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MAKING THE CONNECTION:

A "SAFE ISLAND" IN SEGMENTED MARKETS?

The Impact of the Ethiopia Commodity Exchange on Market Integration of Regional Maize Markets in Ethiopia

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ABSTRACT

Recent decades have seen substantial effort in devising appropriate policy measures to improve market integration in developing countries. Given a history of segmented markets and food insecurity, lack of market integration is particularly acute in Ethiopia. This empirical study analyses the impact of the introduction of the Ethiopia Commodity Exchange on market integration, defined in terms of price transmission. For this purpose, integration between four regional maize markets over the time period 2000-2013 is investigated, using cointegration techniques and an error correction framework. Given heterogeneity in results, no conclusive evidence for a change in market integration following the introduction of the exchange was found. While Engle and Granger cointegration tests weakly suggest a change in market integration, the Johansen test gives strong support for a change. Evidence for directionality in price transmission is found, indicating the presence of a central market. The study provides interesting policy implications, including the potential role of the ECX in the future.

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CONTENTS

1. INTRODUCTION

In 1984 a severe famine struck Ethiopia and claimed millions of lives (Gabre-Madhin, 2012). Shortages in the north of the country resulted in food aid being provided from other parts of the world. Paradoxically, the fertile lands of southern Ethiopia showed a grain surplus during the same period of time, but food could not be accessed by people in deficit areas. Ethiopia experienced a similar effect of the segmented market for commodities when bumper crops in 2000 were followed by food shortage and starvation during 2001-2002 (Webb and von Braun, 1994; Gabre-Madhin, 2012). More recently, the food crisis of 2007-2008 triggered food riots and political instability in the country (Berazneva and Lee, 2013).

With constraints to fast mobilization of food resources, due to infrastructural incapacities and institutional flaws, supply and demand shocks in developing countries can have catastrophic effects on food security (von Braun and Olofinbiyi, 2007). A major determinant of the ability of an economy to handle price shocks is the extent to which its various markets exhibit integration. Other things being equal, the stronger the linkage between markets and thus the greater the depth of market integration, the greater is the transmission of price shocks across markets. In fact, market integration is often defined in terms of price transmission (Fackler and Goodwin, 2001). A high price transmission allows for the mobilization of commodities from markets were they exist in surplus, to markets in which there is a shortage (Baulch, 1997; Ravillion, 1986). In addition, good access to distant markets that can absorb excess supply provides an incentive for firms to adopt improved production technologies, thereby stimulating economic growth. Similarly, government policies aimed at increasing economic growth will only be effective if markets are integrated (Barret, 2005). Therefore, knowledge of market integration and the possible extent and direction of price transmission between regional markets can have important implications for policy decisions and on the ability to device appropriate measures to overcome imperfections in the market. If price transmission from one specific market to another can be found to be particularly high, it may suggest that policy changes with the aim of stabilizing commodity prices should be focused on this pair of integrated markets (Alexander and Wyeth, 1994; Goletti, Ahmed, Farid, 1995; Getnet, 2007).

Recognizing the severe effects of segmented commodity markets in developing countries, a large body of research investigates how market reforms could potentially improve integration. In particular, liberalisation efforts in the 90s have been extensively studied in this context. Literature on the impact of improved market institutions is more limited, and it is within this area of research that the thesis aims to contribute. Ethiopia provides one example of a developing country where liberalisation involved policy reforms that significantly changed the functioning of the commodity market (Negassa, 1998). Dercon (1995) investigates whether these changes had significant effects on market integration. Other authors (e.g. Alderman, 1992; Web *et al*, 1992) have studied market integration in the period before Ethiopian liberalisation, notably covering the famine of 1984. Similarly, the period following liberalisation has also been subject to research in the context of market integration (e.g. Jaleta, Gebremedhin, 2012). A more recent agricultural policy reform is in line with the shift in focus from "getting prices right" to "getting institutions right" (Barret and Mutambatsere, 2008) – the introduction of the Ethiopia Commodity Exchange (ECX).

The official introduction of the ECX in 2006, with actual operations starting in 2008 (henceforth referred to as the year of introduction), is regarded as a successful case of market reform, and widespread evidence has been proposed with regards to its impact on the commodity market (Everitt,

2012). As such, it provides an interesting opportunity to test the hypothesis that the introduction of a commodity exchange provides a "safe island" for segmented markets and improves market integration by providing services related to grain handling and inspection, co-ordination of buyers and sellers and risk management. More specifically, the objective of this empirical analysis is to contribute to literature on market reforms and market integration in Ethiopia by identifying one particular type of market institution and investigating its impact on market integration. On a higher level, the general objective is to provide insights to segmented markets in developing countries on the potential role played by commodity exchanges in improving market integration.

1.1 AIM AND RESEARCH QUESTION

The aim is to investigate whether and to what extent the ECX has had an impact on regional market integration. In doing so, an empirical analysis is conducted, using maize prices in four major Ethiopian regional markets: Addis Ababa, Bahirdar, Dire Dawa and Mekele. Thus, the research question is formulated as follows:

What is the impact of the introduction of the Ethiopia Commodity Exchange on maize market integration in regional markets?

For this purpose, market integration and price transmission will be analysed using a non-structural approach. That is, inferences will be drawn from observed price behaviours before and after the introduction of the commodity exchange, first using the concept of cointegration to investigate whether markets are integrated. Further, an error correction framework allows for the identification of the dynamics of the price adjustment process, and thus, for the extent of integration. Finally, an analysis of Granger causality provides an indication of the nature of market integration. Given potentially interesting policy implications from the direction of causality between markets, a sub-question is specified:

Conditional on integration between regional markets, what is the direction of causality?

In answering our research question, we make two main delimitations. First, the use of a non-structural approach takes factors affecting market integration, as prior external information (Listorti and Esposti, 2012). The emphasis will be placed on an empirical investigation of market integration before and after the introduction of the exchange, and the significance of a *net* effect. We choose not to conduct an empirical investigation of the channels through and the mechanisms by which the exchange introduction could have affected the functioning of the market, and thereby market integration. That is, no attempt is made at *empirically* relating observed changes in price behaviour to specific structural factors. Although such an investigation would enable a more thorough analysis of the relationship between the commodity exchange and market integration, we consider it a research topic in itself.

Second, market integration will be evaluated based on an empirical investigation of the long-run completeness and short-run dynamics of price transmission. A study of possible asymmetries in the transmission process is another relevant aspect in the evaluation of price transmission and would provide a more holistic picture of market integration. Assessing the existence of asymmetries requires a slightly different set of econometric models, and is therefore not investigated in this paper.

The remainder of the paper will be structured as follows. In section 2, the rationale for introducing the ECX is described. Section 3 provides a review of the previous literature within the field of market integration and section 4 provides the conceptual framework of the study. In section 5, the econometric models and methods are explained, followed by section 6 describing the data used. Section 7 presents the empirical findings, which are then discussed in section 8. Finally, section 9 contains concluding remarks.

2. The Role of The Ethiopia Commodity Exchange

To identify the potential role of a commodity exchange in improving market integration, it is desirable and necessary to understand the structure and forces shaping the market. In the first section, the Ethiopian commodity market is explained, with reference to possible impediments to arbitrage and market integration. In the following section, the ECX and its operations are presented. Finally, in the last section, the key regional markets of the empirical study are described.

2.1 Why a Commodity Exchange?

The purpose of this section is to provide the context of the empirical study and identify the need for a commodity exchange. It is structured as follows: the first section outlines the most recent evolution of agricultural policy in Ethiopia. In the second section, the market participants of the Ethiopian maize market and their characteristic traits are identified. Finally, in the third section the maize marketing infrastructure is presented, focusing on the period before ECX.

2.1.1 Evolution of Agricultural Policy Measures

The 1990s saw widespread liberalisation and accompanying radical changes in agricultural marketing policies throughout Africa, leading to reduced government intervention and increased private sector participation. After the fall of the Derge regime in 1991, the transitional government of Ethiopia adopted market-oriented policies and, overnight, all restrictions on private trade were lifted. State control was considerably reduced and, importantly, the pegged exchange rate regime came to an end. Market liberalisation was considered a precondition for "getting prices right" (Quattri, Ozanne, Tamru, 2012). The new government relied on the agricultural sector as the principal engine of future economic growth, and embraced to a large extent the structural adjustment programs of the IMF/World Bank (Rashid, Assefa, Ayele, 2007). However, the influence of the state indirectly remained through the Ethiopian Grain Trading Enterprise (EGTE), mandated to stabilise prices and keep food security stocks. In spite of economic liberalisation initially boosting agricultural productivity, food insecurity remained. The food gap in Ethiopia increased during the 1990s and in early 2000s was around 6 million tons (Rashid, Assefa, Ayele, 2007).

Agricultural grain market policy in the 2000s has been uncertain and influenced by both internal and external factors, and should be discussed in light of these factors. Reforms in 1999 and 2000 considerably redefined the role of the EGTE. An increased focus on export promotion, and less so on price stabilisation, was mandated. National disaster prevention and the maintenance of food reserves was continually a prioritized area for the EGTE (Bekele, 2002). In early 2002, maize prices declined significantly as a result of bumper crops in the two previous years. Maize farming became unprofitable

and as a result some farmers even refrained from harvesting. To restore the situation, the EGTE intervened to stabilize prices, despite its new mandate (Rashid, 2010). Due to adverse weather conditions, the harvest in 2003 became considerably lower, and a potential food security crisis was finally averted by more than one million tons in food assistance (Dorosh and Rashid, 2012). Cereal production in the subsequent years recovered, but the production growth did not lead to lower nominal and real prices. Consequently, local procurement by for example the EGTE was reduced, jeopardizing food security. Along with other measures, an urban food rationing program was eventually initiated in April 2007. Domestic inflation was persistently high in 2007-2009 and between March and August 2008 the nominal wholesale prices of maize increased by 90%, in part also due to crop failure (Rashid 2010). Following the food crisis in 2007-2008, the country experienced riots and political instability (Berazneva and Lee, 2013).

2.1.2 MARKET PARTICIPANTS OF THE MAIZE VALUE CHAIN

The marketing chain of maize, linking producers and consumers, can be complex and involve numerous actors. Figure A.2 provides an illustration of the market structure and the flow of grain, including maize, between market participants, as presented in Gabre-Madhin (2001).

Maize producers can be classified into three main groups: smallholder farmers, state farmers and commercial farmers. Smallholder farmers dominate the Ethiopian maize market, and are responsible for the bulk of the marketed quantity of maize. Only approximately 20% of produce is sold, and the remaining 80% is retained for household consumption and seed (RATES Maize Market Assessment, 2003). To a great extent trade takes place with trusted partners at a close distance to the farm, and as a result trade is largely personalized (Gabre-Madhin, 2012). Over time co-operatives of farmers have gained an increasing role in the grain market in Ethiopia (Minten, Stiffel, Tamru, 2012). However, their role remains limited within cereal market (Bernard *et al*, 2010). Market outlets of smallholder producers include rural assemblers, food processors, retailers, wholesalers, as well as rural and urban consumers directly. Maize is also produced by state farmers and a growing number of commercial farmers. Liberalisation in early 1990s opened up the previously exclusive domain of large-scale farming to commercial actors. However, at the turn of the century, commercial farmers still contributed with only a small quantity of marketed maize as a consequence of lack of credit, low domestic demand and high input costs. Wholesalers in surplus regions, including the parastatal EGTC, are the main buyers of produce of large-scale farms (RATES Maize Market Assessment, 2003). Before the introduction of the ECX, farmers generally carried the full price risk of their output, with forward and inter-linked contracts being virtually non-existent (Gebremeskel, Jayne, Shaffer, 1998).

Local traders, assemblers and co-operatives assemble produce from nearby farms and sell to larger traders. These traders act to realize the movement of maize across regions, responding to spatial arbitrage opportunities. Private wholesale traders have become the principal actors of inter-regional trade in Ethiopia following market reforms in the 1990s, and have gained an increasingly important role in the agricultural market (RATES Maize Market Assessment, 2003). They are generally small-scale enterprises, conducting business on a personalized basis (Gabre-Madhin, 2001). Wholesalers can be located in surplus areas, in urban areas and in deficit areas and are classified accordingly. In addition, a significant part of marketed maize is handled by two other types of wholesale traders: private companies and the EGTC. In many regions wholesalers engage in direct trade with farmers in addition to wholesale activities, and thus appear to be specialised only to some degree (Gabre-Madhin, 2001).

Regional wholesalers resack, store, and sell maize to central market wholesalers, retailers, food processors or directly to consumers. Trade to wholesalers in central markets is primarily conducted via brokers who act as intermediaries, linking buyers and sellers. The majority of brokers are located in Addis Ababa, and also engage in grain handling and inspection. In 2001, 70% of grain traders utilized the services provided by brokers (Gabre-Madhin, 2001). Historically, brokers have played an important role in the markets and their activity has significantly developed during the 2000s (Quattri, Ozanne, Tamru, 2012).

2.1.2 MARKETING INFRASTRUCTURE

In line with the representation of Bacha and Gemeda (2001), marketing infrastructure comprises the following essential components: transportation, storage, processing, information services, and financial services. In the following a brief description of the characteristics of each component in the case of Ethiopia is provided.

The physical infrastructure determines the ease of ***transportation***. In Ethiopia, road conditions are generally poor and the road network underdeveloped (Dercon, 2004). Therefore, agricultural produce is generally transported by pack animals or human beings to local markets, often in small quantities, with a limited use of trucks. Retailers and wholesalers to a greater extent use trucks and sometimes train to move grain over longer distance, across regions (Bacha and Gemeda, 2001). However, with the exception of trade into Dire Dawa, railway transportation plays only a minor role in the transport infrastructure of grains with only one axis linking the port of Djibouti and Addis Ababa. A radial road configuration characterises the infrastructure of Ethiopia, with the capital city Addis Ababa located in the centre (Gabre-Madhin, 2001). The traditional ***storage*** system of farmers involves the use of a local granary. The structure is made with natural materials like mud, and storage losses and quality deterioration can be considerable (Dereje and Abdissa, 2001). High temperature, moisture, rodent and termites are challenges to overcome in the storage of grain. Wholesalers own or rent storage facilities, and keep the grain for 1-2 months. Retailers handle only small quantities of grain, with limited storage (Bacha and Gemeda, 2001). The main quantity of maize that enters the market is unprocessed. The traditional way of grinding cereals is complemented by mills. However, these are often located in urban areas, and are limited in number. ***Processing*** thus becomes a time-consuming activity (Bacha and Gemeda, 2001).

Information will enable market participants to better adapt to market conditions. Informal communication is the most important source of price information for smallholder farmers, who consequently have only limited awareness of market conditions in other regions of the country. Thus, farmers have weak bargaining power with respect to the relatively more informed middlemen (Bacha and Gemeda, 2001). The ***financial sector*** can provide services that enable the development and growth of the agricultural sector. Banks are concentrated in urban areas, and the density of bank branches in relation to total population is low. Although access is limited, the financial sector offers a range of important services such as credit, insurance, savings and payment products. Credit enables the expansion and diversification of businesses. However, the high risk associated with the grain business, as well as the collateral needed to be eligible for bank loans, result in considerable shortage of financial credit among market participants in the grain sector (Dessalegn, Jayne and Shaffer, 1998). Credit constraints, cash needs and the threat of storage loss, induce farmers to sell their produce in immediate connection to harvest. Lack of credit and storage likewise induce state and commercial farmers to sell their produce in close connection to harvest. Because of an inability to fulfil loan procedures, few traders receive credit from financial institutions and a tradition of credit among the

traders themselves has developed (Bacha and Gemeda, 2001). Wholesalers are more often eligible for credit (Gabre-Madhin, 2001).

2.2 THE ETHIOPIA COMMODITY EXCHANGE

Based on the above, constraints can be identified that increase transaction costs for participants in the Ethiopian maize market such as the lack of grain standardization and quality control, poor market information and limited contract enforcement. Several important benefits of commodity exchanges have been suggested in literature, directly linked to the aforementioned constraints (UNCTAD, 2009; Gabre-Mahdin and Goggin, 2005). Operations of the ECX commenced in April 2008, with the over-arching goal of modernizing the commodity market of Ethiopia. The mission of the exchange is to "connect all buyers and sellers in an efficient, reliable, and transparent market by harnessing innovation and technology and based on continuous learning, fairness, and commitment to excellence." To achieve its stated goals, the commodity exchange has adopted an integrated perspective and consequently comprises an array of operations to serve all market actors. The main characteristics together with key operations and market services of the ECX are summarized below (ECX, 2009). Three main functions are: market efficiency, market transparency and risk management.

The ECX is a multi-commodity exchange, based in Addis Ababa, and takes the form of a partnership between the Members of the Exchange and the Government of Ethiopia. As such, it is a unique initiative on the African continent. The trading system is the core operation of the ECX, connecting banks, warehouses, regional trading centres and web users. Trade is based on standardized contracts designed for immediate or future delivery, and clearing and contract settlement is managed internally by partner settlement banks on a daily basis. More than 200 different spot contracts are offered on the exchange, including five main commodities: coffee, sesame, haricot beans, maize and wheat. In order to participate in trading a membership is needed which is purchased as a Membership Seat. The physical trading floor is located in Addis Ababa, and through open outcry bidding buyers and sellers can transact different commodity contracts. Through an automated back office system, transaction orders are reconsolidated in direct response to orders made to ensure the existence and validity of warehouse receipts and funds in buyers' deposit accounts, encouraging confidence in the market. The ECX has a number of authorised warehouses were commodities are weighed, graded, certified and stored with full insurance against loss and damage. Electronic warehouse receipts establish legal titles to deposited commodities, which are managed by an Exchange Central Depository. In order to guarantee fulfilment of contract obligations, the ECX has its own Arbitration Tribunal that assures settlement of commercial disputes, as well as a market surveillance system to further protect market actors. ECX works actively to develop the regulatory infrastructure and legal framework necessary for its trading operations.

Another important function of the ECX is the market information system, acting to increase ***market transparency***. Price information is electronically disseminated in real time across the country, linking rural areas to urban trading centres. Data includes opening price, highest price, lowest price, last traded or current price as well as volume of trade, and is transmitted continuously to price display boards located in 14 major market centres across the country. Remote electronic trading centres, providing computers with internet connection much similar to an internet café, facilitates access to the national commodity market for small farmers and traders living in rural areas.

Gabre-Madhin (2005) suggests that the standardization of grades certificates will significantly reduce handling costs by creating trust between market actors. The need for middlemen to control quality in all stages of the supply chain, a procedure that has previously constituted a meaningful part of handling costs for traders, will diminish as a consequence. The ECX will also contribute to ***risk reduction*** through the provision of forward contracts that enable more strategic risk management for farmers. Gabre-Madhin (2005) further suggests that there are three primary benefits arising from the above operations: price discovery, price transparency and reduced transaction costs. This possibly implies an important contribution to market integration and efficiency, fundamentally changing both farmers' and traders' relationship to the market.

Since its introduction, the volume of trade in maize has decreased. In 2009, trade in maize constituted only a small fraction of overall trade volume. This is partly due to a shift in the focus of the ECX to stimulating trade in export commodities, such as coffee (Rashid, Winter-Nelson, Garcia, 2010). Although the proponents of the ECX are optimistic about the capability of the ECX to transform the market, critics suggest that the ECX by itself cannot address the inherent imperfections of the commodity market (Quattri, Ozanne, Tamru, 2012).

2.3 KEY REGIONAL MARKETS OF THE EMPIRICAL STUDY

In order to investigate the impact of the ECX on a national level, representative markets must be chosen for the empirical study. As outlined below, regional markets differ in several aspects, and therefore the observed impact on individual markets is likely to be differential. The empirical analysis of this study will include four key regional markets, Addis Ababa, Dire Dawa, Mekele and Bahirdar, motivated by their classification into deficit and surplus areas. Below is provided a descriptive overview of the aggregate maize market, in terms of consumption, production and trade flow, and of the four regional markets.

In terms of population, agricultural production conditions and road networks, Ethiopia is an enormously diverse country; a diversity that gives rise to interregional trade in commodities, including maize. Because of a tendency to be food self-sufficient and as a consequence of segmented markets, consumption of food grains have traditionally been closely linked to production. Maize is grown widely across the country, and is one of five major cereals that are cultivated on a large scale in Ethiopia. It is both an important cash crop and a principal staple food, predominantly in rural areas. In 2004/2005 it accounted for 16.7% of per capita calorie consumption of food items (Badhene, 2011). However, the domestic market for maize is limited, explaining the adoption of export promotion strategies in late 90s to avoid the collapse of maize prices in the event of bumper crops (RATES: Maize Market Assessment, 2003). Furthermore, maize price volatility has been shown to be rapidly transmitted to other important food grains such as teff and wheat (Rashid, 2011). Thus, given its importance for food security, understanding integration of maize markets in particular is highly relevant.

In terms of maize production, the surplus areas exist in the western, northern and southern parts of the country, and the north-eastern, eastern and south-eastern Ethiopia comprises the main deficit regions. Maize is shipped from surplus to deficit areas, often passing the central market Addis Ababa (Gabre-

Madhin, 2001), as illustrated by Figure A.1. Due to the rain-dependent nature of agriculture in Ethiopia, the grain market exhibits significant seasonality that characterises both production and marketing of maize. The most important share of annual sales of farmers occurs in the period between January and March (Dereje and Abdissa, 2001).

Characteristics of chosen markets

Markets located in surplus areas

Addis Ababa The capital city Addis Ababa is in the centre of the radial configuration that characterises the road system in Ethiopia. As such, it works as a national clearing house in that regional trade flows physically will pass through its central markets (Gabre-Madhin, 2001)

Bahirdar Bahirdar is located in the Gojam area of north-western Ethiopia, and constitutes an emerging market hub. It is one of the areas in the country where new marketing channels are developing, allowing trade to bypass the Addis Ababa central market (Gabre-Madhin, 2001). The distance to Addis Ababa is 549km.

Markets located in deficit areas

Dire Dawa Dire Dawa constitutes a terminal market in that there is limited outward flow of grain and thus important local demand. It is located in the eastern region of Ethiopia. The distance to Addis Ababa is 528km, and it is one of few markets served by rail transport (Gabre-Madhin, 2001). Dire Dawa is also well-connected to other regional markets by a good road network and exhibits a relatively developed marketing infrastructure. Further, grain trading has a long tradition in the region. Relatively larger purchases and a greater storage capacity as compared to other regions have been recorded (Negassa, Myers, Gabre-Madhin, 2004).

Mekele Mekele is considered a terminal market. It is located in the northern drought affected deficit area, at a distance of 780km from Addis Ababa (Negassa, Myers and Gabre-Madhin, 2004).

3. EXISTING EMPIRICAL EVIDENCE

The characterisation of the Ethiopian agricultural market suggests that market integration may be limited as a result of micro-level realities. In turn, this implies that market reforms may improve market integration. Previous literature constitutes an important foundation for the research design and analysis of results. First, it provides a guide in the choice of method and given that there is no previous literature on the effect of a commodity exchange on market integration, it is important to understand what factors have an impact on market integration. As will become evident later, a commodity exchange is likely to collect the *net*-effect of a combination of individual factors. Second, although the direct impact of a commodity exchange on market integration is largely unexplored, commodity exchanges have been shown to have a significant impact on the functioning of the market. In fact, commodity exchanges have been compared in literature to ”safe islands” in connecting buyers and sellers.

3.1 MARKET INTEGRATION IN AGRICULTURAL COMMODITY MARKETS

In the following a review of literature on market integration is presented, illustrating how spatial market integration has previously been investigated. In the first sub-section, the general approach to market integration is discussed. In the second sub-section, factors that have been identified as underlying factors affecting price transmission, and hence market integration, are presented. Another vein of research focuses on assessing the impact of the combined effects of structural breaks, and the third and final subsection reviews how previous literature has approached this topic.

3.1.1 THE METHODOLOGICAL APPROACH TO MARKET INTEGRATION

Given that price analysis occupies a central role in the field of market integration, a significant part of literature is concerned with developing econometric methods that capture true price behaviour. If market integration is present, prices in spatially distinct markets are expected to co-move. Early literature on spatial market integration was based on a static approach, using simple bivariate correlation (Blyn, 1973) or regression techniques. However, given non-stationarity of prices, regressions were shown to be spurious (Harriss, 1979, Granger and Newbold, 1974). A more dynamic approach to market integration, was developed by Ravallion (1986), recognising that prices do not necessarily adjust instantaneously. Further advancements in the treatment of non-stationary variables, allowed for the development a new range of econometric models based on error-correction mechanisms and cointegration. These advancements were achieved and popularised by Engle and Granger (1987), for which they received the Nobel Prize in 2005 (Matthews, 2005) and brought to the study of agricultural markets by Ardeni (1989).

If markets were integrated, their respective prices were expected to co-move, and thus exhibit a long-run equilibrium relationship. Testing for cointegration allowed for inference on the existence of such a relationship, and thus the possible presence of market integration. On the other hand, strict interpretation of cointegration as conclusive evidence of market integration has been criticised (McCallum, 1993) as non-stationary transaction costs may indicate an absence of cointegration even when markets are integrated (Alexander and Wyeth, 1994; Baulch, 1997). Furthermore, McNew and Fackler (1997) show that prices in well-integrated markets do not necessarily exhibit cointegration. In the Vector Error Correction Models proposed by Engle and Granger (1987), long-run inferences on market integration, as captured by cointegration, was complemented by short-run dynamics, as captured by information on the speed of adjustment. Later, the Maximum-Likelihood Procedure developed by Johansen (1988), was found to be a more powerful test of cointegration in certain settings, and in particular in the multivariate framework.

Although used extensively in spatial market analysis, the use of simple error correction models that rely on the assumption of linearity, has received considerable criticism. Non-linearities in cointegration and short-run adjustment processes may reflect the existence of structural breaks and transaction cost (Barrett, 1996). Given the prevalence of structural breaks and high or non-stationary transaction costs, especially in developing countries, two new strands of research evolved to incorporate for non-linearities (Van Campenhout, 2006). The threshold autoregressive (TRA) models (Blake and Fombey, 1997) take into account the existence of critical thresholds below which transmission may be unprofitable. The parity bounds model (PBM) (Baulch, 1997) accounts for the possible existence of multiple regimes with differing adjustment processes. Extensions to these models have been developed (Negassa and Myers, 2007; Van Campenhout, 2007). However, both models have limitations and the PBM specifically is static by nature (Van Campenhout, 2006). Furthermore, the extended models depend on access to relevant and reliable data. In light of the varying methodological approaches to market integration, it is important to take into account study-specific attributes when comparing results found in previous literature (Perdiguero, 2010).

3.1.2 BARRIERS TO MARKET INTEGRATION IN SUB-SAHARAN AFRICA

Existing literature on agricultural economics, in developing countries in particular, recognises that regional market integration is the key to effective resource allocation on a national level (Goodwin, B.K., Schroeder, T.C., 1991). Transmission of price information across spatially distinct markets will enable economic agents to make decisions that contribute to efficient outcomes (Rapsomanikis, Hallam, Conforti, 2003). Therefore, the prevalence of market integration in the agricultural sector prevents shortages and gluts that otherwise would undermine the welfare of producers, traders and consumers. Therefore, an identification of barriers to market integration can have important policy implications (Baulch, 1997; Ravallion, 1986). Econometric analysis of spatial market integration fails, by construction, to specify why long-run and short-run arbitrage may not be perfect and hence why market integration may not prevail. Although it sheds light on changes in and problems with the relationship between markets, by measuring and comparing the extent of market integration, microeconomic analysis is needed in order to relate measures of market integration to structural factors (Dercon, 1995). However, literature suggests numerous factors acting as barriers to market integration and in the following a brief overview of such factors is provided. Jones (1972) pioneered research on agricultural market integration in Southern Africa, and his study generated further research

in the area. Still, only nine out of 61 empirical studies on market integration published before 2000 are on African markets (Fackler and Goodwin, 2001).

In Ghana, Badiene and Shively (1998) investigate price changes in maize with reference to spatial integration and transport costs. The study is based on monthly wholesale prices, and three different markets, of which two are located in deficit areas and one in a surplus area, are investigated. The surplus market Techiman is defined as the central market, using a Ravallion-based model. Badiene and Shiveley conclude that regional maize markets are relatively well-integrated over the time period 1980-1993. Results indicate that the level of integration differs slightly between the market pairs, explained in the study by differences in geographical distances and trading activity. They show that central market price history explains the price level in outlying markets. Moreover, they show that the price adjustment process in a market is determined by the degree of interdependence between that market and the central market in which the price shock originated. Later, Abdulai (2000) examines market integration in Ghana, testing for the existence of an asymmetric price response using a TRA model on maize prices in three markets, including the central market Techiman. In line with Badiene and Shively (1998), the magnitude and speed of price transmission is greater for markets located closer to the central market, exhibiting a higher trading intensity. Additionally, the nature of the price transmission process in found to be asymmetric, with increases in central market prices being transferred more rapidly to local markets, than reductions. This is explained by the suboptimal market structures and possibly inventory adjustments. Overall, markets are found to be well-integrated. Cudjoe, Breisinger and Diao (2010) find similar results on integration.

In Mozambique, Tostao and Brorsen (2005), using a PBM and trade flow data, find that maize markets in southern and central Mozambique are relatively well-integrated over the period 1994-2001. In Southern Mozambique, spatial arbitrage between markets is found to be efficient more than 55% of the time, and 84% of the time with regard to central Mozambique. Differences in spatial arbitrage efficiency are attributed to high transfer costs, rather than a lack of arbitrageurs. Lack of credit and poor physical road quality are presented as possible reasons for high transfer costs and investments in market infrastructure and marketing institutions are recommended. By contrast, Penzhorn and Arndt (2002) find relatively less integrated markets for the period 1993-1998, when using the PBM-model. This is attributed to bad communication and poor road quality, in accordance with Tostao and Brorsen (2005). Furthermore, Van Campenhout (2012) finds that markets in closer proximity are better integrated for the time period 2000-2011, using an extended TAR model. The author points at the weakness of using a PBM in the work of Penzhorn and Arndt (2002), given the possibility of trade reversals. One main recommendation of the paper includes road rehabilitation and the extension of the railroad network, given the low value to weight ratio of maize. A second recommendation includes facilitating the flow of information between markets.

In Tanzania, Van Campenhout (2007) examines how the speed of adjustment has developed during the nineties in seven maize markets. An overall improvement in market integration over time is explained by reduced transaction costs. Notably, the Dodoma-Iringa trade route exhibited an increasing speed of adjustment in spite of deteriorating roads. The impact of road quality on market integration has proven limited in the case of Mozambique, mainly due to the offsetting effects of high fuel prices (Cicera and Arndt, 2006). In Madagascar, Moser, Barret and Minten (2009) examine the extent of spatial market integration, using a PBM to analyse the rice market on three spatial levels over the period 2000-2001. Spatial integration is found to be limited on both national and regional levels, due in large to high transportation costs and the existence of excess rents to spatial arbitrage. On the sub-regional level, however, markets are found to be fairly well-integrated.

In Ethiopia, Webb *et al* (1992) examine grain market integration, following Ravallion (1989). Three different commodities are analysed: teff, maize and an aggregate of cereals, and 12 provincial markets are compared against a central reference market. Integration with the central market is found to be poor during the period investigated, 1984-1989, providing evidence of market segmentation. Negassa (1997) investigates vertical and spatial market integration for the period 1996-1997 for selected market pairs including Dire Dawa and Mekele, using Addis Ababa as the central market. The direction of causality was shown to emanate from Addis Ababa for all market pairs, except for Mekele-Addis Ababa. Furthermore, no evidence of an asymmetric price transmission process was found. Overall markets were found to be well-integrated. However, price differentials exhibited high volatility, making spatial arbitrage risky. An implication following the results was that the government can stabilize prices by region-specific interventions. Recommendations were made as to how spatial integration could be further improved, including the increased provision of market information services, storage facilities and investments in infrastructure. Finally, the abolishment of grain movement controls was suggested as a means of reducing volatility.

By contrast, Dessalegn, Jayne and Shaffer (1998) find high price spreads in relation to Addis Ababa for 11 out of 19 markets. The authors identify several factors responsible for the unusually high margins, including lack of adequate information and traditional buying and selling practices, which involves trading only in specific markets regardless of prices elsewhere. Recommendations are similar to Negassa (1997). Using an application of the ARDL approach (Pesaran and Shin, 1998) to white teff in the post-liberalization period in Ethiopia, Getnet, Verbekea and Viaene (2005) find that the wholesale price of the central market Addis Ababa plays an important role in determining prices in local supply markets, both in the long and short run. Low price transmission is explained by adverse effects of an uncompetitive wholesale market structure. Data used is from the time period 1996-2000. The overall results from the study are supported by later work in Getnet (2007), in which the important role of the central market Addis Ababa is emphasized. Consequently, the author recommends government intervention targeted at the central market.

Getnet (2008) discusses teff market integration in terms of spatial arbitrage, emphasizing the need for a change in market institutions to fully reap the benefits of market liberalization. Although evidence for market integration is found, short-run price transmission is low and several impediments to spatial arbitrage are found with regards to price and market behaviour. Traders' lack of capital and the unit root properties of prices are seen as impediments to arbitrage. An inadequate marketing infrastructure, including storage and transportation facilities, constitutes another important factor. On the other hand, the characteristics of teff as a homogenous good, and the presence of numerous licensed traders, are seen as indications of a competitive market structure. Thus, imperfect competition is not viewed as a likely barrier to market integration.

Rashid (2011), using cointegration techniques, finds that only central markets such as Addis Ababa are integrated, while markets in the north and east including Dire Dawa and Mekele are not for maize, teff and wheat. The author suggests focusing price stabilization policies on maize, given its high impact on the two other commodities, as measured by long-term memory. In light of recent efforts to increase market price information dissemination in Northern Ethiopia, Jaleta and Gebremedin (2012) investigate market integration, employing cointegration techniques, on teff and wheat retail prices. They find cointegration for a majority of the 15 market pairs examined for both commodities, during 2006-2008, indicative of market integration. The authors conclude that access to information is important and exceptions are seen as an indication of lacking road infrastructure. Minten, Stifen and Tamru (2012) identify five drivers for structural change, including economic growth, urbanization, significant investments in road infrastructure resulting in a reduction of travel time between wholesale

markets by 20%, increased spread of mobile phones and a changing role of cooperatives. Evidence for increasing market integration over the period 2001-2011 in the cereal wholesale market is found.

In summary, although evidence on commodity market integration in Southern Africa is mixed, many of the studies reviewed above provide widespread and relatively consistent evidence of moderate to well-integrated markets. Exceptions include markets that are separated by long distance or poor infrastructure. Literature on market integration in Ethiopia is indicative of relatively well-integrated markets in the long-run, as well as improvements over time. However, considerable barriers to integration appear to exist between deficit markets such as Dire Dawa and Mekele, and central markets such as Addis Ababa.

From a methodological point of view, a lack of market integration, as suggested by parts of the previous literature above, may be attributed to three main factors, following Sexton, Kling and Carman (1991). All three factors cause inefficient spatial arbitrage. First, if markets are not linked by arbitrage, market integration is lacking. An absence of arbitrage is seen as the result of transaction costs exceeding price differentials or the existence of public market protection. In practice, such markets are said to be autarkic. Second, markets may be linked by arbitrage, but impediments to efficient arbitrage inhibit deep market integration. Impediments include trading barriers, imperfect information and risk aversion. Third, a shallow integration may be the result of imperfect competition in one or more of the markets. In fact, much of the observed barriers to market integration identified above can be categorized following this methodology.

3.1.3 STRUCTURAL BREAKS AND MARKET INTEGRATION

The price transmission mechanism is necessarily a complex network influenced by co-existing and intertwined factors. Given the econometric tools available, the effect of individual factors affecting price transmission may be difficult to isolate and quantify. As a consequence, several studies view policy changes aimed at improving market integration as structural breaks (Listorti and Esposti, 2012), collecting the effect of a combination of factors. Studies adopting this approach compare market integration on a before and after basis. Three ways of assessing the impact of a structural change on market integration has been prevalent (Barassi, Caporale, Hall 2001). The recursive method involves a comparison across subsamples, while rolling window estimation uses a fixed-size window that moves along the sample. Finally, the sequential method defines the structural break as a dummy variable. In the following, studies employing recursive and sequential methods are presented.

Dercon (1995) studies the effect of policy reforms and ending civil war on teff markets in Ethiopia using a sequential method and the Engel and Granger co-integration techniques (Engel and Granger, 1987). Addis Ababa is defined as the reference market and nine other regional markets over the time period 1987-1983 are considered, employing monthly prices. The analysis reveals positive effects of reforms on market integration. By contrast, teff markets are not necessarily found to be well-integrated in the periods after the structural breaks. In particular, no long-run integration between Debre Markos, located in a main cereal growing area, and Addis Ababa is found. The slow process of restoring markets after the war is seen as an explanation for the absence of integration. Similarly, Goletti (1994) studies the impact of market liberalization on the extent of market integration in maize markets in Malawi. Monthly retail prices of maize at eight main locations over the period 1984-1991 are considered. The main conclusion is that liberalization improved market integration although price transmission was still incomplete in the after-period. Several other authors show similar effects of

market liberalisation on integration, or at least maintain that effects were not adverse. For example, Amikuzuno (2010) provides evidence that, with some important exceptions, market integration in the fresh tomato market in Ghana improved as a result of liberalisation efforts. However, the author also underlines that benefits from trade liberalisation are contingent on factors such as complementary marketing infrastructure and policies.

In contrast, a number of studies give evidence of deteriorating market integration as a result of liberalisation policies. Lutz *et al* (1994) find that liberalisation policies in Benin had no significant positive effects on the slow adjustment of prices in the maize market. Price series are compared for two periods, before and after liberalisation. Seven different markets are investigated using Johansen's cointegration framework and results indicate that, with one exception, all markets follow a common long-run trend and therefore exhibit some level of integration. However, the author finds no evidence of an improvement with regard to the extent of integration and the speed of adjustment as a consequence of liberalisation. Moreover, Rashid (2004) reports heterogenic results regarding the impact of liberalisation on market integration in Uganda. Tests of cointegration on weekly maize prices for two sub-periods, before and after liberalisation, suggests that market integration has improved on a general level but that some districts continue to exhibit non-integration.

Negassa, Myers and Gabre-Madhin (2004) examine the impact of changing grain trading policies in 1999 on spatial efficiency in the maize and wheat markets of Ethiopia. Recognising that policy changes may have only gradual effects, one of the objectives of the study is to develop a model that allows for an adjustment path, building on the standard PBM. The empirical findings suggest no significant change in spatial market efficiency in most cases. In both the periods before and after the policy change markets are found to be inefficient. The study reports differences in the nature of spatial inefficiency for the two commodities and suggests that policy measures be adapted to specific commodities. Five reasons are underlined as responsible for inefficiencies in the market; lack of storage facilities, poor access to formal credit, lack of market price information, high costs of marketing due to many and small traders, and limited trading skills. Moreover, variance estimates suggest that the trade conducted between Addis Ababa is relatively more risky than trade between Addis Ababa and deficit markets, including Dire Dawa and Mekele.

3.2 THE ROLE OF A COMMODITY EXCHANGE

Agricultural markets in Sub-Saharan Africa have been characterized by highly differentiated goods and an absence of formal standardization and classification rules. Likewise, contracts are often oral and non-standardized, and contract enforcement is lacking. Inspection and certification of grain is limited. These constraints contribute to the high risk involved in the exchange of agricultural commodities. In this context market institutions can provide mechanisms for better coordination and contract enforcement. Agricultural commodities such as staple grains are relatively homogenous, bulky and involve both many buyers and sellers. Given these characteristics, it has been suggested that commodity exchanges constitute the appropriate coordination mechanism in these markets. By contrast, it is argued that auctions would be suitable for traditional export commodities, such as coffee, exhibiting high homogeneity, low value to volume, and many sellers but only a few buyers (Gabre-Madhin, 2006).

In light of the insecurity faced by actors in the agricultural sector, a commodity exchange can constitute a “safe island” allowing buyers and sellers to reduce costs of conducting trade. In practice, commodity exchanges have been found to play many different roles in developing countries, depending on the specific needs of the market (UNCTAD, 2009). Apart from the potential to reduce transaction costs, commodity exchanges have been shown to increase market liquidity, facilitate risk management, uphold order, and build trust. By providing a meeting place for buyers and sellers, enabling and facilitating trade with standardized products and contracts, ensuring contract enforcement, and finally the spread of information, a commodity exchange can significantly reduce transaction costs (Gabre-Mahdin and Goggin, 2005). In terms of market integration, a commodity exchange can consequently lower spatial price dispersion (Rashid, 2010).

Rashid (2010) identifies three categories of conditions necessary for the success of commodity exchanges: commodity-specific conditions, contract-specific conditions, and conditions related to the market and policy-environment including the existence of supportive functions. Commodity-specific conditions that would prevent a robust development of the commodity exchange include a thin market for the commodity, poor storability, the non-existence of clear grades and standards and excessive price variability resulting market failure. The success of a commodity exchange also depends on contract-specific conditions. Contracts need to be attractive to market participants. Finally, a commodity exchange requires supportive functions in its surrounding environment. Such functions involve “allied” sectors including: banking, insurance, transport, IT-services and inspection services (Gabre-Madhin, 2009). The aforementioned conditions are rarely fulfilled in African markets, especially with regards to market activity and size, as well as the existence of necessary supportive functions. Given these constraints, Rashid (2010) suggests a careful evaluation before developing a commodity exchange.

Despite the recognised benefits of commodity exchanges, their success has been limited in Sub-Saharan Africa. Following liberalization in the 90s, Zambia, Zimbabwe, Kenya, Uganda and South Africa introduced agricultural commodity exchanges. However, of the five initiatives, only SAFEX was successful. Zambia and Zimbabwe suspended operations, while the commodity exchanges in Kenya and Uganda play only a limited role today. Malawi and Nigeria followed suit and Zambia made a new attempt to establish a commodity exchange (Rashid, 2010). Sitko and Jayne (2012) analyse the Zambian experience and investigate factors that hindered the successful development of the exchange. Five factors were identified. First, a failure to attract sufficient commitment from financial institutions was identified as a constraint. Second, contract non-compliance and opportunistic behaviour was found to limit development. A third constraint involves conflict of interest among brokers and the fourth constraint identified relates to the potential manipulation of markets resulting from low volumes of trade. Finally, because of a thin market, high costs were imposed on the participating actors. Further, the variability of government intervention was found to exacerbate the aforementioned factors.

Given the importance of country specific attributes on the potential success of a commodity exchange, there is no blueprint that guarantees a viable exchange (Gabre-Madhin, 2009). Further, for continued success, adaption to a changing environment is vital, especially in the context of developing countries that exhibit rapid and unpredictable changes (UNCTAD, 2009). As a conclusion, while there are numerous examples of commodity exchanges that have failed - the Zambian Commodity Exchange positing only one example - those that have survived have frequently evolved into leading institutions.

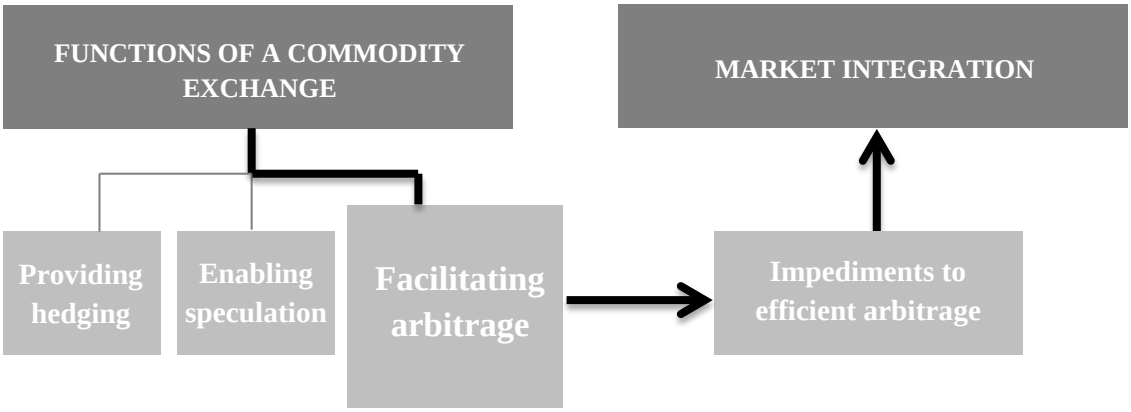
4. CONCEPTUAL FRAMEWORK

In analysing the impact of the commodity exchange on market integration, theory and previous literature is lacking. We present a conceptual model for analysing the impact of a commodity exchange on market integration. Furthermore, given the ambiguity of the theoretical definitions used in previous literature, the section that follows provides definitions of key concepts based on Fackler and Goodwin (2001). In the last section, the approach to studying market integration in this study is presented, as well as the model implications.

4.1 CONCEPTUAL MODEL

Generally, a reduction of the transaction costs of trading and the impediments to efficient arbitrage, act to increase the depth of market integration. Thus, it can be hypothesized that a commodity exchange, with its ability to substantially reduce transaction costs and allow for arbitrage activity, has the potential to improve market integration. Although, empirical findings on the effect of a commodity exchange on the functioning of the market are replete, and the theoretical foundations solid, previous literature and theory on the role of a commodity exchange in improving market integration is lacking. Based on theoretical justifications within each separate field of study, i.e. barriers to market integration and the role played by commodity exchanges in agricultural markets, we provide a conceptualization of how the two fields relate. A commodity exchange has three important functions in theory (Hull, 2012), which include providing hedging services, enabling speculation and facilitating arbitrage activity. One main way in which arbitrage activity is facilitated is through the spread of information and standardization of commodities and contracts. Market integration can be lacking as a result of the existence of barriers. Three broad classes of barriers were described in the previous literature, with two of them relating to arbitrage. While the first implies a complete absence of arbitrage due to the existence of prohibitively high transaction costs, the second barrier involves impediments to efficient arbitrage. Thus, the way in which a commodity exchange can be expected to affect market integration, is through arbitrage activity. A conceptualization is provided below.

Figure 1 *Conceptual model of the impact of a commodity exchange on market integration*



Source: Authors' own model, inspired by Hull (2012) and Sexton, Kling and Carman (1991).

4.2 CONCEPTS AND DEFINITIONS

A *commodity exchange* creates the basic rules and procedures for trade in commodities and provides a meeting place for buyers and sellers, centralizing trade in the commodity. While commodity exchanges in the developed world typically involve trade in futures and more advanced derivatives, commodity exchanges in developing countries focus on a broader range of operations with the aim of facilitating trade. To this end, services include spot trade and trade in forward contracts based on warehouse receipts. In addition, trade can be facilitated through supportive operations such as the provision of price information and storage.

The *spatial arbitrage conditions* is the notion that the actions of spatial arbitrageurs will ensure that the price of a homogenous good in two spatially separated markets A and B will differ, by at most, the cost of moving the good (r_{AB}) from the region with the lower price to the region with the higher price, as shown in (1). It is an equilibrium concept in the sense that, prices may not satisfy the condition at any point in time, but will tend to satisfy the condition as arbitrageurs act to exhaust potential profit opportunities. The concept of spatial arbitrage is sometimes used to refer to the weak form of the *Law of One Price*. By contrast the strong form of LOP states that the price of a homogenous good in two spatially separated markets should be equal, when having accounted for transportation costs. The spatial arbitrage condition, thus, encompasses the strong form of LOP. More specifically, the spatial arbitrage condition is the same as the strong form of LOP when the inequality is replaced by an equality.

$$p_A - p_B \leq r_{AB} \tag{1}$$

Market integration is defined as the degree to which demand and supply shocks arising in one region are transmitted to another region. More specifically, market integration can be viewed as a measure of the expectation of the *price transmission* ratio, where the price transmission ratio is defined as follows:

$$R_{AB} = \frac{\frac{\partial p_B}{\varepsilon_A}}{\frac{\partial p_A}{\varepsilon_A}} \tag{2}$$

and $\varepsilon_A$represents a shock to demand of the good in region A but not in region B. When the ratio equals one, perfect market integration is said to prevail. In the absence of price transmission, two markets are said to be non-integrated or segmented.

The concepts of the spatial arbitrage condition, law of one price and market integration, as defined above, are simplistic in the sense that they are static. However, they provide an intuition of the behaviour of prices in spatially separated markets, and can be used as a starting point for the investigation of the dynamic relationship. Often such an investigation, transcends to methodological aspects, and is more closely tied to econometric specifications. Currently no definition of the dynamic relationship between prices across spatially separated markets exists, and reference to such a concept often limits itself to intuition. Such intuition distinguishes between the short run and the long run, suggesting that prices in spatially distinct markets may be different at a specific point in time, but that they in the long run should exhibit convergence. There will be no attempt made here to explicitly define dynamic versions of the aforementioned concepts. The market integration concept in this paper is, in line with Fackler and Goodwin (2001), defined as perfect price transmission. Rather than relying on the price transmission ratio stated in (2) a more dynamic definition of price transmission is

employed in the empirical study. The dynamic definition of price transmission is presented in the methodological framework.

In previous literature, market integration has been defined both in terms of trade and prices (Barrett, 2002). When basing the definition of market integration on trade, it has been natural to study tradability (Barrett, 2002). However, predominantly market integration is defined in terms of price transmission, or price pass-through (Fackler and Goodwin, 2006). When defining market integration in terms of price transmission, two main approaches have been adopted: the structural and the non-structural approach (Myers, Sexton, Tomek, 2010).

4.3 Approach and Economic Model

The structural approach involves the direct investigation of how market structure determines integration. An examination of the micro-level realities of the market allows for the identification of the extent to which arbitrage opportunities exist and are exploited. In practice such an approach could be realized by interviewing traders and other actors involved in arbitrage activities, as well as studying the means by which commodities flow between markets (Baulch, 1997). Although, the structural approach would be the most direct way of approaching market integration, lack of data makes it of limited use. By contrast, price data is more easily accessed and readily analysed. In the non-structural approach market integration is studied through an econometric analysis of observed price behaviour, determined by structural factors that are treated as external prior information (Conforti, 2004). Therefore, inference on factors affecting market integration is made ex-post and data instead of theory has been the natural starting point. Thus, statistical criteria, rather than economic phenomena, are used to analyse market integration (McNew, 1996) and spatial market integration analysis becomes inherently empirical (Barrett, 1996). However, the non-structural approach may impose great structure on market relationships (Barrett, 2005) and does not directly provide an economic explanation of observed price behaviour (Fackler and Goodwin, 2006). Despite its shortcomings, the non-structural approach has nevertheless been proven useful in assessing market integration (Myers, Sexton, Tomek, 2010; Fackler and Goodwin, 2006), and is currently the predominant approach.

According to Negassa and Jayne (1997), the chosen approach has important implications for model specification. The structural approach involves the specification of large structural models that consist of behavioural equations, which reflect demand and supply decisions made by market participants. Such models incorporate over-identifying restrictions, usually requiring the exclusion of certain variables, based on economic theory. The model necessarily relies on correct identification. The use of a structural approach and model necessitates a large system of structural equations including all market participants. By contrast, the non-structural approach allows for a reduced-form model, in which prices are the sole variables. Its advantage lies in that it requires only minimal restrictions and therefore can include a host of economic structures. Its disadvantage lies in the inability to directly provide economic explanations for observed price behaviour.

In line with the main body of previous research, this study uses a non-structural approach and reduced-form model in investigating market integration. Given the aim of the research question to capture the *net* effect of a structural break on market integration and price transmission, a reduced-form model is considered a suitable choice (Negassa and Jayne, 1997).

4.4 RESEARCH FOCUS AND THEORETICAL HYPOTHESES

Two assumptions are necessary as a starting point of the empirical analysis. First, the introduction of the ECX is assumed to be exogenously determined in relation to changes in market integration. That is, changes in market integration should not trigger the introduction of the commodity exchange. This rules out issues related to simultaneity and reversed causality. Second, the introduction of the ECX is assumed to be the most important event influencing market integration in April 2008, and consequently, confounding effects are assumed to be negligible.

Further, in order to answer the research question and sub-question of the empirical study three aims have been specified. The aims relate to the different aspects of the nature of market integration that will be assessed in the empirical study. Specifically, the aims are to:

1. Investigate the ***existence*** of market integration, as indicated by long-run price transmission between maize prices in regional market pairs, before and after the ECX.
2. Given integration, investigate the ***extent***, as indicated by short-run maize price transmission between regional market pairs, before and after the ECX.
3. Given integration, investigate the ***direction*** of causality between regional market pairs, before and after the introduction of the ECX.

The main aim of the hypothesis formulation is not to determine the absence or presence of market integration in any one period. To a greater extent, it serves the purpose of a cross-period comparison. Thus, the overarching idea is a *change* in the ability to reject or accept hypotheses. However, assuming a change in the existence of market integration across the two sub-periods imposes unnecessarily restrictive assumptions on the first sub-period. That is, an observed change that supports improved market integration would require the absence of market integration in the first sub-period. Therefore, we instead expect an ability to reject the null hypothesis in the second sub-period, irrespective of the ability to reject the null hypothesis in the first sub-period. Incorporating change into the null hypothesis related to the short-run dynamics of prices is less restrictive since such a hypothesis is based on the idea of change in the *extent* of a process rather than a change in its *existence*.

The hypotheses of the study are based on material presented in previous sections. In section 2, the context in which the ECX was introduced was presented and some important impediments to arbitrage and thus market integration were suggested. Section 3 presented what role a commodity exchange could potentially play in reducing the influence of several of these impediments. Finally, section 4 provided a conceptual understanding of the mechanism through which a commodity exchange could improve market integration. In light of the above, the three hypotheses of the empirical study are formulated as follows:

Hypothesis #1: Existence of Market Integration

H_0: No long-run price transmission exists in the second sub-period.

H_1: Long-run price transmission exists in the second sub-period.

Hypothesis #2: Extent of Market Integration

H_0: Short-run price transmission is equal across the sub-periods

H_1: Short-run price transmission is not equal across the sub-periods

Hypothesis #3: Direction of causality

H_0: Deficit regions determine prices in surplus regions
H_1: Deficit regions do not determine prices in surplus regions

H_0: Addis Ababa is not a central market
H_1: Addis Ababa is a central market

In the following section, the methodological framework used to achieve the aims above is presented and explained.

5. METHOD

In analysing how the introduction of the ECX has affected market integration, a methodological framework is required that can capture various dimensions of price transmission. Using the methodology in FAO (2003) as a spring board, three main dimensions of price transmission are stated in terms of the *completeness* of transmission, the *speed* at which adjustment occurs, and the *directionality* of transmission. The analysis of the first dimension is commonly performed through cointegration analysis, in which the presence of cointegration is seen as evidence for a long-term equilibrium relationship and thus, market integration. The second dimension is most frequently analysed in an error correction model, in which the speed of adjustment parameter indicates the extent of market integration. Finally, directionality of price transmission can be determined through an analysis of causality. Given cointegration, causality can be inferred from the ECM. The multifaceted methodological approach to analysing price transmission adopted in this paper is based on previous literature (Goletti and Babu, 1994; Dercon 1995) and advocated by FAO (2003).

In the following, the first three sections present a methodology for analysing price transmission, based on the notions above. The models and procedures used in analysing cointegration, error correction mechanisms and causality is largely based on Engle and Granger (1987), but is also partly complemented by the Johansen methodology. The final section includes variable and econometric hypothesis specification, drawing on the methods applied in previous literature.

5.1 COINTEGRATION ANALYSIS

While individual variables can exhibit considerable variation over time, pairs of variables often exhibit some tendency of co-movement. In fact, co-movement is an expected behaviour if the variables are part of an equilibrium relationship. In such cases, deviations from equilibrium are only possible in the short-run and equilibrium forces ensure that deviations will never be too large. Such long-run relationships can be investigated using cointegration analysis. An investigation of the stationarity properties of the individual variables, and their combinations, reveals cointegration. The stationarity properties of a variable give an indication of the nature of its joint probability distribution. While variables with stationary processes are defined by constant variance and mean, implying a constant joint probability distribution, non-stationary variables have exploding variances and increasing means, making statistical inference difficult. Many price series are integrated of order one, I(1), implying a non-stationary stochastic process. First-differencing these variables, will yield I(0) processes that are stationary. When the linear combination of two I(d) variables is I(0), as in (3) the variables are said to be cointegrated, as illustrated below:

$$x_t \sim I(d) \quad (1)$$

$$y_t \sim I(d) \quad (2)$$

$$z_t = x_t - a y_t \sim I(0) \quad (3)$$

In the bivariate setting, the co-integrating vector is the slope parameter (α) from a simple OLS regression of x_t on y_t. Such a regression is referred to as the cointegrating regression. Since the

variables are assumed to be jointly endogenous, the cointegrating regression is specified in both directions. Formally, cointegration is defined as follows (Engle and Granger, 1987):

> DEFINITION: The components of the vector x_t are said to be *co-integrated of order d, b*, denoted $x_t \sim CI(d,b)$, if (i) all components of x_t are I(d); (ii) there exists a vector $\alpha(\neq 0)$ so that $z_t = \alpha' x_t \sim I(d-b), b > 0$. The vector α is called the *co-integrating vector*.

5.1.1 ESTIMATION PROCEDURE

Various procedures exist for testing cointegration between variables. Two main procedures are based on the Engle and Granger methodology and the Johansen methodology. Both are adopted in this empirical study. While the former is a residual-based test for cointegration, the latter is based on maximum likelihood estimation.

The Engle and Granger two-step procedure

The Engle and Granger two step procedure is classified into a more detailed four-step procedure in Enders (2010). The first two steps in Enders (2010) involve testing for cointegration in the bivariate setting:

1. Test order of integration of variables
2. Estimate long-run equilibrium relationship

In the first step, the order of integration of each variable can be tested by conducting unit root tests. In doing so the Dickey-Fuller (DF) test is a standard procedure. The DF test has the null hypothesis of a unit root, or equivalently a random walk. Thus, if variables are I(1), the null hypothesis cannot be rejected. In the regression equation in (4), the variable follows a pure random walk if the null hypothesis $H_0: \gamma = 1$ cannot be rejected. Alternative specifications of a random walk exist and it is possible that the variable under consideration follows a random walk with a drift term (5) or a drift and a trend term (6). An appropriate specification is important as the inclusion of deterministic terms that are not present in the actual data-generating process reduces the power of unit root tests (Campbell and Perron, 1991). Similarly the exclusion of terms that are present in the actual data-generating process adversely affects power. In specifying the deterministic terms of the regression equation, visual inspection of the plotted data should serve as a guide (Enders, 2010). If the variable is trending, a trend term should be included. Correspondingly, if the variable tends to revolve around the x-axis, a constant should not be included in (4).

$$\Delta y_t = \gamma y_{t-1} + \varepsilon_t \quad (4)$$

$$\Delta y_t = a_0 + \gamma y_{t-1} + \varepsilon_t \quad (5)$$

$$\Delta y_t = a_0 + \gamma y_{t-1} + a_2 t + \varepsilon_t \quad (6)$$

The DF test is often augmented to include for lags (ADF) in order to correct for serial correlation. In determining the number of lags to include, a general-to-specific approach (Hall, 1994) can be adopted. In choosing the lag order to start with, p_{max}, the Schwert's Rule of Thumb can be used (Schwert, 1989), where T is the sample size:

$$p_{max} = \left[12 \times \left(\frac{T}{100}\right)^{1/4}\right]$$

Alternative unit root test include the Philips-Perron test and the DFGLS test. While the former takes into account potential heteroskedasticity of residuals the latter is a more efficient test. In contrast to ADF, the PP test directly takes into account residual correlation by modifying the critical values (Phillips, Perron, 1988). To confirm that the two variables are in fact integrated of order one, the first differences of the variables can be examined. If the null hypothesis of a unit root can be rejected in the differenced variables, y_t and x_t are I(1).

$$H_0: y_t \sim I(1) \tag{7}$$
$$H_0: x_t \sim I(1) \tag{8}$$
$$H_0: \Delta y_t \sim I(0) \tag{9}$$
$$H_0: \Delta x_t \sim I(0) \tag{10}$$

Second, given that the variables are integrated of the same order, a cointegrating regression can be estimated (11). Cointegration requires that a linear combination of the two variables is stationary. This can be tested by rearranging equation (11), letting the residual sequence e_t be the RHS-variable, as in equation (12).

$$y_t = \beta_0 + \beta_1 x_t + e_t \tag{11}$$
$$e_t = y_t - \beta_0 - \beta_1 x_t \tag{12}$$
$$H_0: e_t \sim I(0)$$

An acceptance of the null hypothesis implies stationarity in the residual sequence. In practice, the absence of a unit root would imply that a_1 in equation (13) is not significantly different from zero. In a time series plot, the residual sequence tends to move around the x-axis. The ADF test estimation can be made more efficient by restricting the intercept-term to zero in (13), as long as the residuals do in fact revolve around the x-axis.

$$\Delta \widehat{e_t} = a_1 \widehat{e_{t-1}} + \varepsilon_t \tag{13}$$

If after having conducted step one and two y_t and x_t are found to be cointegrated, $\widehat{\beta_0}$ and $\widehat{\beta_1}$ estimated from an OLS regression are superconsistent estimators of the true population cointegrating parameters β_0 and β_1. When y_t and x_t represent prices series, $\widehat{\beta_1}$ has been interpreted as an estimate of the long-run relationship between the two variables, and as a "long-run elasticity of price transmission" if the variables are in logarithms.

Johansen's Test for Cointegration

The Johansen test for cointegration is based on maximum-likelihood estimation in the determination of cointegrating ranks (Johansen, 1988), where the cointegrating rank signifies the number of cointegrating relationships between multiple variables. In a setting with more than two variables, it is possible that certain variables are cointegrated while others are not. Thus, in the multivariate framework, the Johansen test has been suggested as a more powerful test for cointegration. However, it can be inappropriate in small samples. Given its complex mathematical foundation, a derivation is not presented in this paper, and the interested reader is referred to the original work by Johansen (1988).

5.2 ERROR CORRECTION MODELS

To capture the extent to which a shock to a variable is transmitted to other variables, an error correction framework can be used. The Granger representation theorem states, that given cointegration an error correction framework is appropriate, and vice versa.

In theoretical terms and in the commodity markets setting, an error correction model captures the impact on current prices, of a difference in prices in the previous period. If there is an equilibrium relationship between two price series, as predicted by the spatial arbitrage theorem, any deviation from that relationship will result in an adjustment in the future. The model estimates the speed at which the adjustment occurs. In the absence of a shock in the previous period, the future period will see no adjustment. Intuitively, cointegration ensures that a long-run relationship between the two variables exists so that adjustment to short-run equilibrium deviations occurs. Technically, if y_t and x_t are cointegrated, the error correction term exhibits a stationary stochastic process. Furthermore, if y_t and x_t are I(1), their first differences also exhibit stationary stochastic processes. Given these stationarity properties regression (14) including all these variables can be estimated and classical estimation procedures such as OLS will yield efficient and unbiased parameters.

$$\Delta Y_t = \gamma_1 \Delta X_t + (\gamma_2 - 1)(Y_{t-1} - \alpha - \beta X_{t-1}) + e_t \tag{14}$$

5.2.1 REPRESENTATION OF A BIVARIATE ECM

Given that an estimation of (14) requires cross-restrictions, Engle and Granger (1987) proposed the following general model in estimating the ECM:

$$\Delta y_t = \alpha_1 + \alpha_y \hat{e}_{t-1} + \sum \alpha_{11}(i)\Delta y_{t-i} + \sum \alpha_{12}(i)\Delta x_{t-i} + \varepsilon_{yt} \tag{15}$$

In this setting, $\hat{e}_{t-1}$ is the error correction term, estimated in the cointegrating regression (11). The real power in the ECM in (15) lies in the estimation of α_y, referred to as the speed of adjustment. If two price series have an equilibrium relationship, the speed of adjustment ought to be negative. This implies that a shock to the system, represented by a positive error correction term, will cause current values of x or y to fall, or adjust. The greater the absolute magnitude of α_y, the greater is the speed of adjustment, and the rate at which the system re-equilibrizes. When α_y is -1, the error correction mechanism is perfect in the sense that a shock producing a difference between the two variables in the previous period, results in a complete adjustment of the error in the current period. Given perfect adjustment, future periods are not affected by shocks occurring in the previous two periods. The maximum absolute value of α_y is by construction 2. In such cases, the shock results in an *overreaction* to the error in the current period. In fact, when the speed of adjustment exceeds 1, the system is said to overact to shocks. When the speed of adjustment is below 1, the system underreacts.

Given the assumption of jointly endogenous variables, and no knowledge of the direction of causality, the cointegrating regressions should be done using both *y* and *x* as the dependent variable in alternative specifications of the model and an alternative ECM should be specified, taking *x* as the dependent variable.

$$\Delta x_t = \alpha_2 + \alpha_x \hat{e}_{t-1} + \sum \alpha_{21}(i)\Delta y_{t-i} + \sum \alpha_{22}(i)\Delta x_{t-i} + \varepsilon_{xt} \quad (16)$$

A simple investigation of the statistical significance of α_y and α_x reveals whether or not an error correction framework is appropriate for the two variables under consideration. Although cointegration does not imply that both α_y and α_x are statistically different from zero, at least one of α_y and α_x should be. Interestingly, this also has implications on the direction of causality as discussed in section 5.3.

5.2.2 ESTIMATION PROCEDURE

In estimating an ECM, steps three and four in Ender's (2010) generalization can be used as a benchmark for the following procedure:

1. Specification of ECM and lag length selection using the general-to-specific approach
2. Estimation of ECM parameters using OLS
3. Testing null hypothesis of appropriateness of an ECM

Discussion of model specification is here limited to lag selection, using the general-to-specific approach. If at least one of the variables has a significant lag of the nth order, that lag order is chosen for the model. To ascertain the appropriateness of an ECM at least one of α_y and α_x has to be statistically different from zero. In theory, this is an implication of cointegration. In estimating the ECM, an ordinary least squares regression is performed.

5.3 DIRECTION OF CAUSALITY

The direction of causality between two variables can be inferred upon by evaluating the speed of adjustment parameters in an ECM. It is possible that none of the variables granger-cause each other, in which case both speed of adjustment parameters are zero. However, such a scenario also implies that the error correction framework may be inappropriate. If both speed of adjustment parameters are significant, causality is bi-directional. In practice, bi-directionality implies that both variables adjust following a shock to equilibrium in any one of the variables. Such a system is said to exhibit simultaneity. If only one of the speed of adjustment parameters is significant, the dependent variable in the equation with the insignificant speed of adjustment parameter is said to be weakly exogenous, and causality is uni-directional. This implies that one of the variables alone is responsible for correction of disequilibrium, while the weakly exogenous variable does not respond to deviations.

Table 1 *Granger causality in the bivariate setting*

Direction of Causality / Speed of Adjustment	$\alpha_y = 0$ $\alpha_x = 0$	$\alpha_y \neq 0$ $\alpha_x = 0$	$\alpha_y = 0$ $\alpha_x \neq 0$	$\alpha_y \neq 0$ $\alpha_x \neq 0$
No Directionality	**X**			
Uni-directionality		**X**	**X**	
Bi-directionality				**X**
Weakly exogenous		*x*	*y*	
Granger caused		*y*	*x*	

5.4 VARIABLES AND ESTIMATION WINDOW

Only price variables are used in the empirical study, following the non-structural approach. In resemblance to methods employed in previous literature (Goletti and Babu, 1994; Dercon 1995), cointegration analysis is conducted in the bivariate setting, by letting the unit of analysis be defined as regional market pairs. Given four regional markets, six regional market pairs were formed. For each regional market pair, the two price series were tested for cointegration and, when appropriate, represented in an ECM framework. Finally, causality was inferred from the ECM specifications.

When testing for cointegration both the Engle and Granger methodology and Johansen methodology were applied as described in section 5.1.1 and the ECM specification follows the procedure outline in 5.2.2. In the event that unit root tests of the Engle and Granger methodology gave conflicting results, hypothesis testing was aided by visual inspection of the stationarity properties of data. The structural break was analysed using a recursive method as in Baffes and Gardner (2003). The full sample, starting in January 2000 and ending in February 2013, was split into two sub-periods, with the event date defined as April 2008. The approach of this study was to first visualize the data and then estimate the econometric models, following Enders (2010).

5.5 ECONOMETRIC HYPTOHESES

In the following the hypotheses that were tested in the empirical study are presented. This section is an alternative representation of the theoretical predictions made in section 4.4 and presents an empirical approach to hypothesis testing. It focuses on hypotheses for cointegration coefficients, speed of adjustment coefficients and directions of causality.

Hypothesis #1: Cointegration analysis

H_0: Variables are not cointegrated in the second sub-period
H_1: Variables are cointegrated in the second sub-period.

Hypothesis #2: Error correction models

H_0: Speed of adjustment parameters are equal across the sub-periods
H_1: Speed of adjustment parameters are not equal across the sub-periods

Hypothesis #3: Direction of causality

H_0: Deficit regions are weakly exogenous in deficit-surplus market pairs
H_1: Deficit regions are not weakly exogenous deficit-surplus market pairs

H_0: Addis Ababa is not weakly exogenous
H_1: Addis Ababa is weakly exogenous

6. DATA

6.1 DATA DESCRIPTION

The framework for analysing market integration, as presented in the methodology, is applied to the Ethiopian maize market. Four regional markets are chosen to represent the national market and these are Addis Ababa, Bahirdar, Dire Dawa and Mekele. Given these four regional markets, market pairs are formed. Monthly wholesale prices for maize for each market, quoted in US dollars per 100kg, are retrieved from GIEWS FAOSTAT and originally compiled by the EGTE. This is considered a reliable source, previously used in literature. The maize price series of each regional market within the regional pair is the variable used in the cointegration tests, ECM specifications and causality tests of the empirical study. The time span covers twelve years of monthly data, starting in January 2000 and ending in February 2013, and covers the introduction of the ECX in April 2008. The first sub-period covers January 2000-March 2008 and the second sub-period covers April 2008-February 2013. With a monthly frequency, the full period consists of 158 observations, the first sub-period consists of 99 observations and the second sub-period consists of 59 observations.

6.2 DATA PROPERTIES

Figure B.1.1 illustrate the evolution of regional market pair prices of maize over time. Visual inspection reveals close co-movement of regional prices in both sub-periods, suggesting the existence of a long-run equilibrium relationship and cointegration. In several cases the maize price level for one of the regional markets is consistently above the price level of the other market, the most apparent examples being Addis Ababa-Mekele and Bahirdar-Mekele, suggesting a permanent difference induced by e.g. transportation costs. This also implies the absence of trade reversals, which would be evidenced by frequent intersections of the curves. Furthermore, some price pairs appear to move more closely than others, such as Dire Dawa-Mekele and Addis Ababa-Bahirdar, suggesting that the cointegrating relationships are stronger for certain regional market pairs. There is some visual evidence of a closer co-movement after the introduction of the exchange, as seen in Dire Dawa-Mekele and Bahirdar-Mekele, although closer co-movement is by no means an apparent feature. Overall figure B.1.1 gives strong visual evidence of a lack of stationarity in maize prices, and suggests the possibility of the price series being integrated of order one. The first differenced price series of B.2.1 support this view.

An apparent feature of figure B.1.1 is the jump in price levels in January 2008, as well as a possible increase in price volatility following the jump. Furthermore, the evolution of prices over the time period shows a slight tendency to trend upwards. Both these findings may have implications for the specification of unit root tests for the price series. First, the increase in volatility suggests the need to utilize a heteroskedasticity-robust test such as the PP test when testing for a unit root in the price series over the entire period. This should be further investigated by visual inspection of the variance of first

differenced price series, as well as the residuals from the cointegrating regressions. Second, the trending behaviour suggests the need to incorporate a trend term in the ADF test of the price series. Table B.3.1 reports the results of the unit root tests on the price levels. When conducting the ADF test without a trend term the test is unable to reject the null hypothesis of a unit root for Bahirdar and Mekele. When including a trend term, the test is unable to reject the null for Addis Ababa and Mekele, giving conflicting results. Given the possibility of heteroskedasticity, the PP test was conducted indicating an inability to reject the null hypothesis for all markets. Taken together, visual inspection and unit root tests seem to suggest the existence of unit roots in the price series over the entire period, however results are not conclusive. Given the limitations of conducting unit root tests on wide estimation windows that may include structural breaks, the fact that results are conflicting is not surprising. Of greater importance, is the outcome of the unit root tests on each sub-period, which by definition, ought not to include a structural break.

Table B.3.1 also reports the results from the ADF test, with and without and trend term and the PP test for each of the sub-periods. For the first sub-period, the ADF test with a trend still indicates an ability to reject the null hypothesis of a unit root for Dire Dawa, ruling out the possibility that the series is I(1). It is also unable to reject the null hypothesis in the differenced price series for Bahirdar and Mekele, ruling out the possibility that they are difference-stationary. On the other hand, the DFGLS test results based on the SC-criterion for lag selection, reported in table B.3.2, suggest that all of the price series are I(1). The PP test results indicate the same. For the second sub-period, the DFGLS test gives no support for I(1) processes in the price series, while both the ADF test with a trend and PP test do. Once again, results do not give conclusive evidence of the price series being I(1), although the ADF test and PP test results suggest such properties. Visual inspection of the stationarity properties of the differenced series in figure B.2.1, gives evidence of stationarity, as prices exhibit a strong tendency to fluctuate around the x-axis. Furthermore, figure B.2.1 also indicate an increase in volatility after 2008, with Addis Ababa and Bahirdar exhibiting the largest fluctuations. This suggests that the PP test may give more reliable results.

Taken together, visual inspection and the PP test lend support to the view that the price series are I(1). The ADF test suggests that prices are I(1), while the DFGLS test give no such clear indication. Special caution should be taken in the first sub-period when analysing Dire Dawa, which appears not to have a unit root, and to Bahirdar and Mekele that may have multiple unit roots, according to the ADF test.

7. EMPIRICAL RESULTS

7.1 COINTEGRATION ANALYSIS

In testing for the presence of cointegration in regional market pairs, section 5.1 described two possible procedures. The Engle and Granger two-step approach tests the order of integration of variables and stationarity of residuals to determine whether two variables are cointegrated. Visual inspection and unit root tests found in appendix B gave support to the view that all regional prices are integrated of order one. Thus, the result of the first step of the two-step procedure was presented in section 6.2. In determining the presence of cointegration, the next step involved constructing cointegrating regressions and testing the stationarity of the corresponding residuals.

Table C.1.1.1 reports the cointegrating vectors of the cointegrating regressions. Although hypothesis testing of the cointegrating vectors cannot be conducted, the coefficients should be consistent estimates of the true population price. In all cases the parameters are close to 1, suggesting a strong link between regional prices in any given time period. The law of one price, given parameter consistency, appears to hold remarkably well in all regional market pairs. The lowest coefficient estimate, 0.762, is the coefficient of a regression of Bahirdar on Dire Dawa, implying that in any given time period a one dollar increase in prices in Dire Dawa result in a 0.762 dollar increase on average in Bahirdar. If the law of one price would hold perfectly, the one dollar increase in maize prices in Dire Dawa would have been accompanied by an equal increase in Bahirdar. In general, compared to the other three regional markets, Dire Dawa is the market in which price changes are transmitted the least to the other markets. In Table C.1.1.1 this can be seen by comparing the cointegrating vector when Dire Dawa is the independent variable, compared to when the other three markets are specified as independent variables – the cointegrating vector is consistently lower compared to the other markets.

Moving from the first sub-period to the second sub-period, the cointegrating vectors increase in absolute value for almost all market pairs, the exceptions being when Addis Ababa is specified as the dependent variable. The cointegrating vectors of the full sample tend to be averages of the cointegrating vectors of the two sub-periods, indicating that the division of the entire period into two sub-periods may be appropriate. Table C.1.1.2 reports the cointegrating vectors, interpreted as long-run transmission elasticities, from regressions based on logarithmic prices. Although some cointegrating vectors have increased in value while others have decreased, in all cases the direction of change has been toward one.

The coefficients from the cointegrating regressions have no absolute interpretation in terms of market integration, but constitute a necessary step in testing for cointegration. The second step of the two-step approach involves the investigation of stationarity in the residuals. An examination of the residuals from the cointegrating regression over the entire period (figure C.1.1.3), generally do not support the view of stationarity in the residuals. All regressions including Dire Dawa have residual movement resembling random walks, while regressions including Mekele (and not Dire Dawa) reflect stationarity to a greater extent. There is once again some evidence of increased variance in the post-period, demonstrating the importance of conducting heteroskedasticity-robust unit root tests. Interestingly, the number of oscillations per time period appears to be greater after the event date, possibly suggesting a

greater responsiveness in prices. Figures C.1.1.4 and C.1.1.5 illustrate residuals over time for each sub-period. For the first period, once again, regressions including Dire Dawa appear to yield residuals that follow random walks, while regressions including Mekele yield more stationary residuals. Mekele-Addis Ababa and Addis Ababa-Mekele are the market pairs with residuals that are closest to being stationary. The evolution of residuals in the second sub-period does not provide evidence of stationarity, although the previously mentioned market pairs including Dire Dawa, now appear to resemble random walks to a smaller extent.

The results from unit root tests on the residuals are presented in table C.1.1.6. Because of a tendency for the residuals to revolve around the x-axis, the ADF tests are estimated with and without an intercept. Both the ADF-test without an intercept and PP test give strong support for residual stationarity in the full period and both sub-periods, the exception being Bahirdar-Dire Dawa in the full period. The DFGLS test (table C.1.1.8) on the other hand, indicates co-integration between fewer market pairs. As a concluding remark, visual inspection of figures gives strong evidence of co-movement and thus possible cointegration, unit root tests of price levels suggest the presence of I(1) processes, while unit root tests of residuals yield mixed results. Overall, the Engle and Granger methodology and its residual-based unit root tests weakly suggest the presence of cointegration in both sub-periods. If this is the true relationship in the data-generating process, it is in accordance with *hypothesis #1*, but implies no change in cointegration following the introduction of the ECX.

Cointegration was also tested using the Johansen methodology. Table C.1.2.1 reports the results from the Johansen test of cointegration. In contrast to the table C.1.1.6, table C.1.2.1 indicates no cointegration within all regional pairs in the first sub-period, the exception being Bahirdar-Mekele. By contrast, all regional pairs exhibit cointegration in the second sub-period. These findings lend further support to *hypothesis #1*, and also suggest that there has been a change in cointegration across the entire period, marked by the introduction of the ECX. In conclusion, the nature of the data and tests appear to yield results that in some cases are conflicting, and the preliminary indication of the presence of cointegration ought to be cautiously considered. The estimation of ECM's in the following section will present additional evidence on the presence of cointegration, following the implications of the Granger representation theorem.

7.2 ERROR CORRECTION MODELS

In estimating an ECM, cointegration was shown to be a precondition. As discussed above, cointegration is by no means evident based on the statistical tests. The Johansen's test for cointegration suggested the absence of cointegration in the first sub-period. Despite this absence, ECM's were estimated based on the ability to reject the null hypothesis of no cointegration when conducting the Engle and Granger residual-based tests. It is important to note that an absence of cointegration in the true data-generating process can influence the ECM parameters (Suzanna Deboef, 2000). At the same time, if cointegration is absent, the speed of adjustment parameters in an ECM ought not to be significant.

Table C.2.1 reports the speed of adjustment parameters for bivariate ECM's for all regional market pairs. An estimation of the ECM using the entire sample, yield five significant parameters for Dire Dawa-Addis Ababa, Mekele-Addis Ababa, Dire Dawa-Bahirdar, Mekele-Bahirdar and Mekele-Dire Dawa (table C.2.1). In accordance with the error correction framework, the parameters are negative,

indicating adjustment back to equilibrium when the disequilibrium error, captured but the error correction term, is positive. The absolute values of the speed of adjustment parameters are low, Mekele-Addis Ababa exhibits the highest speed – disequilibrium errors are corrected at a rate of 39.4% per month. The speed is lowest for Dire Dawa-Bahirdar, in which case disequilibrium is corrected at a rate of 16.2% per month.

Inspection of the first sub-period reveals a different picture. The speed of adjustment is significant in only three cases: Mekele-Addis Ababa, Mekele-Bahirdar and Dire Dawa-Mekele. The speed is once again highest for Mekele-Addis Ababa, in which case disequilibrium is corrected at a rate of 117.9% a month, indicating an overreaction in Mekele to price shocks in Addis Ababa. By contrast, Dire Dawa-Mekele exhibits a speed of only 26.0% per month. In the second sub-period, the market pairs that exhibit significant adjustments coefficient in the first sub-period, are no longer significant. Instead three new market pairs have significant adjustment coefficients: Bahirdar-Addis Ababa, Dire Dawa-Addis Ababa and Mekele-Dire Dawa. Prices in Dire Dawa tend to overreact to shocks to prices in Addis Ababa, given an adjustment coefficient of 114.0%. Moreover, the absolute value of the adjustment coefficients in the second sub-period are significantly greater than those estimated using the full sample, indicating that an aggregation of the two periods may be in appropriate. Because, the same market pairs do not exhibit significant adjustment coefficient across the two sub-periods, however, cross-period comparisons are not possible. Mekele and Dire-Dawa is the exception, for which it can be seen that the adjustment coefficient has increased from 0.260 to 0.633 in absolute terms, disregarding the specification of the cointegrating regression.

The ECM model does however, have important implications for cointegration. By comparing table C.2.1 to tables C.1.1.6-C.1.1.7 it can be seen that the market pairs for which the ADF test with a constant classifies as cointegrated are the market pairs which exhibit significant adjustment coefficients. This may suggest that the ADF test with a constant is more reliable than the other unit root tests conducted. Complementing the unit root tests of tables C.1.1.6-C.1.1.7 with an analysis of the ECM, yields a different insight into cointegration. In the first sub-period Mekele-Addis Ababa, Mekele-Bahirdar and Dire Dawa-Mekele are cointegrated, while in the second sub-period Bahirdar-Addis Ababa, Dire Dawa-Addis Ababa and Mekele-Dire Dawa are cointegrated. In conclusion, the speed of adjustment parameters in the ECMs do not conform to *hypothesis #2* since insignificant parameters in the second sub-period makes comparison difficult.

7.3 DIRECTION OF CAUSALITY

In table C.3.1, it can be seen that for the market pairs which exhibit an error correction mechanism, only one of the parameters is significant. This implies that price adjustment for none of the market pairs is simultaneously determined and causality is always uni-directional. For the full period, it can be seen that Addis Ababa is both weakly exogenous and granger causes price adjustments in Dire Dawa and Mekele. Similarly, Bahirdar is weakly exogenous and granger causes price adjustments in Dire Dawa and Mekele. Finally, in the Mekele-Dire Dawa market pair, Dire Dawa is weakly exogenous and granger causes price adjustments in Mekele. For the market pairs that have significant adjustment coefficient, the directions of causality identified in the full sample, hold in two out of three cases in the first sub-period. As before, Addis Ababa and Bahirdar are both weakly exogenous and granger cause price adjustments in Mekele. By contrast, Mekele is now found to be weakly exogenous, granger

causing price adjustments in Dire Dawa. Finally, in the second sub-period Addis Ababa is weakly exogenous, granger causing Bahirdar and Dire Dawa, while Dire Dawa once again is found to granger cause price adjustments in Mekele.

These finding are in accordance with *hypothesis #3*. The deficit regions Dire Dawa and Mekele never granger cause the surplus regions Addis Ababa and Bahirdar, although Dire Dawa or Mekele are found to granger cause when part of a pair in which both are included. Furthermore, in no case is the central market Addis Ababa granger caused by any of the other three markets.

8. DISCUSSION

In the following section, the empirical findings are discussed in relation to previous literature, with reference to the characteristics of the Ethiopian grain market.

The aim of the empirical study was to investigate how and to what extent the introduction of the ECX had an impact on price transmission, and hence market integration. To that end, the study employs co-integration techniques to test hypotheses related to long-run and short-run price behaviour of regional markets. More specifically, hypotheses relate to the existence of cointegration between maize price series in the period before and after the introduction of the exchange, and the extent to which prices exhibit short-run price adjustment. Cointegration was expected in the post-period, and it was hypothesised that the speed of adjustment of prices should differ across the two periods. In addition, surplus regions were expected to be weakly exogenous.

Overall the empirical results reveal sensitivity to the specific test employed, and give no consistent evidence for a change in cointegration. However, the combined test results together with visual inspection indicate that cointegration is a prevalent feature of most market pairs in the post-period. Results for the pre-period give no such clear indication, rendering comparison across periods difficult. Although the Johansen test of cointegration indicates an absence of cointegration in the pre-period and cointegrated price series in the post-period, implying that the ECX had a positive effect on market integration, we are reluctant to rely on this test alone in evaluating the impact of the ECX on the market as a whole. Given the absence of cointegration for many of the market pairs, the speed of adjustment parameter was found to be insignificant in the majority of cases. Therefore, in only one case was cross-period comparison possible. By contrast, inference on causality reveals relatively clear evidence of uni-directional causality in market pairs, as well as the existence of a central market. Thus, evidence of improved integration for the entire market, as represented by the selected markets of the empirical study, following the introduction of the exchange, is at best, mixed.

Previous research on market integration does not immediately address the impact of a commodity exchange, but provides insight as to why market integration may not have improved following the introduction of the ECX. It is likely that the role of the ECX has been limited by the various constraints to successful development identified in literature, of which the most important may be the thinness of the maize market. With a low trading volume and the focus of the ECX on export commodities, the maize market has remained thin during the post-period. It is possible that the impact found would have been greater had the coffee market instead been studied. The thinness of the maize market may also have implications for the riskiness of conducting trade in the commodity, limiting arbitrage activity. Another constraint may be the lack of supportive functions such as the provision of financial services. Given Ethiopian traders' observed lack of credit, this is likely to be an important constraint. Moreover, it is possible that the volatility and extent of government intervention has limited the role of the ECX. Taken together, these constraints, and the thinness of the market in particular, has most likely limited the potential role of the ECX in improving market integration.

It is important to recognise that the impact of the ECX, regardless of its extent, is gradual by nature and the limited effects found in this study may be attributed to a short time frame. Several characteristics of the Ethiopian commodity market suggest that the impact of the ECX on the market is in fact gradual. First, the ECX is taking on the role of connecting buyers and sellers, which is a role

that historically has been played by brokers. Changing these traditional modes of conducting trade, may involve only a slow adaptation by market participants. Therefore, in line with Gabre-Mahdin, we believe that it is critical to include this group of professionals in the operations of the ECX. However, this can be a challenge as such roles appear to be deeply rooted. Second, the dominance of traditional smallholder farmers with limited access to information suggests that a learning process is required before utilisation of the ECX becomes widespread in rural Ethiopia and arbitrage facilitated. This suggests that time is needed for traders to "learn how to arbitrage". Thus, the relatively short time frame of the empirical study may not capture the complete effect of the commodity exchange on market integration. At the same time, considering the past record of commodity exchanges in Africa, it is not evident that the ECX will transform commodity markets even in the long run.

Given the choice of approach and models, the results attained can only give an indication of the *net* effect of the ECX on market integration. Thus, it may be the case that the ECX has been successful in facilitating arbitrage and thereby increasing market integration, but that other significantly high barriers act to offset these positive effects. Such an offsetting effect cannot be identified in the empirical study, but rather in previous literature. It is for instance likely that the ECX may have facilitated arbitrage activity, but that high transfer costs remained and acted as impediments to efficient arbitrage, as was the case in Mozambique (Tostao and Brorsen, 2005; Penzhorn and Arndt, 2002) where poor physical road quality and lack of credit made trade costly, and Madagascar (Moser, Barret and Minten, 2009). Thus, policies aimed at improving marketing infrastructure and providing financial services, may be necessary complements to a well-functioning commodity exchange. Furthermore, the limited impact on market integration following a structural change, reflected in this study, resembles the findings of Negassa, Myers and Gabre-Madhin (2004) who found no significant effect of spatial efficiency in Ethiopia following policy reforms in 1999. This may suggest the presence of significant barriers to market integration that limit the intended effects of reforms. Barriers such as limited trading skills and poor access to credit (Negassa, Myers and Gabre-Madhin, 2004; Dessalegn, Jayne and Shaffer, 1998; Getnet, 2008) are applicable in our case. Moreover, the high volatility of prices observed in the post-period may yield arbitrage a risky activity, as was the case described by Negassa (1997) for the period 1996-1997 in Ethiopia, thereby offsetting the positive effects from facilitated arbitrage induced by the ECX.

At the same time, a complete picture of the impact of the ECX on overall market integration requires an understanding of integration on a regional level. Similar to Rashid (2004), reporting heterogenic results on the impact of liberalization in Uganda on market integration, empirical findings in this study differ substantially between regional pairs and the impact of the ECX varies. In line with previous literature (Badiene and Shively, 1998; Abdulai, 2000; Van Campenhout, 2012) heterogeneity in results is probably mainly attributed to geographical distance and characteristics, as well as trade intensity. Nevertheless, two clear conclusions emerge. First, Bahirdar and Dire Dawa is the market pair which appear to be the least integrated in both periods, as indicated by low cointegrating coefficients and an absence of cointegration on the 5% level of significance for both specifications of the ADF-test and the DFGLS-test. Thus, it represents the market pair least affected by the introduction of the ECX. This is supported by the relatively long geographical distance between Bahirdar and Dire Dawa. In line with Rashid (2011), Dire Dawa appears to be an isolated market. However, it contradicts the fact that road networks connecting Dire Dawa to other regions are considered relatively well-developed and suggests that other impediments, such as lack of credit, may play an important role. Second, Mekele and Dire Dawa were found to be integrated in both periods. Furthermore, an examination of the change in speed of adjustment reveals a significant improvement in the price transmission process, suggesting that ECX contributed to an increase in the *extent* of market integration for this pair. Given

that both markets are geographically dispersed and located in deficit regions, there is no evident reason why this is found to be the case.

In line with previous literature (Negassa, 1997; Badiene and Shively, 1998; Getnet, Verbekea and Viaene, 2005; Getnet, 2007; Rashid, 2011;), and an infrastructure characterized by a radial road configuration (Gabre-Madhin, 2001), Addis Ababa is found to be the central market in both periods, indicating that the ECX has not had an impact on the directionality of price transmission. Likewise, in no case is a deficit market found to be weakly exogenous. These findings address the sub-question of the study and are in accordance with the hypotheses made. The findings have important policy implications. Similar to previous literature (Negassa, 1997; Getnet, Verbekea and Viaene, 2005), we suggest that price stabilization policies be targeted on the central market Addis Ababa. Moreover, it can be concluded that the role of Addis Ababa as a central market, justifies the location of the ECX.

Finally, it should be noted that the volatile political and economic climate in Ethiopia during the time period studied, as well the drivers of structural change identified by Minten, Stiffen and Tamru (2012) for the period 2001-2011 including economic growth, urbanization, investments in road and infrastructure and spread of mobile phones, can give rise to non-negligible confounding effects. Furthermore, volatility of commodity prices, especially during the financial crisis, may have had significant implications for efficient arbitrage and thus, market integration. While the aforementioned structural changes could cause an overestimation of the impact of the ECX, an increased volatility could cause an underestimation. This should be taken into account when interpreting the results of this study.

In conclusion, given heterogeneity in the observed impact of the ECX on market integration within regional pairs, as implied by cointegration analysis, the net effect of the exchange on market integration, on a national level, is unclear. Although, the potential effect of a commodity exchange on market integration in theory can be substantial, it is not surprising that a stronger effect was not found. In the case of the ECX, historically segmented markets and the dominance of traditional agriculture suggest a gradual adjustment path to institutional change, regardless of the significance of that change.

9. CONCLUDING REMARKS

The recent decades have seen substantial effort and debate on appropriate policy reforms to increase the depth of market integration. Fuelled by severe food insecurity, the debate has been particularly relevant in Ethiopia. While government intervention has been common in the past, the present view is that of market-based solutions. The introduction of a commodity exchange represents such a solution. Recognizing the gap in literature on the role of commodity exchanges for market integration, our study aims at addressing this topic by investigating the impact of the introduction of the ECX in 2008 on maize market integration in Ethiopia. For this purpose, cointegration, error correction and causality analysis were conducted. Empirical evidence is characterized by heterogeneity and sensitivity to the methods employed. While Engle and Granger cointegration tests suggest little improvement in market integration, the Johansen cointegration test gives consistent evidence of the opposite. Further, in most cases an error correction representation does not exist. In light of this, the effect of the ECX on market integration should be evaluated with caution. Finally, inference on causality suggests that Addis Ababa is the central market.

Several important policy implications can be drawn from the study. First, the success of the ECX appears to crucially hinge on the lifting of important barriers to market integration. Barriers preventing the exchange from playing the significant role it is intended to play include high transaction costs, lack of credit of market participants, and traditional modes of conducting trade. Thus, complementary policy reforms aimed at reducing barriers to arbitrage are recommended. Such policy reforms should aim at improving infrastructure and facilitating access to credit. Given the low value to weight of maize, an extension of the railroad network may be beneficial. Through coordinated efforts, the true potential of each individual policy reform can be realized. Furthermore, the heterogeneity in the observed impact of the ECX on regional pair market integration suggests that the complementary policy reforms adopted should be tailored to meet the specific problems of the region. For instance, Dire Dawa was found to be poorly integrated with several of the other markets in both periods, although its infrastructure is relatively well-developed compared to the other markets, suggesting the existence of additional barriers to integration such as lack of credit. A regionally targeted policy reform approach would aim at increasing credit availability in Dire Dawa, while improving infrastructure in other regions. Such a targeted approach would allow for the full reaping of the benefits of the ECX. In the long-run, the ECX can only have a sustained impact on market integration if it is able to adapt to its environment and the needs of its users.

On a higher level, the study suggests that a commodity exchange can potentially play an important role in improving agricultural market integration in developing economies. However, a critical factor determining its impact on market integration is the existence of certain barriers to integration, which are context-specific. Thus, although a commodity exchange has the potential to improve market integration when combined with relevant policy initiatives, no blueprint exists and country-specific factors will determine its success. Given this potential, a commodity exchange constitutes an important market-based solution to market segmentation in developing countries. We believe that commodity exchanges will play an increasingly important role for market integration in the future.

The limitations of this study deserve attention. In analysing the impact of the ECX on market integration, two main assumptions were made. First, the introduction of the ECX was regarded as an exogenous structural break. Second, the introduction of the exchange was assumed to be the major

event affecting market integration during 2008, implying minimal confounding effects. The second assumption merits special attention. Given the volatile political and economic climate often present in developing countries, and with Ethiopia being no exception, it is possible that other factors during the period following the introduction of the ECX had an impact on market integration. Government intervention is one such important factor. In addition, structural changes induced by drivers such as sustained investments in infrastructure and the better access to mobile phones could potentially have had a significant effect on market integration. The examples suggest that confounding effects may in fact be present. Moreover, the ECX is likely to only gradually affect the market, and thus the time frame used would preferably have been longer.

In addition to this, limitations to the employed methodology exist. First, the use of bivariate cointegration analysis ignores the possibility of multiple cointegrating relationships between variables. Second, cointegration has been seen as indicative of market integration. However, it is possible that markets that were viewed as segmented in this study based on the absence of a cointegration relationship are in fact integrated. It is therefore desirable that the study be conducted with a wider time frame, using a multivariate framework in testing for cointegration, in order to capture feedback effects between markets. Further, given the absence of strong cointegrating relationships and observed significant impediments to efficient arbitrage, it is of interest to investigate the drivers of spatial arbitrage. The PBM allows for such an investigation. The interpretation of the model in terms of arbitrage activity is useful in evaluating the effect of a commodity exchange, which in theory should facilitate arbitrage. In particular, the extension of the PBM developed by Negassa, Myers and Gabre-Madhin (2004), which allows for a gradual response to reforms, is well-suited and can provide further valuable insights. Given the absence of trade reversals for the regional market pairs of this study, the PBM can be an appropriate choice of model.

This suggests the need for further research.

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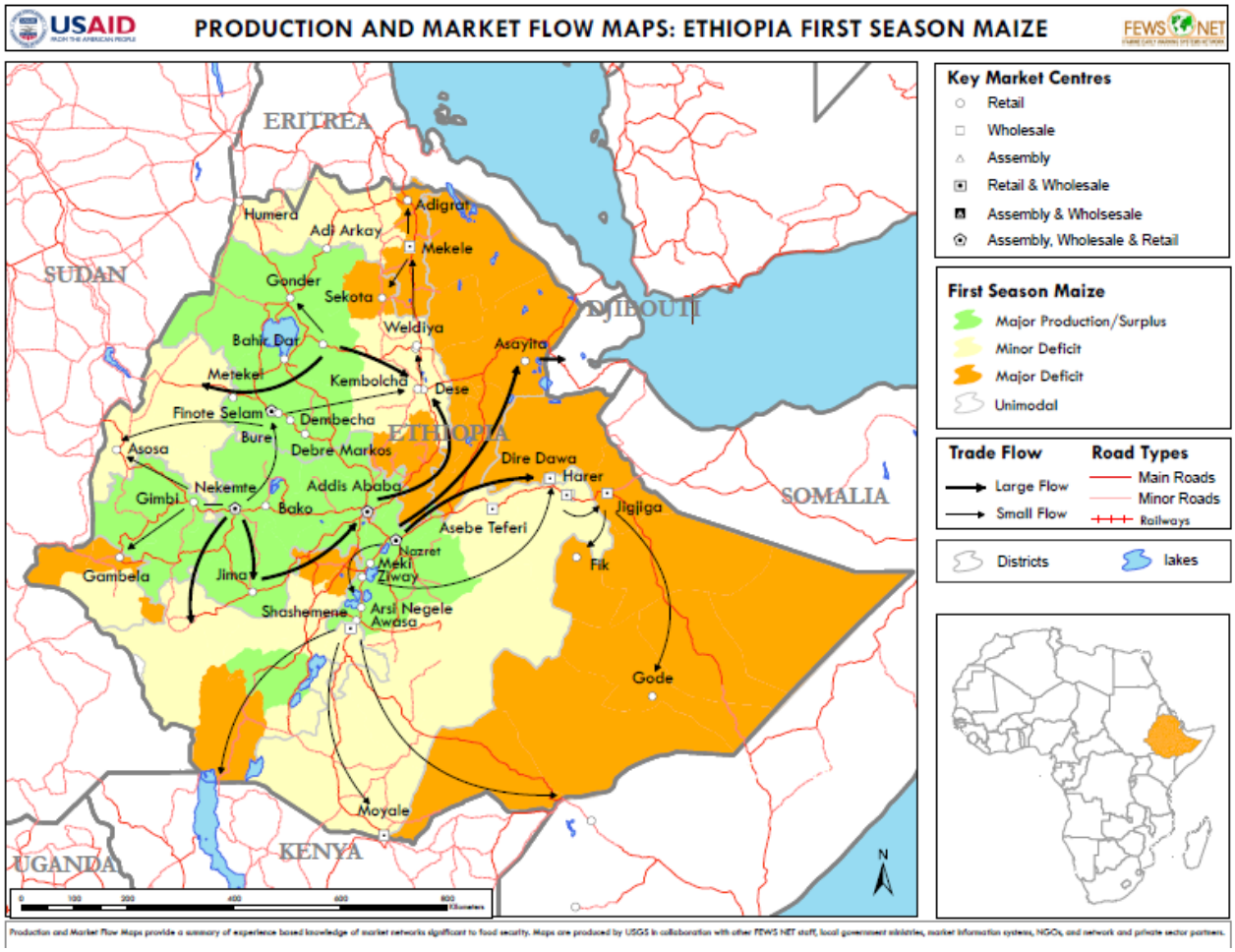
APPENDIX

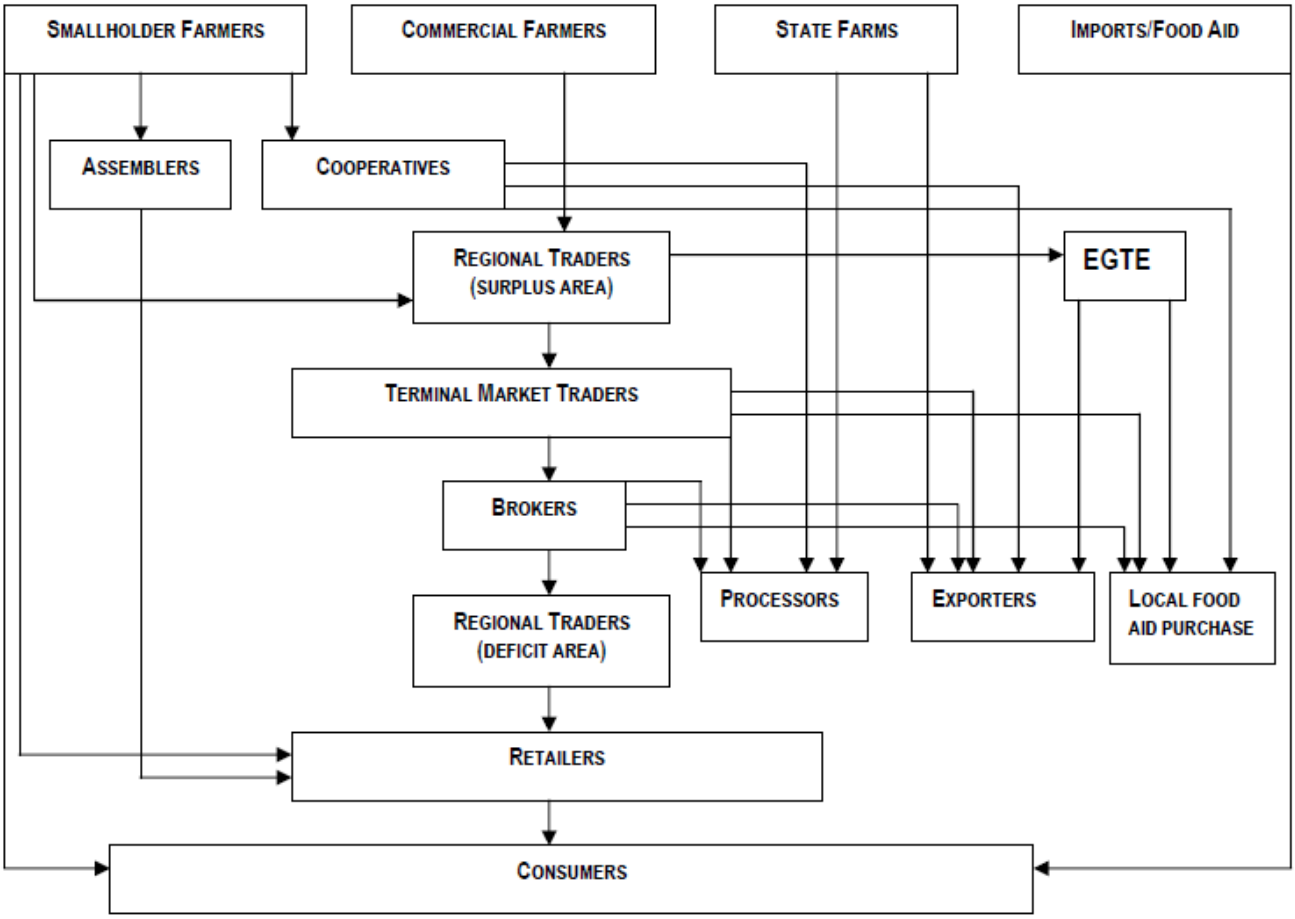
A THE ROLE OF THE ETHIOPIA COMMODITY EXCHANGE

FIGURE A.1 Maize trade flows in Ethiopia



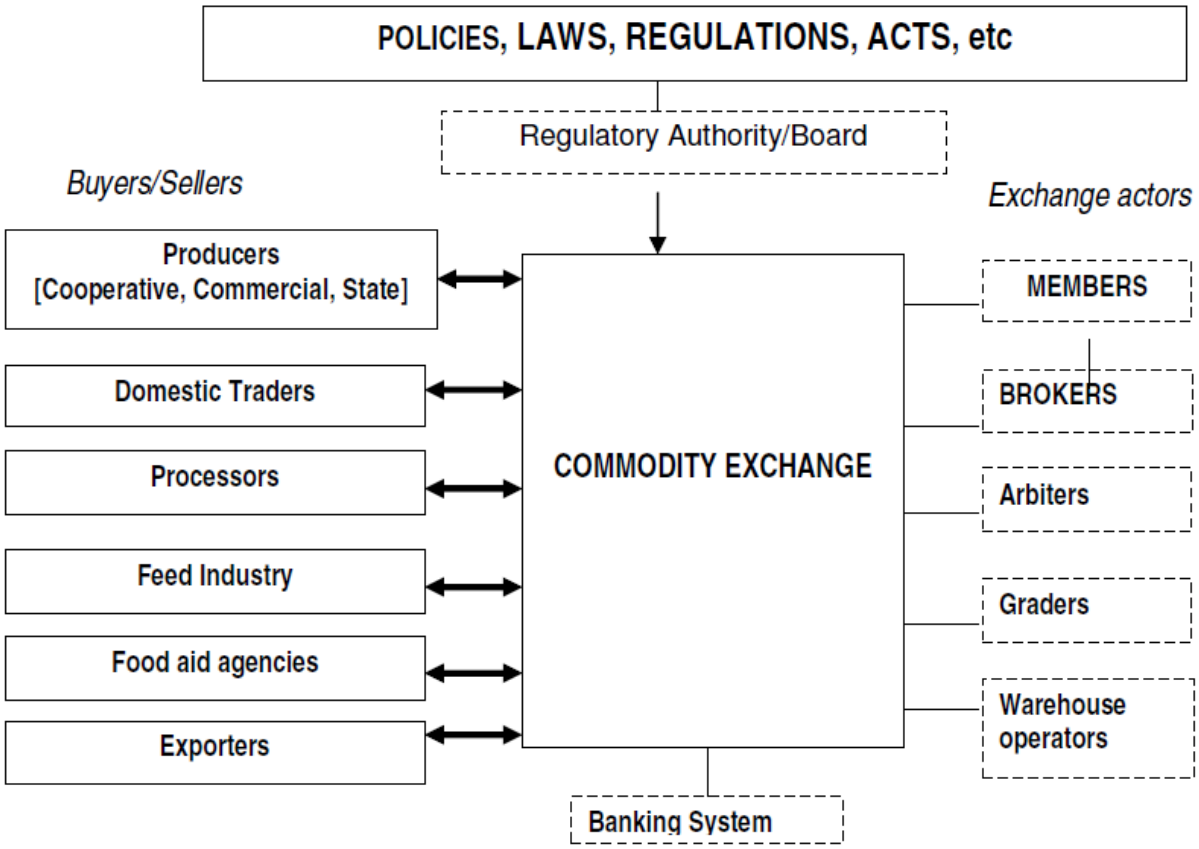
Source: FEWS NET http://www.fews.net/pages/marketcenter.aspx?gb=et&loc=3

FIGURE A.2 Grain trade flows in Ethiopia



Source: Gabre-Madhin, 2005

FIGURE A.3. Structure of a commodity exchange

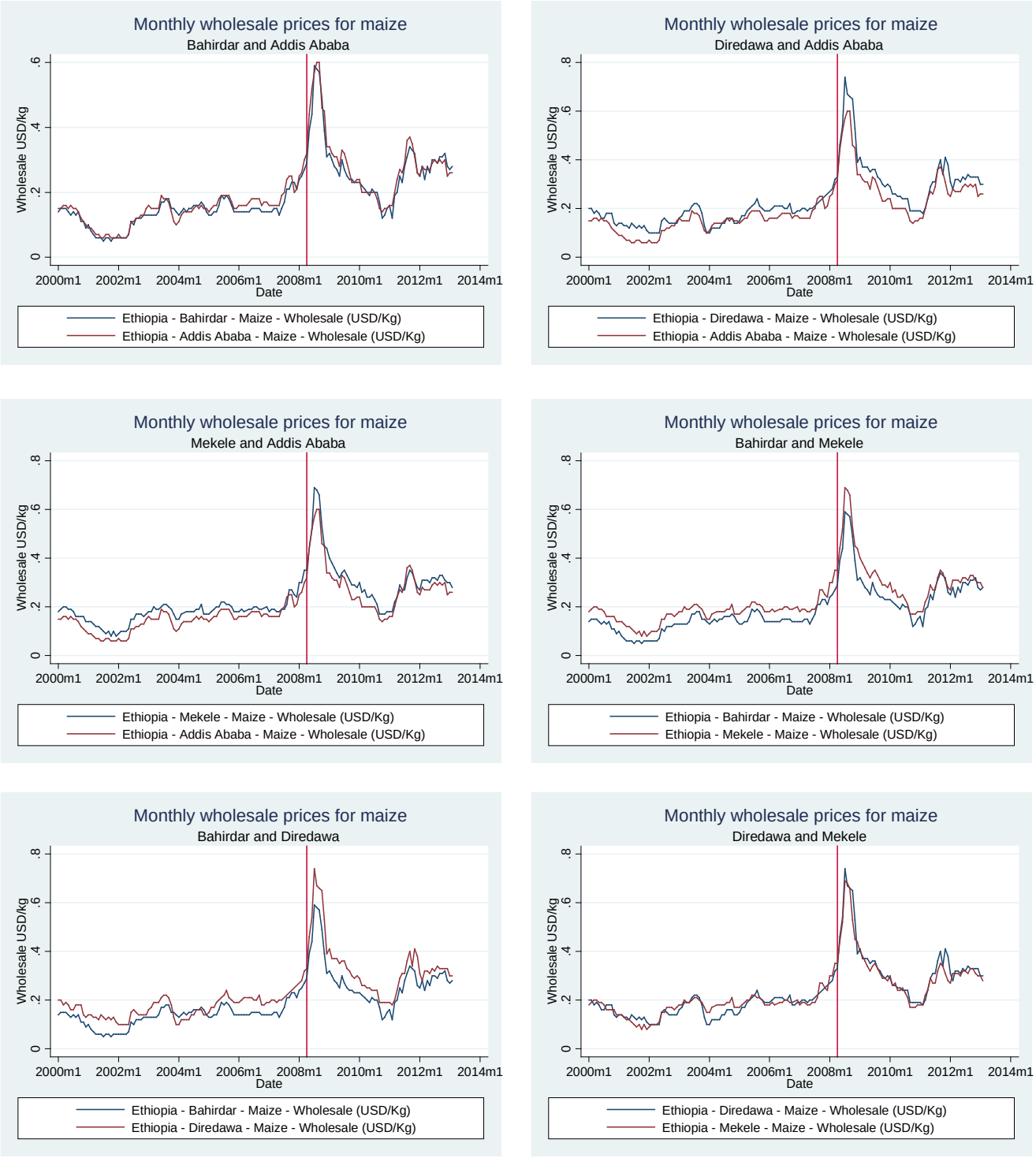


Source: Gabre-Madhin *et al*, 2003

B DATA PROPERTIES

B.1 Time series in levels

FIGURE B.1.1 Monthly wholesale prices of maize



Source: Authors' own calculations

B.2 Time series in first differences

FIGURE B.2.1 First differenced monthly wholesale prices of maize

Source: Authors' own calculations

B.3 Unit root tests of time series in levels and first differences

TABLE B.3.1 ADF and PP unit root tests

	Augmented Dickey Fuller						***Philips-Perron***			
	Without Trend			*With Trend*			*Without trend*		*With trend*	
	t-statistic	*Nr of lags*	*Reject H_0*	*t-statistic*	*Nr of lags*	*Reject H_0*	*t-statistic*	*Reject H_0*	*t-statistic*	*Reject H_0*
FULL PERIOD										
Levels										
Addis Ababa	-2.788*	2	Yes	-3.085	10	No	-2.157	No	-2.866	No
Bahirdar	-2.036	11	No	-3.302*	11	Yes	-2.163	No	-3.022	No
Dire Dawa	-4.930***	5	Yes	-5.727***	8	Yes	-2.176	No	-2.835	No
Mekele	-1.891	9	No	-2.514	9	No	-2.097	No	-2.620	No
First differences										
Addis Ababa	-6.226***	2	Yes	-6.206***	2	Yes	-9.185***	Yes	-9.157***	Yes
Bahirdar	-6.453***	2	Yes	-6.437***	2	Yes	-10.084***	Yes	-10.057***	Yes
Dire Dawa	-6.382***	6	Yes	-6.374***	6	Yes	-9.829***	Yes	-9.797***	Yes
Mekele	-3.698***	8	Yes	-3.678**	8	Yes	-8.453***	Yes	-8.423***	Yes

* p<10%; ** p<5%; *** p<1%

Source: Authors' own calculations

	Augmented Dickey Fuller						*Philips-Perron*			
	Without Trend			*With Trend*			*Without trend*		*With trend*	
	t-statistic	*Nr of lags*	*Reject H_0*	*t-statistic*	*Nr of lags*	*Reject H_0*	*t-statistic*	*Reject H_0*	*t-statistic*	*Reject H_0*
PRE-ECX										
Levels										
Addis Ababa	-0.276	1	No	-2.076	1	No	-0.197	No	-1.904	No
Bahirdar	-0.583	7	No	-2.520	7	No	-0.243	No	-1.720	No
Dire Dawa	-2.468	1	No	-3.260*	1	Yes	-1.304	No	-2.200	No
Mekele	-0.482	7	No	-2.599	7	No	-0.420	No	-0.950	No
First differences										
Addis Ababa	-5.212***	3	Yes	-5.594***	3	Yes	-7.448***	Yes	-7.652***	Yes
Bahirdar	-1.41	11	No	-1.436	11	No	-9.316***	Yes	-9.599***	Yes
Dire Dawa	-7.519***	0	Yes	-7.533***	0	Yes	-7.485***	Yes	-7.497***	Yes
Mekele	-0.896	6	No	-1.664	6	No	-8.670***	Yes	-9.071***	Yes
POST-ECX										
Levels										
Addis Ababa	-3.470***	2	Yes	-3.075	2	No	-1.814	No	-2.037	No
Bahirdar	-3.237**	2	Yes	-3.035	2	No	-1.978	No	-2.106	No
Dire Dawa	-5.277***	3	Yes	-2.718	5	No	-1.939	No	-2.331	No
Mekele	-4.335***	3	Yes	-1.728	8	No	-1.775	No	-2.126	No
First differences										
Addis Ababa	-3.281**	5	Yes	-3.357*	5	Yes	-6.097***	Yes	-6.085***	Yes
Bahirdar	-5.945***	2	Yes	-6.443***	2	Yes	-6.212***	Yes	-6.174***	Yes
Dire Dawa	-4.865***	4	Yes	-3.996***	6	Yes	-6.502***	Yes	-6.436***	Yes
Mekele	-3.497***	7	Yes	-3.275*	7	Yes	-4.903***	Yes	-4.848***	Yes

* p<10%; ** p<5%; *** p<1%

Source: Authors' own calculations

TABLE B.3.2 DF-GLS-test for unit root

	$DF\text{-}GLS_{opt\text{-}lag}$	$k_{opt\text{-}lag}$	$DF\text{-}GLS_{SC}$	k_{SC}	$DF\text{-}GLS_{MAIC}$	k_{MAIC}
PRE-ECX						
Levels						
Addis Ababa	-1.455	1	-1.455	1	-1.455	1
Bahirdar	-1.633	7	-1.161	1	-1.161	1
Dire Dawa	-1.879	1	-1.879	1	-1.879	1
Mekele	-1.922	7	-0.814	1	-0.814	1
First differences						
Addis Ababa	-7.434***	0	-5.291***	1	-1.835	11
Bahirdar	-1.436	11	-4.959***	1	-1.436	11
Dire Dawa	-1.783	11	-4.728***	1	-1.783	11
Mekele	-1.784	6	-4.991***	1	-1.784	6
POST-ECX						
Levels						
Addis Ababa	-1.522	1	-1.522	1	-1.522	1
Bahirdar	-1.638	0	-1.165	1	1.165	1
Dire Dawa	-1.428	3	-1.274	1	-1.274	1
Mekele	-1.556	0	-1.290	1	-1.290	1
First differences						
Addis Ababa	-1.792	8	-2.705	1	-1.792	8
Bahirdar	-2.288*	3	-2.908*	1	-2.288*	3
Dire Dawa	-1.854	2	-1.854	2	-1.854	2
Mekele	-1.999	7	-2.870	1	-1.696	8

* p<10%; ** p<5%; *** p<1%

Source: Authors' own calculations

C EMPIRICAL RESULTS

C.1 COINTEGRATION ANALYSIS

C.1.1 Engle and Granger test for cointegration

TABLE C.1.1.1 Cointegrating vectors in levels

Independent variable/ Dependent variable	Addis Ababa	Bahirdar	Dire Dawa	Mekele
FULL SAMPLE				
Addis Ababa	1	1.020***	0.867***	0.959***
Bahirdar	0.943***	1	0.830***	0.922***
Dire Dawa	1.088***	1.124***	1	1.064***
Mekele	1.003***	1.041***	0.890***	1
PRE-ECX				
Addis Ababa	1	1.028***	0.935***	1.025***
Bahirdar	0.879***	1	0.762***	0.948***
Dire Dawa	0.816***	0.781***	1	0.833***
Mekele	0.894***	0.964***	0.861***	1
POST-ECX				
Addis Ababa	1	1.025***	0.841***	0.902***
Bahirdar	0.924***	1	0.804***	0.855***
Dire Dawa	1.099***	1.165***	1	1.032***
Mekele	1.041***	1.094***	0.910***	1

* p<10%; ** p<5%; *** p<1%

TABLE C.1.1.2 Cointegrating vectors in logs

Independent variable/ Dependent variable	Addis Ababa	Bahirdar	Dire Dawa	Mekele
FULL SAMPLE				
Addis Ababa	1	0.965***	1.090***	1.201***
Bahirdar	0.996***	1	1.078***	1.217***
Dire Dawa	0.810***	0.776***	1	0.998***
Mekele	0.794***	0.780***	0.900***	1
PRE-ECX				
Addis Ababa	1	0.963***	1.213***	1.332***
Bahirdar	0.961***	1	1.060***	1.328***
Dire Dawa	0.565***	0.493***	1	0.763***
Mekele	0.694***	0.692***	0.858***	1
POST-ECX				
Addis Ababa	1	0.969***	1.022***	1.039***
Bahirdar	0.964***	1	1.013***	1.023***
Dire Dawa	0.907***	0.903***	1	0.978***
Mekele	0.903***	0.893***	0.958***	1

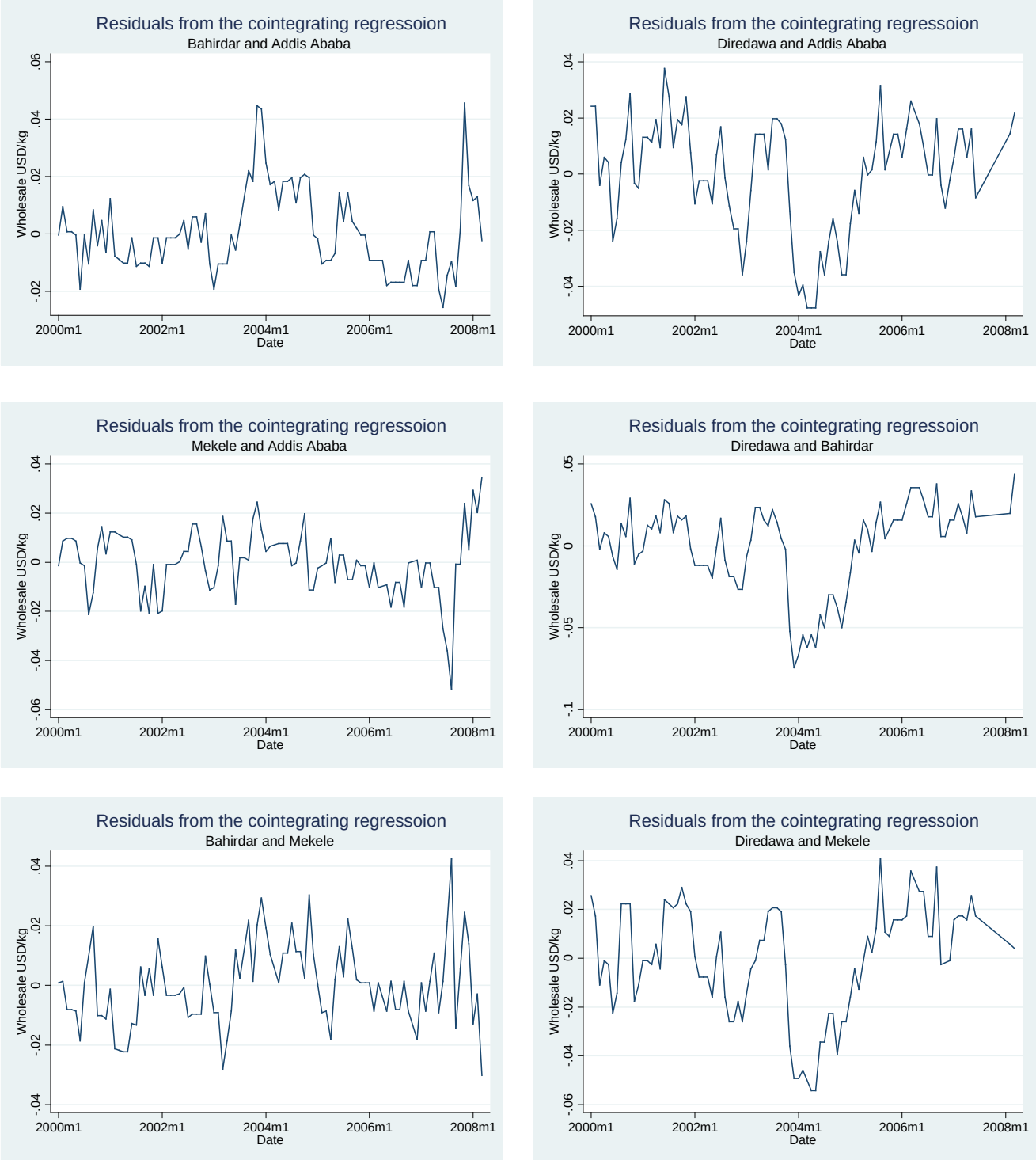
* p<10%; ** p<5%; *** p<1%

Source: Authors' own calculations

FIGURE C.1.1.3 Residuals from cointegrating regressions, full sample

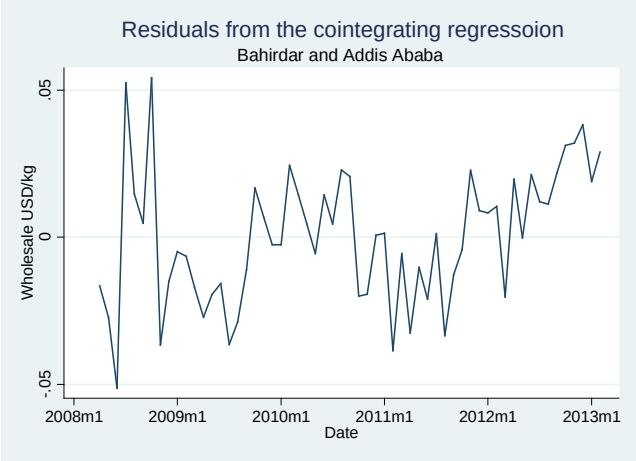
Source: Authors' own calculations

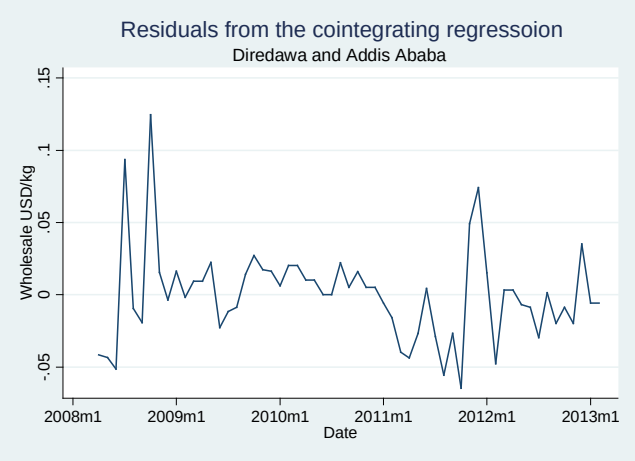
FIGURE C.1.1.4 Residuals from cointegrating regressions, first sub-sample

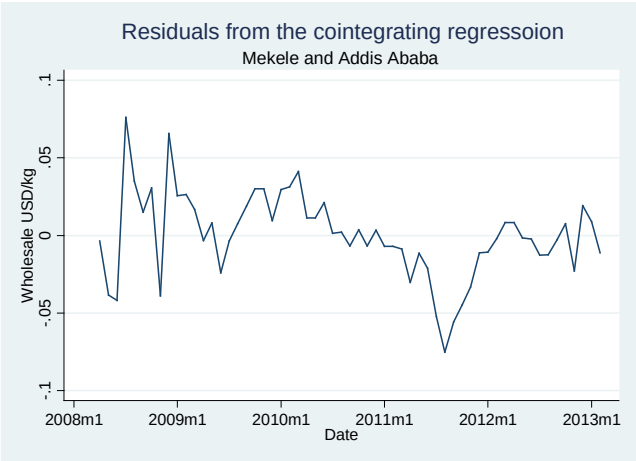


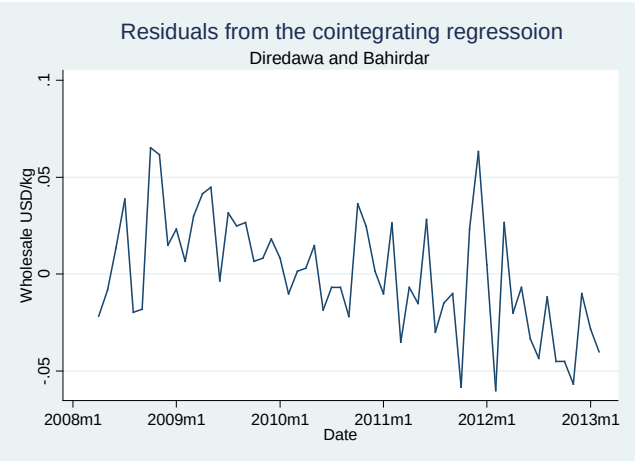
Source: Authors' own calculations

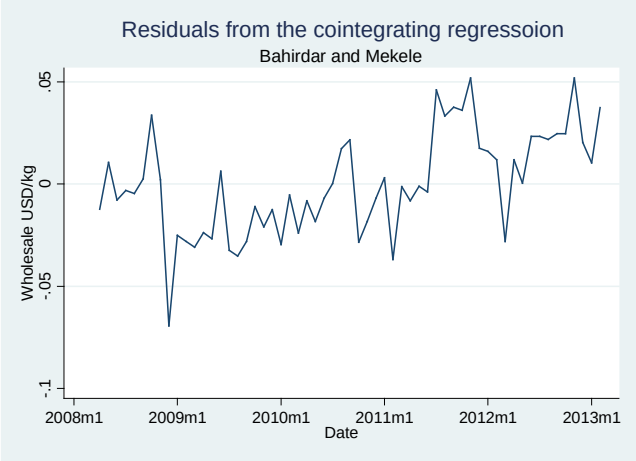
FIGURE C.1.1.5 Residuals from cointegrating regressions, second sub-sample

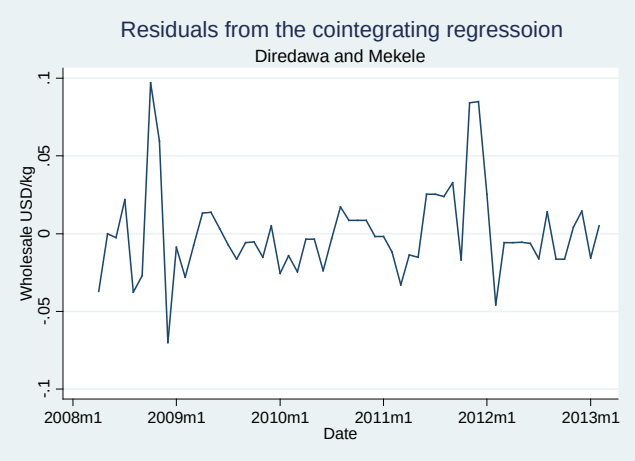












Source: Authors' own calculations

TABLE C.1.1.6 ADF and PP unit root tests for cointegrating residuals

	Augmented Dickey Fuller						***Philips-Perron***	
	With constant			*Without Constant*				
	t-statistic	*Nr of lags*	*Reject H_0*	*t-statistic*	*Nr of lags*	*Reject H_0*	*t-statistic*	*Reject H_0*
FULL PERIOD								
Bahirdar-Addis Ababa	-2.698*	11	Yes	-2.752***	11	Yes	-7.584***	Yes
Dire Dawa-Addis Ababa	-3.827***	2	Yes	-3.841***	2	Yes	-7.523***	Yes
Mekele-Addis Ababa	-3.143**	4	Yes	-3.153***	4	Yes	-6.825***	Yes
Bahirdar-Dire Dawa	-1.603	12	No	-1.598	12	No	-5.348***	Yes
Bahirdar-Mekele	-2.416	3	No	-2.438**	3	Yes	-6.207***	Yes
Dire Dawa-Mekele	-2.398	10	No	-2.258**	10	Yes	-6.665***	Yes
PRE-ECX								
Bahirdar-Addis Ababa	-2.535	5	No	-2.561**	5	Yes	-4.068***	Yes
Dire Dawa-Addis Ababa	-2.171	8	No	-2.178**	8	Yes	-3.280**	Yes
Mekele-Addis Ababa	-3.770***	4	Yes	-3.839***	4	Yes	-4.591***	Yes
Bahirdar-Dire Dawa	-1.785	1	No	-1.796*	1	Yes	-2.379	No
Bahirdar-Mekele	-3.752***	7	Yes	-3.673***	7	Yes	-5.571***	Yes
Dire Dawa-Mekele	-3.255**	0	Yes	-3.275***	0	Yes	-3.282**	Yes
POST-ECX								
Bahirdar-Addis Ababa	-5.424***	0	Yes	-5.476***	0	Yes	-5.535***	Yes
Dire Dawa-Addis Ababa	-6.584***	0	Yes	-6.641***	0	Yes	-6.561***	Yes
Mekele-Addis Ababa	-1.789	4	No	-1.813*	4	Yes	-4.577***	Yes
Bahirdar-Dire Dawa	-1.565	3	No	-1.611*	3	Yes	-5.333***	Yes
Bahirdar-Mekele	-2.557	1	No	-2.585**	1	Yes	-3.739***	Yes
Dire Dawa-Mekele	-6.017***	1	Yes	-6.070***	1	Yes	-6.052***	Yes

* p<10%; ** p<5%; *** p<1%

Source: Authors' own calculations

TABLE C.1.1.7 ADF and PP unit root tests for cointegrating residuals, alternative cointegrating regressions

	Augmented Dickey Fuller						***Philips-Perron***	
	With constant			*Without Constant*				
	t-statistic	*Nr of lags*	*Reject H_0*	*t-statistic*	*Nr of lags*	*Reject H_0*	*t-statistic*	*Reject H_0*
FULL PERIOD								
Addis Ababa-Bahirdar	-2.698*	11	Yes	-2.752***	11	Yes	-7.550***	Yes
Addis Ababa-Dire Dawa	-3.813***	2	Yes	-3.826***	2	Yes	-7.439***	Yes
Addis Ababa-Mekele	-1.900	12	No	-1.908*	12	Yes	-6.815***	Yes
Dire Dawa-Bahirdar	-1.786	12	No	-1.745*	12	Yes	-5.408***	Yes
Mekele-Bahirdar	-2.369	3	No	-2.394**	3	Yes	-6.164***	Yes
Mekele-Dire Dawa	-2.606*	10	Yes	-2.450**	10	Yes	-6.566***	Yes
PRE-ECX								
Addis Ababa-Bahirdar	-2.339	5	No	-2.353**	5	Yes	-4.011***	Yes
Addis Ababa-Dire Dawa	-1.848	8	No	-1.863*	8	Yes	-2.834*	Yes
Addis Ababa-Mekele	-4.260***	2	Yes	-4.288***	2	Yes	-4.678***	Yes
Dire Dawa-Bahirdar	-2.558	0	No	-2.576**	0	Yes	-2.491	No
Mekele-Bahirdar	-3.952***	7	Yes	-4.027***	7	Yes	-5.509***	Yes
Mekele-Dire Dawa	-2.809*	0	Yes	-2.826***	0	Yes	-2.648*	Yes
POST-ECX								
Addis Ababa-Bahirdar	-3.428***	1	Yes	-3.468***	1	Yes	-5.433***	Yes
Addis Ababa-Dire Dawa	-6.487***	0	Yes	-6.542***	0	Yes	-6.453***	Yes
Addis Ababa-Mekele	-1.764	4	No	-1.787*	4	Yes	-4.610***	Yes
Dire Dawa-Bahirdar	-1.387	3	No	-1.450	3	No	-5.355***	Yes
Mekele-Bahirdar	-2.454	1	No	-2.483**	1	Yes	-3.547***	Yes
Mekele-Dire Dawa	-5.925***	1	Yes	-5.976***	1	Yes	-5.911***	Yes

* p<10%; ** p<5%; *** p<1%

Source: Authors' own calculations

TABLE C.1.1.8 DF-GLS unit root test for residuals

	DF-GLS$_{opt-lag}$	$k_{opt-lag}$	DF-GLS$_{SC}$	k_{SC}	DF-GLS$_{MAIC}$	k_{MAIC}
FULL PERIOD						
Bahirdar-Addis Ababa	-2.752**	11	-4.639***	1	-3.605***	2
Dire Dawa-Addis Ababa	-3.214**	2	-3.214**	2	-3.214**	2
Mekele-Addis Ababa	-2.337	12	-4.892***	1	-3.225**	4
Bahirdar-Dire Dawa	-2.791**	13	-2.938*	2	-2.618	3
Bahirdar-Mekele	-2.874*	3	-4.575***	1	-1.573	10
Dire Dawa-Mekele	-2.413	11	-3.362**	2	-2.075	12
PRE-ECX						
Bahirdar-Addis Ababa	-2.408	5	-3.103*	1	-2.741*	2
Dire Dawa-Addis Ababa	-3.281**	0	-2.948*	1	-2.526	2
Mekele-Addis Ababa	-3.580**	2	-3.106**	1	-3.106**	1
Bahirdar-Dire Dawa	-2.859*	0	-2.321	1	-2.321	1
Bahirdar-Mekele	-3.261**	4	-3.822***	1	-2.781*	3
Dire Dawa-Mekele	-3.272**	0	-2.719	1	-2.412	2
POST-ECX						
Bahirdar-Addis Ababa	-1.712	3	-2.819	1	-2.819	3
Dire Dawa-Addis Ababa	-2.366**	3	-3.977***	1	-1.959	5
Mekele-Addis Ababa	-4.859***	0	-2.361	1	-2.361	1
Bahirdar-Dire Dawa	-1.714	3	-3.588**	1	-1.261	5
Bahirdar-Mekele	-5.028***	0	-2.999*	1	-2.395	3
Dire Dawa-Mekele	-5.753***	0	-4.206***	1	-2.821*	3

* p<10%; ** p<5%; *** p<1%

Source: Authors' own calculations

TABLE C.1.1.9 DF-GLS unit root test for residuals, alternative cointegrating regressions

	$DF\text{-}GLS_{opt\text{-}lag}$	$k_{opt\text{-}lag}$	$DF\text{-}GLS_{SC}$	k_{SC}	$DF\text{-}GLS_{MAIC}$	k_{MAIC}
FULL PERIOD						
Addis Ababa-Bahirdar	-2.644*	11	-4.535***	1	-3.486**	2
Addis Ababa-Dire Dawa	-3.320**	2	-3.320**	2	-2.839*	4
Addis Ababa-Mekele	-2.297**	12	-5.058***	1	-3.439**	4
Dire Dawa-Bahirdar	-2.555*	13	-2.776*	2	-2.554	3
Mekele-Bahirdar	-2.625	3	-3.299*	2	-1.626	10
Mekele-Dire Dawa	-2.448	11	-3.363***	2	-2.112	12
PRE-ECX						
Addis Ababa-Bahirdar	-2.323	5	-3.265**	1	-3.265**	5
Addis Ababa-Dire Dawa	-3.767***	0	-3.208**	1	-2.635	2
Addis Ababa-Mekele	-3.959***	2	-3.425**	1	-3.425**	1
Dire Dawa-Bahirdar	-2.599	0	-2.446	1	-2.446	1
Mekele-Bahirdar	-3.250**	7	-3.679***	1	-2.585	3
Mekele-Dire Dawa	-2.631*	11	-2.551	1	-2.099	2
POST-ECX						
Addis Ababa-Bahirdar	-1.762	3	-2.814	1	-1.762	3
Addis Ababa-Dire Dawa	-2.048	3	-3.534**	1	-1.648	5
Addis Ababa-Mekele	-4.687***	0	-2.272	1	-2.272	1
Dire Dawa-Bahirdar	-1.975	3	-4.066***	1	-1.512	5
Mekele-Bahirdar	-5.669***	0	-3.385**	1	-2.664	3
Mekele-Dire Dawa	-5.903***	0	-4.091***	1	-2.345	4

* p<10%; ** p<5%; *** p<1%

Source: Authors' own calculations

C.1.2 Johansen's test for cointegration

TABLE C.1.2.1 Test for cointegration in regional market pairs

	FULL PERIOD			PRE-ECX			POST-ECX		
	Trace statistic	Reject H_0	Nr of lags (AIC)	Trace statistic	Reject H_0	Nr of lags (AIC)	Trace statistic	Reject H_0	Nr of lags (AIC)
Bahirdar-Addis Ababa	14.966	No	4	12.094	No	2	20.330***	Yes	3
Dire Dawa-Addis Ababa	23.863***	Yes	4	13.570	No	2	30.763***	Yes	3
Mekele-Addis Ababa	23.240***	Yes	4	13.517	No	2	22.182***	Yes	3
Bahirdar-Dire Dawa	18.357**	Yes	4	9.016	No	2	31.117***	Yes	4
Bahirdar-Mekele	12.542**	Yes	4	28.676***	Yes	1	24.096***	Yes	4
Dire Dawa-Mekele	22.652***	Yes	4	10.754	No	3	43.13***	Yes	4

* p<10%; ** p<5%; *** p<1%
Source: Authors' own calculations

C.1.3 Summarizing note on tests for cointegration

TABLE C.1.3.1 Engle and Granger test for cointegration, without constant

	FULL PERIOD	PRE-ECX	POST-ECX
Bahirdar-Addis Ababa	**X**	**X**	**X**
Dire Dawa-Addis Ababa	**X**	**X**	**X**
Mekele-Addis Ababa	**X**	**X**	**X**
Bahirdar-Dire Dawa	**--**	**X**	**X**
Bahirdar-Mekele	**X**	**X**	**X**
Dire Dawa-Mekele	**X**	**X**	**X**

Source: Authors' own calculations

TABLE C.1.3.1 Johansen's test for cointegration

	FULL PERIOD	PRE-ECX	POST-ECX
Bahirdar-Addis Ababa	**--**	**--**	**X**
Dire Dawa-Addis Ababa	**X**	**--**	**X**
Mekele-Addis Ababa	**X**	**--**	**X**
Bahirdar-Dire Dawa	**X**	**--**	**X**
Bahirdar-Mekele	**X**	**X**	**X**
Dire Dawa-Mekele	**X**	**--**	**X**

Source: Authors' own calculations

C.2 ERROR CORRECTION MODEL

TABLE C.2.1 ECM estimation for all regional pairs

	FULL PERIOD			PRE-ECX			POST-ECX		
	Adjustment Coefficient	*Nr of lags*	*p-value*	*Adjustment Coefficient*	*Nr of lags*	*p-value*	*Adjustment Coefficient*	*Nr of lags*	*p-value*
Bahirdar-Addis Ababa	-0.268 (0.223)	13	0.234	-0.218 (0.142)	10	0.128	-0.669*** (0.203)	0	0.002
Addis Ababa-Bahirdar	-0.247 (0.223)	13	0.270	-0.103 (0.119)	3	0.387	-0.379 (0.360)	10	0.309
Dire Dawa-Addis Ababa	-0.278*** (0.105)	7	0.009	-0.207 (0.140)	11	0.146	-1.140*** (0.347)	5	0.002
Addis Ababa-Dire Dawa	-0.112 (0.117)	13	0.341	-0.012 (0.082)	8	0.883	-0.399 (0.435)	5	0.364
Mekele-Addis Ababa	-0.394* (0.213)	13	0.068	-1.179*** (0.294)	7	0.000	-0.463 (0.298)	10	0.132
Addis Ababa-Mekele	0.045 (0.230)	13	0.846	0.034 (0.182)	4	0.851	-0.145 (0.219)	3	0.513
Bahirdar-Dire Dawa	-0.088 (0.099)	12	0.373	-0.048 (0.051)	1	0.349	-0.202 (0.296)	3	0.497
Dire Dawa-Bahirdar	-0.162* (0.096)	13	0.098	-0.101 (0.099)	10	0.311	-0.309 (0.338)	10	0.369
Bahirdar-Mekele	0.081 (0.153)	6	0.598	-0.123 (0.171)	4	0.476	-0.211 (0.249)	7	0.403
Mekele-Bahirdar	-0.346** (0.161)	8	0.034	-0.706** (0.302)	7	0.023	-0.190 (0.189)	6	0.321
Mekele-Dire Dawa	-0.270** (0.123)	7	0.031	0.017 (0.077)	3	0.824	-0.633** (0.309)	7	0.047
Dire Dawa-Mekele	-0.178 (0.118)	6	0.133	-0.260*** (0.082)	1	0.002	-0.384 (0.263)	5	0.152

* p<10%; ** p<5%; *** p<1%

Source: Authors' own calculations

C.3 DIRECTION OF CAUSALITY

TABLE C.3.1 Granger Causality based on ECM parameter significance

	FULL PERIOD			PRE-ECX			POST-ECX		
	Directionality	*Granger caused*	*Granger causing*	*Directionality*	*Granger caused*	*Granger causing*	*Directionality*	*Granger caused*	*Granger causing*
Bahirdar and Addis Ababa	No directionality	--	--	No directionality	--	--	Uni-directional	Bahirdar	Addis Ababa
Dire Dawa and Addis Ababa	Uni-directional	Dire Dawa	Addis Ababa	No directionality	--	--	Uni-directional	Dire Dawa	Addis Ababa
Mekele and Addis Ababa	Uni-directional	Mekele	Addis Ababa	Uni-directional	Mekele	Addis Ababa	No directionality	--	--
Bahirdar and Dire Dawa	Uni-directional	Dire Dawa	Bahirdar	No directionality	--	--	No directionality	--	--
Bahirdar and Mekele	Uni-directional	Mekele	Bahirdar	Uni-directional	Mekele	Bahirdar	No directionality	--	--
Mekele and Dire Dawa	Uni-directional	Mekele	Dire Dawa	Uni-directional	Dire Dawa	Mekele	Uni-directional	Mekele	Dire Dawa

* p<10%; ** p<5%; *** p<1%

Source: Authors' own calculations