ala	1	.	.	.	.	.
l_mak	3.33e-16	.	.	.	.	.
l_abi	-1.73e-18	.	.	.	.	.
l_haw	5.55e-17	.	.	.	.	.
l_adi	-2.554592	.32228	-7.93	0.000	-3.186249	-1.922935
l_axum	.8667151	.2563385	3.38	0.001	.364301	1.369129
l_adw	.9700034	.4460054	2.17	0.030	.0958489	1.844158
l_adr	-.5695874	.5654195	-1.01	0.314	-1.677789	.5386145
l_wmp	.0923034	.0611538	1.51	0.131	-.027556	.2121627
_cons	1.134965	.	.	.	.	.

	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]
_ce3						
l_may	8.33e-17	.	.	.	.	.
l_ala	-1.11e-16	.	.	.	.	.
l_mak	1	.	.	.	.	.
l_abi	-1.39e-17	.	.	.	.	.
l_haw	(dropped)					
l_adi	-2.61497	.3732908	-7.01	0.000	-3.346606	-1.883333
l_axum	1.12367	.296912	3.78	0.000	.5417327	1.705606
l_adw	-1.466019	.5165995	-2.84	0.005	-2.478536	-.4535028
l_adr	1.897122	.6549147	2.90	0.004	.6135123	3.180731
l_wmp	.1381275	.0708333	1.95	0.051	-.0007033	.2769583
_cons	-.4925075	.	.	.	.	.
_ce4						
l_may	(dropped)					
l_ala	-1.11e-16	.	.	.	.	.
l_mak	8.33e-17	.	.	.	.	.
l_abi	1	.	.	.	.	.
l_haw	-5.55e-17	.	.	.	.	.
l_adi	-2.066099	.6045066	-3.42	0.001	-3.25091	-.8812876
l_axum	2.247643	.4808188	4.67	0.000	1.305256	3.190031
l_adw	4.419508	.8365805	5.28	0.000	2.77984	6.059175
l_adr	-6.114033	1.060568	-5.76	0.000	-8.192708	-4.035358
l_wmp	.219819	.1147074	1.92	0.055	-.0050033	.4446414
_cons	1.40852	.	.	.	.	.
_ce5						
l_may	6.42e-17	.	.	.	.	.
l_ala	-2.78e-17	.	.	.	.	.
l_mak	3.64e-17	.	.	.	.	.
l_abi	-1.90e-17	.	.	.	.	.
l_haw	1	.	.	.	.	.
l_adi	-2.206003	.2557156	-8.63	0.000	-2.707196	-1.70481
l_axum	.6456998	.2033938	3.17	0.002	.2470553	1.044344
l_adw	1.805809	.3538865	5.10	0.000	1.112205	2.499414
l_adr	-1.358486	.4486366	-3.03	0.002	-2.237798	-.4791745
l_wmp	.1234156	.048523	2.54	0.011	.0283122	.2185189
_cons	.1876015	.	.	.	.	.

A3. Impact parameters from the vector error correction models

A3.1 Impact parameters Maychew market model

Pi	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]
D_l_may						
l_may						
L1.	-.0984768	.1110323	-0.89	0.375	-.3160961	.1191425
l_ala						
L1.	-.4532345	.215933	-2.10	0.036	-.8764554	-.0300137
l_mak						
L1.	.2391685	.1960379	1.22	0.222	-.1450588	.6233957
l_abi						
L1.	-.0478452	.0861436	-0.56	0.579	-.2166835	.120993
l_haw						
L1.	.3535596	.1261475	2.80	0.005	.1063151	.6008041
l_adi						
L1.	-.3097219	.3445882	-0.90	0.369	-.9851024	.3656586
l_axum						
L1.	.2059054	.2525277	0.82	0.415	-.2890397	.7008506
l_adw						
L1.	-.4537825	.5369098	-0.85	0.398	-1.506106	.5985414
l_adr						
L1.	.7096735	.6233115	1.14	0.255	-.5119945	1.931342
l_wmp						
L1.	.0103521	.0290621	0.36	0.722	-.0466085	.0673126

A3.2 Impact parameters Alamata market model

D_l_ala						
l_may						
L1.	-.0175109	.08009	-0.22	0.827	-.1744845	.1394627
l_ala						
L1.	-.4644686	.1557572	-2.98	0.003	-.7697472	-.1591901
l_mak						
L1.	.217276	.1414065	1.54	0.124	-.0598756	.4944276
l_abi						
L1.	.0163906	.0621373	0.26	0.792	-.1053962	.1381774
l_haw						
L1.	.3544248	.0909929	3.90	0.000	.1760818	.5327677
l_adi						
L1.	-.2260032	.2485591	-0.91	0.363	-.7131701	.2611636
l_axum						
L1.	.1444813	.1821538	0.79	0.428	-.2125336	.5014961
l_adw						
L1.	-.0727023	.387285	-0.19	0.851	-.8317669	.6863623
l_adr						
L1.	.1280572	.4496084	0.28	0.776	-.753159	1.009273
l_wmp						
L1.	.0320009	.0209631	1.53	0.127	-.0090861	.0730878

A3.3 Impact parameters Mek'ele market model

D_l_mak						
l_may						
L1.	-.2331851	.1030578	-2.26	0.024	-.4351748	-.0311955
l_ala						
L1.	.0047827	.2004244	0.02	0.981	-.3880419	.3976074
l_mak						
L1.	-.2730248	.1819582	-1.50	0.133	-.6296564	.0836068
l_abi						
L1.	-.0602907	.0799566	-0.75	0.451	-.2170028	.0964214
l_haw						
L1.	.1873833	.1170874	1.60	0.110	-.0421038	.4168703
l_adi						
L1.	.0316205	.3198395	0.10	0.921	-.5952533	.6584944
l_axum						
L1.	.1782769	.2343908	0.76	0.447	-.2811207	.6376745
l_adw						
L1.	.262462	.4983484	0.53	0.598	-.7142828	1.239207
l_adr						
L1.	.0327761	.5785445	0.06	0.955	-1.10115	1.166703
l_wmp						
L1.	-.0604683	.0269748	-2.24	0.025	-.1133379	-.0075987

A3.4 Impact parameters Abi-Adi market model

D_l_abi						
l_may						
L1.	.0669839	.0886568	0.76	0.450	-.1067804	.2407481
l_ala						
L1.	-.3933639	.1724178	-2.28	0.023	-.7312965	-.0554314
l_mak						
L1.	.3756405	.156532	2.40	0.016	.0688434	.6824375
l_abi						
L1.	-.0996864	.0687837	-1.45	0.147	-.2345001	.0351272
l_haw						
L1.	.1467111	.100726	1.46	0.145	-.0507082	.3441304
l_adi						
L1.	.0144468	.2751462	0.05	0.958	-.5248298	.5537233
l_axum						
L1.	-.190485	.2016378	-0.94	0.345	-.5856879	.2047178
l_adw						
L1.	-1.046317	.4287108	-2.44	0.015	-1.886574	-.2060591
l_adr						
L1.	1.220651	.4977006	2.45	0.014	.2451763	2.196127
l_wmp						
L1.	.0212706	.0232054	0.92	0.359	-.0242112	.0667524

A3.5 Impact parameters Hawzen market model

D_1_haw						
1_may						
L1.	-.0748694	.1014638	-0.74	0.461	-.2737348	.1239959
1_ala						
L1.	.2830134	.1973243	1.43	0.151	-.1037352	.669762
1_mak						
L1.	-.1547007	.1791438	-0.86	0.388	-.505816	.1964147
1_abi						
L1.	-.0237482	.0787199	-0.30	0.763	-.1780364	.1305399
1_haw						
L1.	-.139834	.1152763	-1.21	0.225	-.3657715	.0861035
1_adi						
L1.	-.0833346	.3148924	-0.26	0.791	-.7005122	.5338431
1_axum						
L1.	.0868636	.2307654	0.38	0.707	-.3654283	.5391554
1_adw						
L1.	.0750238	.4906401	0.15	0.878	-.8866132	1.036661
1_adr						
L1.	.0215525	.5695959	0.04	0.970	-1.094835	1.13794
1_wmp						
L1.	-.0283414	.0265575	-1.07	0.286	-.0803932	.0237105

A3.6 Impact parameters Adigrat market model

D_1_adi						
1_may						
L1.	.1564846	.0704938	2.22	0.026	.0183192	.29465
1_ala						
L1.	-.0246818	.1370948	-0.18	0.857	-.2933826	.244019
1_mak						
L1.	.3087431	.1244635	2.48	0.013	.0647991	.5526871
1_abi						
L1.	-.0853772	.0546921	-1.56	0.119	-.1925718	.0218174
1_haw						
L1.	.3590171	.0800904	4.48	0.000	.2020429	.5159914
1_adi						
L1.	-1.104009	.2187773	-5.05	0.000	-1.532804	-.6752129
1_axum						
L1.	.0329758	.1603286	0.21	0.837	-.2812624	.347214
1_adw						
L1.	-.0617217	.3408814	-0.18	0.856	-.729837	.6063935
1_adr						
L1.	.3391908	.3957374	0.86	0.391	-.4364401	1.114822
1_wmp						
L1.	.0881012	.0184514	4.77	0.000	.0519372	.1242652

A3.7 Impact parameters Axum market model

D_1_axum						
1_may						
L1.	.4594616	.1064714	4.32	0.000	.2507814	.6681418
1_ala						
L1.	.0847063	.2070631	0.41	0.682	-.32113	.4905426
1_mak						
L1.	.1713896	.1879853	0.91	0.362	-.1970548	.5398341
1_abi						
L1.	-.2839373	.0826051	-3.44	0.001	-.4458402	-.1220343
1_haw						
L1.	.4042268	.1209657	3.34	0.001	.1671383	.6413152
1_adi						
L1.	-.2183257	.3304336	-0.66	0.509	-.8659637	.4293124
1_axum						
L1.	-1.08738	.2421547	-4.49	0.000	-1.561995	-.6127659
1_adw						
L1.	-.271632	.5148553	-0.53	0.598	-1.28073	.7374659
1_adr						
L1.	.5979833	.5977079	1.00	0.317	-.5735026	1.769469
1_wmp						
L1.	.0841266	.0278683	3.02	0.003	.0295057	.1387474

A3.8 Impact parameters Addis Ababa wholesale market model

D_l_adw						
l_may						
L1.	.4094716	.1220729	3.35	0.001	.170213	.6487302
l_ala						
L1.	-.6843854	.2374046	-2.88	0.004	-1.14969	-.2190809
l_mak						
L1.	.7848067	.2155312	3.64	0.000	.3623732	1.20724
l_abi						
L1.	.1338287	.0947094	1.41	0.158	-.0517982	.3194556
l_haw						
L1.	-.1773822	.1386911	-1.28	0.201	-.4492117	.0944474
l_adi						
L1.	.4804626	.3788528	1.27	0.205	-.2620754	1.223
l_axum						
L1.	-.3950296	.2776381	-1.42	0.155	-.9391903	.1491311
l_adw						
L1.	-1.166844	.5902982	-1.98	0.048	-2.323807	-.0098809
l_adr						
L1.	.5298459	.6852913	0.77	0.439	-.8133004	1.872992
l_wmp						
L1.	.1108303	.0319519	3.47	0.001	.0482057	.1734548

A3.9 Impact parameters Addis Ababa retail market model

D_l_adr						
l_may						
L1.	.4207384	.0990579	4.25	0.000	.2265885	.6148883
l_ala						
L1.	-.4613155	.1926455	-2.39	0.017	-.8388937	-.0837373
l_mak						
L1.	.5050679	.174896	2.89	0.004	.162278	.8478578
l_abi						
L1.	.1399839	.0768533	1.82	0.069	-.0106458	.2906137
l_haw						
L1.	-.0283476	.112543	-0.25	0.801	-.2489278	.1922325
l_adi						
L1.	.3190543	.3074258	1.04	0.299	-.2834892	.9215978
l_axum						
L1.	-.4298972	.2252936	-1.91	0.056	-.8714646	.0116701
l_adw						
L1.	-.2336749	.4790063	-0.49	0.626	-1.17251	.7051602
l_adr						
L1.	-.3892353	.5560899	-0.70	0.484	-1.479152	.7006808
l_wmp						
L1.	.1141248	.0259278	4.40	0.000	.0633072	.1649424

A3.10 Impact parameters world market model

D_l_wmp						
l_may						
L1.	.0143056	.0694569	0.21	0.837	-.1218274	.1504386
l_ala						
L1.	.2302869	.1350781	1.70	0.088	-.0344613	.4950352
l_mak						
L1.	-.0532118	.1226326	-0.43	0.664	-.2935674	.1871437
l_abi						
L1.	.0137354	.0538876	0.25	0.799	-.0918824	.1193531
l_haw						
L1.	-.0999332	.0789123	-1.27	0.205	-.2545984	.054732
l_adi						
L1.	-.2336745	.2155591	-1.08	0.278	-.6561626	.1888137
l_axum						
L1.	.0757515	.1579701	0.48	0.632	-.2338643	.3853673
l_adw						
L1.	.1947827	.3358671	0.58	0.562	-.4635047	.85307
l_adr						
L1.	-.2072952	.3899161	-0.53	0.595	-.9715167	.5569263
l_wmp						
L1.	.0066211	.0181799	0.36	0.716	-.029011	.0422531