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The Ethiopian Commodity Exchange and the coffee market: Are local prices more integrated to global markets?

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The Ethiopian Commodity Exchange (ECX) was established in April 2008 with the objective of improving market efficiency by better linking smallholder farmers to markets, encouraging reliable trading relationships and increasing market information. In December 2008 it became mandatory to trade all coffee through the ECX. This paper examines whether Ethiopian coffee prices have become more integrated to world prices after the implementation of the ECX. We follow a multivariate GARCH approach to evaluate the degree of correlation and volatility transmission across international, auction and producer price returns. We focus on the five major Ethiopian coffee varieties using monthly data for the period 1992 through 2013. The estimation results indicate that not all coffee regions have necessarily become more connected to world markets, at least not in the first five years after the implementation of the mandatory regulation. We also do not find a higher integration across regional coffee prices.

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1. Introduction

In the 1990s, several African countries started to implement market-oriented agricultural policies as part of their development policy framework. Around that time, African economies had experienced dramatic changes in their export commodity markets, including shocks associated with price declines, which needed to be addressed (Akiyama, 2001; Gemch and Struthers, 2007; Rashid et al., 2010). The interventions differed across countries and commodities, but the ultimate goal remained the same. The policies intended to stabilize producers' income through marketing boards that provided a single channel for exports and imports, state ownership of processing centers, and administration of domestic prices that were normally pan-seasonal, pan-territorial, and detached from international prices (Akiyama et al. 2003; Gemch and Struthers, 2007). But there were still institutional and infrastructural challenges in agriculture related to high transaction and marketing costs, which affected these new policy interventions, compelling economists and policymakers to turn to other market-based approaches (Deaton, 1999; Gabre-Madhin, 2001). It was at this stage that African countries became keen on promoting commodity exchanges.

Commodity exchanges are organized markets which serve as a means for risk management and transaction costs reduction for both buyers and sellers. Historically, commodity exchanges date back to the middle ages.[1] Until recently, commodity exchanges were strictly confined to industrialized countries, but with the advent of affordable technology many developing countries in Africa have been keen on establishing one. The wave began in the 1990s, starting with Zambia and Zimbabwe and followed by Kenya and Uganda (see Table A.1 in the Appendix). The most recent one to join the group of exchanges in Africa was the Ethiopian Commodity Exchange established in 2008.

Agricultural markets in Ethiopia have long been exposed to high transaction costs, price fluctuations and excessive risk (Gabre-Madhin, 2006; Gemech and Struthers, 2007; Rashid et al., 2010). With only one third of the output reaching the market, commodity buyers and sellers tend to trade only with the people they know to avoid the possibility of default or being cheated (Gabre-Madhin, 2001). Small-scale farmers, who produce 95 percent of Ethiopia's agricultural output, also have limited access to market information (Worako et al., 2008). Often, smallholders only

[1] The first exchange was established in the sixteenth century in England, followed by the Berlin Grain Exchange in Germany established around the 1840s and the Chicago Stock Exchange in the United States in 1848 (Forrester, 1931; Hirschstein, 1931).

have access to local price information, being unable to negotiate better prices and subject to the potential market power exerted by local merchants. If farmers in a particular region are especially productive, their local market becomes glutted and prices drop precipitously. In addition, local producers often receive a small share of the export price, particularly in the coffee market; this is largely explained by the participation of several intermediaries along the value chain resulting in market inefficiencies (Akiyama et al., 2001; Gabre-Madhin, 2006).

To curb the situation, the government of Ethiopia together with its development partners (The World Bank, International Monetary Fund, Oxfam GB, among others) launched the Ethiopian Commodity Exchange (ECX) with the aim of creating an efficient, transparent and orderly marketing system to serve the needs of buyers, sellers and intermediaries, and promote increased market participation of Ethiopian small-scale producers. It further envisioned creating a centralized trading floor for buyers and sellers. The new system anticipated to develop more secure and reliable schemes for handling, grading, storing, among other services, encourage risk-free payments, and offer a goods delivery system to settle transactions (Gabre-Madhin, 2006; Alemu amd Meijerink, 2010). It also intended to build trust and transparency among all market actors through the dissemination of market information and clearly defined rules for trading and warehousing, as well as the eventual provision of internal dispute settlement services.

In this study, we focus on examining whether Ethiopian coffee prices have become more integrated to world prices after the implementation of the ECX. We base our analysis on the coffee sector because coffee is a major export commodity and an important source of employment in Ethiopia. Coffee is also the most traded agricultural commodity in the ECX both in terms of volume and value, and significant reforms have occurred in the coffee sector in the past years. We are particularly interested in examining whether the institutional changes resulting from the implementation of the ECX have better linked local producers to global markets in terms of higher price interrelationships. Certainly, a higher price interdependence between domestic and international prices may signal that part of the objectives of the ECX are being achieved in terms of stronger linkages with external markets and improved market information, but does not necessarily mean that it is a welfare-improvement system, particularly among the most vulnerable groups of farmers. Higher volatility interactions from international to local prices may also have serious implications for farmers and low-income consumers by making them more vulnerable to international shocks.

We follow a multivariate GARCH (MGARCH) approach, which permits us to better assess the potential dynamic relationship between local and international coffee markets by formally accounting for market interactions in terms of the conditional second moment. In particular, we implement a dynamic model of conditional volatilities in price returns that allows us to evaluate if the degree of interdependence between markets, measured through time-varying conditional correlations, has intensified after the establishment of the ECX. Similarly, we explore volatility transmission across markets and whether volatility spillovers from international to domestic markets have increased in recent years. We also test for structural changes in the dynamics of local coffee prices. The study focuses on the five major coffee varieties in Ethiopia using monthly data for the period 1992 through 2013. The use of monthly data further allows us to capture price dynamics that would otherwise be hidden in lower frequency data.

The remainder of the paper is organized as follows. Section 2 provides further details about the coffee market in Ethiopia and the ECX. Section 3 presents the methodological approach used in the study. Section 4 describes the data and Section 5 reports and discusses the estimation results. Section 6 concludes.

2. Background

Ethiopia is one of the largest coffee producers in Africa and ranks fifth in the world after Brazil, Vietnam, Colombia and Indonesia.[2] According to the Ministry of Trade (MoT) of Ethiopia, the country produced an average of 300 thousand tons of coffee per year between 2000 through 2012. Oromiya and SNNP (Southern Nations Nationality Peoples) are the two major coffee producing regions, which together roughly account for 97 percent of the total national production as shown in Table 1. Ethiopia also grows a wide variety of coffee. The south-west part of the country, which covers Illubabor, Kelem, Jimma, Kaffa, Shaka, Bench Maji and Wollega (Lekemt), produces dry coffee and represents about 70 percent of the total production. The southern region, which includes Sidama, Yirgachefe and Wolayeta, produces washed coffee beans and represents 22 percent of the total production. The eastern coffee growing region, which includes West and East Hararghe (Harar), produces both dry and washed coffee beans and account for the remaining 8 percent of the national production. Figure A.1 in the Appendix presents a map with all growing areas of

[2] International Coffee Organization (2013), http://www.ico.org.

Arabica coffee in Ethiopia, distinguishing by volume of production, and indicates the five regions focused in the study.

[Insert Table 1]

In terms of exports, Ethiopia is the highest exporter in Africa and is among the top 10 exporters in the world after Mexico.[3] According to the National Bank of Ethiopia (NBE), the annual average volume of coffee exports was 160 thousand tons between 2000 and 2012, and the highest volume of exports was registered in 2012 (192 thousand tons). Besides, coffee is a major source of foreign exchange inflows, constituting about 35 percent of total export earnings. It is also estimated that 95 percent of the total coffee output is produced by small-scale producers and the remaining 5 percent by cooperatives and private commercial farmers (Worako et al., 2008). This reflects the importance of the sector in improving the livelihood of the poor and contributing to the overall economic growth of the country.

Given the importance of the coffee sector to the economy, the sector has also been exposed to a wide set of different policies over the past three major regimes: monarchic regime (prior 1974), central planning regime (1974 to 1991) and Ethiopian People's Republic Democratic Front (EPDRF) regime (1991 to present). The substantial policy changes across regimes resulted in significant changes in the marketing channels, licensing and price setting, which affected the development of the coffee sector. The market-oriented reforms that started in 1991 aimed at opening the Ethiopian domestic and export coffee markets with more competitive prices as means of stimulating farmers' productivity and growth. However, despite efforts, the performance of the coffee sector still remains lagging. Poorly instituted modes of production (Zewdu et al., 2010), high marketing costs (Rashid et al. 2010), volatile prices (Gemech and Struthers, 2007), inadequate market infrastructure (Rashid et al 2010, Gabre-Madhin, 2009), and an unorganized commodity marketing approach (Gabre-Madhin, 2009; Gemech and Struthers, 2007) are indicators of market inefficiency that significantly limit coffee growers' share from the value of exports and total earnings from the sector.

[3] International Coffee Organization (2013), http://www.ico.org.

2.1. *The Ethiopian Commodity Exchange (ECX)*

To resolve market inefficiencies, particularly concerning prices along the agricultural marketing channel, a landmark proclamation was issued by the parliament in 2007 that paved the way for the establishment of the ECX under the supervision of the Ministry of Agriculture and Rural Development (MoARD) in Proclamation No-551/2007. The ECX was finally established in April 2008 with the aim of filling the gap created by missing institutions and infrastructure in agricultural commodity markets (Gabre-Madhin, 2001).[4] The objective of the commodity exchange was to perform four basic functions: (i) reduce transaction costs, (ii) ensure price transparency and price discovery by creating a secure and reliable system for handling, grading and storing services for commodity transactions, (iii) promote risk-free payments, and (iv) provide a goods delivery system to settle transactions (Gabre-Madhin, 2006; Alemu and Meijerink, 2010).

While the commodity exchange initially focused on trading maize, wheat and beans, it eventually included other commodities such as coffee, sesame and haricot bean (Rashid et al., 2010). In the case of coffee, in December 2008 it became mandatory to trade all coffee through the ECX. The volume of coffee traded through the ECX also rapidly increased in the following years; from about 64 thousand tons in the crop year of 2008/09 to more than 200 thousand tons in 2010/11, representing around 47 percent of the total volume of transactions of the ECX (Gabre-Madhin, 2012). This rapid transaction growth could be attributed to the measures incorporated by the ECX to ensure the security of the transactions for its stakeholders. In the new system, trading through the ECX guarantees a trade day plus one payment schedule for agents, which reduced information asymmetries and boosted confidence among agents. To stimulate market transparency, the ECX also started to use several mechanisms to facilitate the disclosure of market information. Besides using the radio, television and print media to disseminate price information to farmers, the ECX started to rely on new information and communication technologies (ICTs); for example, displaying real time price information through electronic ticker boards located in 32 rural sites, instant messaging through mobile phones to more than 250,000 subscribers and providing website access to more than 107 countries (Gabre-Madhin, 2012).[5] In sum, the priorities

[4] The budget allocated by the international community for the first phase of the ECX (period 2008-2013) was around 10 million US dollars.

[5] The adoption of mobile technology and internet is on surge in Ethiopia due to major recent developments in mobile phone and internet service provision. Subscription per 100 people for mobile phones and internet has grown from 1.1

of the ECX include providing accurate market information to all the market participants and increase trust among buyers and sellers.

We now turn to formally examine whether local coffee prices become more integrated to the world market after the implementation of the ECX. We focus on the level of interdependence and volatility transmission between producer, auction and international price returns.

3. Methodology

This section briefly describes the two MGARCH models used to separately analyze the degree of interdependence (conditional correlations) and volatility dynamics between producer, auction and international prices for different major Ethiopian coffee varieties. In particular, we use a DCC and BEKK model. The DCC model, developed by Engle (2002), is suitable to identify if the degree of interdependence across the marketing channel for each variety of coffee has changed over time based on time-varying conditional correlations. The BEKK model, proposed by Engle and Kroner (1995), is suitable to characterize volatility transmission across markets since it is flexible enough to account for own- and cross-volatility spillovers and persistence.[6] We are particularly interested in the transmission of volatility from international to domestic markets.

Consider the following vector stochastic process of price returns for each variety of coffee analyzed,

$$r_t = \theta_0 + \sum_{j=1}^{p} \theta_j r_{t-j} + e_t, \quad e_t \mid I_{t-1} \sim (0, H_t), \tag{1}$$

where r_t is a 3x1 vector of farm gate, auction and international price returns; θ_0 is a 3x1 vector of long-term drifts; θ_j, j=1,..,p, are 3x3 matrices of parameters; and e_t is a 3x1 vector of forecast errors for the best linear predictor of r_t, conditional on past information denoted by I_{t-1}, and with a corresponding variance-covariance matrix H_t. Similar to a standard VAR model, the elements

to 22.4 and from 0.1 to 1.5, respectively, between 2005 and 2012 (World Develolpment Indicators, The World Bank, http://data.worldbank.org/data-catalog/world-development-indicators).

[6] See Bauwens et al. (2006) and Silvennoinen and Teräsvirta (2009) for an overview of different MGARCH models.

of θ_j , j=1,…, p, provide direct measures of own and cross lead-lag relationships at the mean level between markets.[7]

In the DCC model, the degree of volatility interdependence between markets is assumed to be time-dependent across time and is captured through a conditional correlation matrix $R_t = (\rho_{ij,t})$, $i, j = 1,...,3$. The conditional variance-covariance matrix H_t is defined as

$$H_t = D_t R_t D_t \tag{2}$$

where $D_t = diag(h_{11,t}^{1/2} ... h_{33,t}^{1/2})$; $h_{ii,t}$ is a GARCH(1,1) specification, i.e. $h_{iit} = \omega_i + \alpha_i e_{i,t-1}^2 + \beta_i h_{ii,t-1}$, i=1,…,3; $R_t = diag(q_{ii,t}^{-1/2}) Q_t diag(q_{ii,t}^{-1/2})$; $Q_t = (q_{ij,t}), i, j = 1,...,3,$ is a 3x3 symmetric positive-definite matrix given by $Q_t = (1-\alpha-\beta)\overline{Q} + \alpha u_{t-1} u_{t-1}^{'} + \beta Q_{t-1}$; and $u_{it} = e_{it} \big/ \sqrt{h_{iit}}$. $\overline{Q}$ is the 3x3 unconditional variance matrix of u_t, and α and β are non-negative adjustment parameters satisfying $\alpha + \beta < 1$. The unconditional variance matrix Q_t could be seen as an autoregressive moving average (ARMA) type process capturing short-term deviations in the correlation around its long-run level.

In the BEKK model, the conditional variance-covariance matrix H_t with one time lag is given by

$$H_t = C'C + A'e_{t-1}e_{t-1}^{'}A + G'H_{t-1}G, \tag{3}$$

where C is a 3x3 upper triangular matrix of constants c_{ij} , A is a 3x3 matrix of elements a_{ij} that capture the degree of innovation from market i to market j, and G is a 3x3 matrix of elements g_{ij} that measure the persistence in conditional volatility between markets i and j. This specification allows us to analyze the magnitude and persistence of volatility transmission across

[7] We checked for cointegration between producer, auction and international log prices and did not find cointegrating relationships based on the Johansen test. Hence, the VAR specification defined in equation (1) adequately captures the dynamics of the price returns used in the analysis.

the markets under analysis. We can derive impulse-response functions for the estimated conditional volatilities to show, for example, how a shock in international markets may affect local auction and producer markets.

4. Data

The data used for the analysis are monthly average producer, auction and international prices for the period January 1992 through June 2013. The producer and auction price data include the five major Ethiopian coffee varieties by origin of growing regions namely: Sidama, Yirgachefe, Harar, Lekemt and Jimma. Sidama and Yirgachefe are part of the Oromiya producing region while Harar, Lekemt and Jimma are part of the SNNP producing region. The five varieties constitute about 95 percent of the total coffee produced and exported in the country.[8]

Unlike many coffee growing countries, Ethiopian coffee varieties are often differentiated by agro-ecological and local conditions, shape, acidity, body, flavor, aroma and processing method, and they are generally auctioned by their corresponding origin. In particular, Ethiopian coffee is traded in the world market based on their origin of production (e.g., Sidama, Yirgachefe, Harar, Jimma, Lekemt, Teppi, Limu and Bebeka). Recently, Ethiopia also secured exclusive trademark rights for Sidama, Yirgachefe and Harar coffee, which serves to further highlight the differences between Ethiopian coffee types.[9] It is worth then examining the degree of interdependence and volatility transmission between international and domestic markets for different coffee varieties in Ethiopia.

Producer prices were obtained from the monthly published producer price survey reports of the Central Statistical Agency (CSA) of Ethiopia.[10] Auction prices were obtained from the Agricultural Market Promotion Department (AMPD) of MoARD for the period January 1992 to December 2008 and directly from the Ethiopian Commodity Exchange (ECX) for the following

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[8] According to the Ethiopian Coffee Authority, in 2011 Sidama accounted for 41% (65,470 bags) of the total country exports; Jimma for 21% (33,476 bags), Lekempti for 17% (26,128 bags), Harar for 9% (13,697 bags), and Yirgachefe for 6% (9,914 bags).

[9] Ethiopia owns trademark rights for the distinctive fine coffee of Sidamo, Yirgacefe and Harar brands since 2008.

[10] The CSA conducts monthly surveys and release monthly reports since 1981. Monthly Bulletins No. 44 to 450 were used to compile the producer price data.

years.[11] The international price is the New York Arabica coffee price indicator calculated by the International Coffee Organization (ICO) on the basis of different Arabica coffees traded.[12]

The sample period covered allows us to evaluate if there have been important changes in the degree of interdependence and dynamics of volatility before and after the mandatory regulation of trading and exporting coffee through the ECX, which became effective in January 2009. All prices in the analysis are standardized to US cents per pound.

Figure 1 shows the evolution of the international price and the producer and auction price for the five coffee varieties. We observe that international and local prices, particularly auction prices, generally co-move in all five markets. The important spikes in the international price of coffee in 1994 and 2011, due to weather-related supply disruptions in Brazil and Colombia, are also observed in the auction price across all five coffee varieties; the international price spike of 1997, also due to supply shortages, is only observed in the auction price in Yirgachefe. Producer prices in all five markets, in turn, only exhibit an important spike in 2011. Table A.2 in the Appendix also compares producer coffee prices collected in monthly surveys by CSA, before and after the implementation of the implementation of the ECX, and shows that prices in all local markets have increased in recent years.

[Insert Figure 1]

Figure 2 plots the corresponding price returns (in percentage points). The price returns are defined as $r_t = \ln(p_t / p_{t-1})$, where p_t is the producer, auction or international price at time *t*. This logarithmic transformation is generally used in empirical finance as a standard measure for net returns in a market, which also provides a convenient support for the distribution of the error terms in the estimated models. Two patterns emerge from this figure. First, all price returns exhibit important fluctuations across time, which is indicative of time-varying volatility in returns and motivates the use of MGARCH models. Second, the fluctuations in price returns decrease as we move from producer to auction and international markets; i.e., the returns in international markets

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[11] Prior to 2009, the AMPD kept record in monthly (unpublished) bulletins of the average prices paid to suppliers at the Coffee Auction Market (CAM).

[12] We also considered the Brazilian Naturals price indicator as another relevant approximation of the international price for the Ethiopian coffee and find qualitatively similar results. The Brazilian Naturals price indicator is the combination of ex-dock prices in New York and Germany of a group of traditional exporting coffee countries including Ethiopia. The correlation between the New York and Brazilian Naturals prices is 0.987.

are more stable than in auction and producer markets. At the producer level, Jimma is clearly the region that shows the highest fluctuations over the sample period. Jimma's coffee is of lower quality compared to the other four coffee varieties, fluctuating between 3rd and 2nd grade coffee, which could explain this higher dispersion.

[Insert Figure 2]

To further analyze the co-movement of price returns, Figure 3 presents three-year pairwise Pearson correlations between producer, auction and international markets in all five growing regions. Each point in the figure indicates the correlation coefficient between the two returns series over the last three years; hence, the first values in the graph report correlation coefficients for 1992, 1993 and 1994. In terms of levels, auction and international price returns show a higher correlation than producer and auction and international returns in most markets (except Harar). In terms of the evolution across time, Sidama is the region that shows a higher interdependence across markets in recent years, particularly after 2009 when trading through the ECX became effective. We observe an important increase in the region in the correlation between auction and international price returns, producer and auction returns and to a lower extent between producer and international returns. Lekemt also shows an important increase in the past few years in the correlation between auction and international markets while Yirgachefe exhibits a higher inter-linkage between producer and auction markets. Jimma and Harar markets, in contrast, do not show any specific trend in the correlation between local and international prices. Opposite to Jimma, Harar's coffee has the highest quality relative to the other varieties; as a well-established high premium coffee, the institutional changes resulting from the implementation of the ECX may not have further changed the price linkages of this variety with international markets.

[Insert Figure 3]

These patterns are further confirmed in Table 2, which reports pairwise correlations for different subsample periods. For example, we find that the correlation between international and auction markets in Sidama increased from 0.37 in 1992-1995 to 0.64 in 2009-2013 and from cero to 0.63 in Lekemt; the correlation between these markets also increased in Yirgachefe, from cero to 0.33, but it was highest (0.45) in 2005-2008. Similarly, the correlation between producer and auction markets increased to 0.35 in Sidama and returned to the levels exhibited at the beginning of the sample period in Yirgachefe (around 0.4).

[Insert Table 2]

Finally, Table 3 reports summary statistics of all returns series. We observe that the returns in the international market are on average higher than in the auction and producer markets. In particular, the average monthly return in the international market is 0.2%, which is only exceeded by the average return in the auction market in Yirgachefe (0.28%). Yirgachefe is also the region that together with Jimma exhibit the highest return in the producer market (0.19%), although Jimma shows a much higher dispersion. We also note that the returns are on average higher in auction than producer markets in Sidama, Harar and Yirgachefe.[13] As noted above, producer returns show a higher variation (standard deviation) than the returns in the other markets; in particular, they exhibit between 1.2 and 2.1 times more dispersion than auction returns and between 1.6 and 2.7 times more dispersion than international returns.

[Insert Table 3]

In addition, the Jarque-Bera test reveals that all returns series seem to follow a non-normal distribution. The kurtosis is greater than three in all series, pointing to a leptokurtic distribution of returns and motivating the use of a Student's t density in the estimation of the DCC and BEKK models (hereafter T-DCC and T-BEKK). The Ljung-Box (LB) for up to 6 and 12 lags generally reject the null hypothesis of no autocorrelation for the squared returns in most markets, which further motivates the use of MGARCH models given the apparent non-linear dependencies in returns. Lastly, the Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests confirm the stationarity of the returns series.

5. Results

This section presents the results of the MGARCH models estimated to examine the level of interdependence and volatility transmission between international, auction and producer price returns for five different varieties of Ethiopian coffee. We first focus on the estimation results of the T-DCC model, which allows us to identify if the degree of interdependence (conditional correlations) between markets has changed across time. We then discuss the results of the T-BEKK model, which permits us to characterize volatility transmission from international to domestic

[13] When segmenting the sample, we find that producer and auction price returns seem to have increased across time in most of the analyzed coffee markets, as opposed to the price returns in the international market. As shown in Table A.3, in the 90s and early 2000s the average returns in several of the markets were negative. Yet, we start to observe higher average returns from 2005 and not necessarily after the implementation of the ECX in December 2008.

markets both before and after the mandatory regulation of trading and exporting all coffee through the ECX. We further test whether the change in the regulation in December 2008 was accompanied by a structural break in the mean and volatility of the analyzed price return series.

5.1. Market interdependence

Table A.4 presents the estimation results of the T-DCC model. The upper panel reports the estimated coefficients of the conditional mean equation and the lower panel reports the coefficients of the conditional variance-covariance matrix defined in equation (2). The estimated degrees of freedom parameter (v) is relatively small in all cases, ranging between 4 and 6, which supports the adequacy of the estimations using a Student's *t* distribution. The residual diagnostic tests, reported at the bottom of the table, also support the appropriateness of the model specification. The Ljung-Box (LB), Lagrange Multiplier (LM) and Hosking Multivariate Pormanteau (M) tests statistics for 6 and 12 lags generally show no or weak evidence of autocorrelation, ARCH effects and cross-correlation in the standardized model residuals.

In terms of interactions at the mean level, we do not find any own and cross lead-lag relationships in the return series analyzed in each of the five regions. The Schwarz's Bayesian information criterion (SBIC) indicates that the expected price returns in a certain month do not depend on their past values and are also not affected by past returns in the other markets. Hence, lagged local and international price returns do not seem to affect current local price returns at the mean level.

Turning to the conditional variance-covariance equation, however, we do find time-varying conditional correlations between international and domestic price returns in some regions. In particular, the Wald test rejects the null hypothesis that the adjustment parameters α and β are jointly equal to zero with a 95 percent confidence level in Sidama, Lekemt and Yirgachefe. In Jimma and Harar, in turn, these correlations seem to have remained constant over the entire period of analysis.

To appreciate the evolution of the correlations over time, Figure 4 presents the pairwise dynamic conditional correlations between producer, auction and international price returns for each growing region, resulting from the T-DCC model estimates.[14] Several patterns emerge from the figures. First, the estimated conditional correlations confirm a higher interdependence between auction and international markets as compared to producer with auction and international markets. Second, we observe important fluctuations across time in the correlation between international and domestic markets, particularly in Lekemt and Sidama, and to a lower extent in Yirgachefe; in Jimma and Harar, which are the coffee varieties of the lowest and highest quality among the five varieties, the correlations across markets have remained constant across time. Third, similar to the preliminary analysis based on unconditional correlations, Lekemt and Sidama show a higher interdependence between auction and international markets in more recent years. The case of Lekemt is particularly notable; as shown in Table 4, which reports the average conditional correlations for different subperiods, the correlation between the auction market in Lekemt and the international market more than doubled from 0.20 in 1992-1995 to 0.44 in 2009-2013. In Sidama, this correlation has already been relatively high, fluctuating around 0.42 between 1992 and 2008, but it further increased to 0.44 after 2008. The auction market in Yirgachefe also shows a higher interrelation with the international market (as compared to the early 90s), but the increase in the correlation occurred prior to 2009.

[Insert Figure 4]

[Insert Table 4]

The correlation between producer and auction markets in Sidama also exhibits an important increase after 2008, although the level of interdependence between these markets (0.09) is still not as strong as in Yirgachefe, Harar and Lekemt (0.18-0.27). In both Lekemt and Yirgachefe, however, the degree of correlation between producer and auction price returns is lower in recent years than in the early 90s. Finally, international and producer markets in Sidama, Lekemt and Yirgachefe also appear to have become more interconnected during the last decade, but the increase in the correlation did not necessarily occurred after 2008 when the regulation of trading and exporting all coffee through the ECX became effective.

Despite some differences in the evolution of the correlations between local and international prices across different coffee varieties, the existence of the Coffee Auction Market

[14] The figure also includes constant conditional correlations and one standard deviation confidence bands based on Bollerslev’s (1990) Constant Conditional Correlation (CCC) model.

(CAM) prior to the ECX could generally explain the relatively high correlation between international and auction prices and the lack of further significant increases in the correlation between international and several domestic coffee prices after 2008. The CAM was established by the Ethiopian government in 1992 as part of the liberalization of the domestic coffee marketing system. Thus, some markets could already have been more connected to world markets, and it would probably take a couple more years to observe the full effects of the ECX in terms of further linking local coffee producers to global markets. Note also that while market (price) transparency has further increased with the implementation of the ECX (favoring a higher correlation between domestic and international prices), direct trade agreements between exporters and local coffee producers have disappeared (favoring a lower correlation between domestic and international prices).

As an additional analysis, we examine whether local Ethiopian coffee markets have become more integrated at the producer and auction level in recent years. We estimate two separate T-DCC models, one model including the five producer price returns series (corresponding to the five coffee varieties) and a second model including the five auction price returns series. The full estimations results are reported in Table A.5 while Figure A.2 presents the estimated pairwise conditional correlations for different subsample periods. Two patterns are worth remarking from the figure. First, markets are more integrated at the auction than at the producer level; except for Lekemt and Harar, the conditional correlations between markets at the auction level are higher and in most cases more than double the conditional correlations at the producer level. Second, markets in Ethiopia both at the producer and auction stage have not necessarily become more integrated after the implementation of the EXC.

5.2. Volatility transmission

We now turn to examine the cross-volatility dynamics from international to domestic price returns based on the estimation results of the T-BEKK model. Since we are interested in analyzing volatility interactions between international and domestic markets before and after the mandatory regulation of trading all coffee through the ECX, we estimate the model over two subperiods: 1992 through 2008 and 2009 through 2013. Tables A.6 and A.7 present the corresponding results with the estimated coefficients of the conditional variance-covariance matrix defined in equation (3).[15] As in the T-DCC model, the estimated degrees of freedom parameter (v) supports the adequacy of the estimation with a Student's *t* distribution and the reported diagnostic tests for the standardized squared residuals (LB, LM and M statistics) generally support the appropriateness of the model specification.

The diagonal a_{ii} coefficients, $i = 1,...,3$, capture own-volatility spillovers (the effect of own lagged shocks on the current conditional return volatility in market *i*), while the diagonal g_{ii} coefficients capture own-volatility persistence (the dependence of volatility in market *i* on its own past volatility). The off-diagonal coefficients a_{ij} and g_{ij} measure, in turn, direct spillover and persistence effects from market *i* to market *j*. The Wald joint test for cross-volatility rejects the null hypothesis that the off-diagonal coefficients a_{ij} and g_{ij} are jointly equal to zero, indicating that there are cross spillovers and persistence effects across markets.

To examine volatility spillovers between specific markets, in our case from international to domestic markets, it is important to account for both direct and indirect cross effects. This is because markets may be directly related through the conditional variance and indirectly related through the conditional covariance.[16] Following Gardebroek and Hernandez (2013) and Hernandez et al. (2014), we derive impulse-response functions, which control for both direct and indirect effects, to simulate how a shock in the (conditional) volatility of price returns in the international market will transmit to the volatility of price returns in the producer and auction markets.

Figure 5 presents the impulse-response functions resulting from a shock equivalent to a 1% increase in the own conditional volatility of the international market. The responses in each market are normalized by the size of the original shock. Two patterns are worth noting. First, it is clear that there is a higher volatility transmission from international to auction markets than to producer markets, but these spillover effects have not generally intensified after 2008. In Sidama and Lekemt, for example, the higher (conditional) correlation in price returns between international and auction markets observed in recent years is not accompanied by higher volatility spillovers

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[15] To save space, we do not report the estimated constant terms in the conditional mean equation, which are similar to the T-DCC estimates.

[16] The volatility dynamics across markets ultimately comprises all off-diagonal a_{ij} and g_{ij} coefficients.

from international to domestic markets; while a shock in the international market had a somewhat similar initial effect on the conditional volatility of auction returns in these two regions during 1992-2008, the effects after 2008 are much smaller (a 1% increase in volatility in international markets only results in a 0.2% initial increase in the volatility in auction markets). Second, except for Jimma, the volatility spillovers from international to producer price returns have either remained constant or marginally increased after 2008, although these cross effects are still relative small; in the case of Sidama and Lekemt, a 1% increase in volatility in international markets results in a 0.2% increase in volatility in producer markets, while in Yergachefe and Harar it only results in a 0.1% increase in volatility. Hence, the volatility transmission analysis is not conclusive on whether volatility spillovers from international to domestic markets have intensified after the mandatory regulation of December 2008.

[Insert Figure 5]

5.3. Structural breaks

As a complementary exercise, we examine if the change in the regulation in the coffee market is correlated with a structural break in the mean and volatility of the producer and auction returns series in any of the five growing regions. We want to assess whether the mandatory regulation had a major impact (break) in the dynamics of price returns in these markets.

We implement the test for the presence of unknown breakpoints developed by Lavielle and Moulines (2000). This test is suitable for strongly dependent processes such as GARCH processes as it assumes beta-mixing conditions (Carrasco and Chen, 2002).[17] We test for structural breaks on the mean of the price returns and the square of the price returns as a proxy of volatility.[18]

Table A.8 reports the identified break dates for each returns series representing major change-points in both their mean and volatility. We observe important shifts in the mean of the producer returns of most regions in recent years, as opposed to the shifts in volatility, although the breaks did not occur right after the change in the regulation. The shifts occurred in December 2010 in Sidama and Lekemt, in April 2011 in Harar and in February 2012 in Yergachefe. Sidama also

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[17] Bai and Perron's test, for example, assumes uniform mixing conditions that are not satisfied by series exhibiting time-varying volatility, which is the case of the series used in the present analysis.

[18] The test searches for breaks over a maximum number pre-defined potential segments, and uses a minimum penalized contrast to identify the breaks. We set the minimum length of a segment as 2 months.

shows a shift in volatility around December 2010. The breaks in the auction markets, and naturally in the international market, are more linked to the global supply shortages of 1994 and 1997. Hence, it is not clear that the mandatory trading regulation resulted in a breakpoint in the dynamics of the returns series in the growing regions, at least not immediately.

Overall, while a simple comparison between local coffee prices before and after the implementation of the ECX in December 2008 reveal that local prices have increased (see Table A.2), our estimation results suggest that the mandatory regulation of trading all coffee through the ECX has not necessarily promoted a higher integration of all Ethiopian regional coffee prices to world prices. Only Sidama and Lekemt show a higher interdependence, measured through conditional correlations, between local (mainly auction markets) and international markets. Yet, the correlation between producer (farm gate) and international markets is still low. In addition. Ethiopian local markets do not seem to have become more integrated in recent years. We also do not find major volatility spillovers from international to local markets in recent years. The breakpoint analysis further do not suggests structural breaks in the dynamics of the producer and auction return series around the implementation of the mandatory regulation.

6. Concluding remarks

This paper has examined the degree of interdependence and volatility transmission between international and domestic price returns to assess whether Ethiopian coffee prices have become more integrated to world prices in recent years, particularly after the implementation of the ECX in December 2008. We focus on monthly prices of the five major coffee varieties in Ethiopia, which include Sidama, Jimma, Lekemt, Harar and Yirgachefe. We implement a MGARCH approach to derive dynamic conditional correlations and evaluate volatility transmission from international to domestic markets.

The estimation results indicate that not all coffee regions have become more interrelated with the world markets after the implementation of the ECX. Despite the general increase in producer coffee prices after 2008, only few regions show a higher interdependence between local and international price returns. In particular, only Sidama and Lekemt exhibit a higher interrelation (conditional correlation) between auction and international prices while the correlation between producer and international prices is still low. We further do not observe a higher price integration across different local coffee markets. Volatility spillovers from international to domestic prices have also not increased in the past years. Finally, the ECX does not seem to have produced a major shift in the dynamics of domestic coffee price returns, at least not in the following months after its implementation.

The lack of a higher integration between local and world markets in recent years, measured through interdependencies in prices, could be explained by several factors. First, there have only been a few years since the ECX was established such that the process of better linking farmers to markets, encouraging reliable trading relationships, and improving market information is still ongoing. We observe so far that farmers are receiving higher prices than before the establishment of the ECX and the volume of coffee transactions through the ECX have considerably increased in the past years. Second, a coffee auction system (CAM) was already functioning for more than fifteen years prior to the ECX. This could also explain the absence of further major increases in the price correlation between international and several domestic coffee varieties, at least in the short run, as some markets (particularly auction markets) could already have been connected with global markets although with varying degrees. This is also in line with the lack of structural breaks in the domestic price series around the implementation of the ECX. Third, there are still additional bottlenecks across the coffee supply chain that need to be addressed, like lagging production technologies, lack of infrastructure and, in particular, the higher regulations for the licensing of traders, that could be limiting the correlation between domestic and international prices. While the ECX intended to reduce the potential market power exerted by a few major coffee exporters, it has also eliminated direct trading relationships between exporters and small coffee producers, which now have to sell their product through still a few licensed traders operating in each region. In addition, the lack of traceability of the coffee purchased by exporters from specific growing areas (producers) and the decrease in the predictableness of particular coffee stocks and corresponding price movements (that allow exporters to mitigate price risks) could also be limiting the local-international price correlation, despite the higher aggregate (regional) price information.

Future research should continue to study the evolution of the price interrelationship between international and local coffee markets, especially at the producer level, and assess the effects of an eventual higher international dependence (if any) of local producers. A higher integration between local and international markets in the medium- and long-term, which is in line with the objectives of the ECX, does not certainly mean that the welfare of local coffee producers will increase and vice versa. For example, higher price volatility transmission from international to local markets could make small-scale farmers and low-income consumers more vulnerable to international price shocks, particularly in the absence of efficient risk sharing mechanisms. Policies to address potential periods of excessive price volatility in the future should also need to pay greater attention to external sources of variation.

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Table 1. Coffee production in Ethiopia by region, 2005-2013

Region	Production Estimate (In thousand tons)		
	2005-2008	2008-2013	Average
Oromiya	199.7	259.0	229.4
SNNP	113.0	138.1	125.5
Gambella	3.4	2.2	2.8
Total National	316.1	400.5	358.3
Share of total (%)			
Oromiya	63.2	64.7	64.0
SNNP	35.7	34.5	35.0
Gambella	1.1	0.5	0.8

Note: Volume of production obtained from Central Statistical Agency (CSA). SNNP=Southern Nations Nationality Peoples. Of the five main coffee varieties analyzed in the study, Harar, Lekemt and Jimma are part of the Oromiya production region and Sidama and Yirgachefe are part of the SNNP production region.

Table 2. Unconditional correlations of price returns

Price	Jan1992-Dec 1995			Jan 1996-Dec 2004			Jan 2005-Dec 2008			Jan 2009-Jun 2013			Full sample		
	PP	AP	IP	PP	AP	IP	PP	AP	IP	PP	AP	IP	PP	AP	IP
Sidama															
Producer price (PP)	1.000	-0.201	0.044	1.000	0.194*	0.059	1.000	-0.125	0.259	1.000	0.346*	0.126	1.000	0.070	0.089
Auction price (AP)		1.000	0.368*		1.000	0.221*		1.000	0.285*		1.000	0.636*		1.000	0.333*
International price (IP)			1.000			1.000			1.000			1.000			1.000
Jimma															
Producer price (PP)	1.000	-0.181	0.004	1.000	0.108	0.051	1.000	-0.020	0.078	1.000	0.207	0.240	1.000	0.021	0.060
Auction price (AP)		1.000	0.216		1.000	0.211*		1.000	0.473*		1.000	0.266		1.000	0.242*
International price (IP)			1.000			1.000			1.000			1.000			1.000
Lekemt															
Producer price (PP)	1.000	0.403*	0.194	1.000	0.062	0.099	1.000	0.171	0.207	1.000	0.225	0.198	1.000	0.187*	0.146*
Auction price (AP)		1.000	-0.048		1.000	0.222*		1.000	0.593*		1.000	0.624*		1.000	0.167*
International price (IP)			1.000			1.000			1.000			1.000			1.000
Harar															
Producer price (PP)	1.000	0.017	0.101	1.000	0.244*	0.152	1.000	0.242	0.260	1.000	0.083	-0.148	1.000	0.143*	0.038
Auction price (AP)		1.000	0.491*		1.000	0.062		1.000	0.000		1.000	0.057		1.000	0.204*
International price (IP)			1.000			1.000			1.000			1.000			1.000
Yirgachefe															
Producer price (PP)	1.000	0.410*	0.021	1.000	0.052	-0.066	1.000	0.267	0.323*	1.000	0.404*	0.150	1.000	0.161*	0.027
Auction price (AP)		1.000	-0.004		1.000	0.095		1.000	0.453*		1.000	0.331*		1.000	0.135*
International price (IP)			1.000			1.000			1.000			1.000			1.000
# obs.			48			108			48			54			258

Note: The correlations reported are the Pearson correlations. The symbol (*) denotes significance at 5% level.

Table 3. Summary statistics for price returns

Statistic	Sidama		Jimma		Lekemt		Harar		Yirgachefe		International price
	Producer price	Auction price	Producer price	Auction price	Producer price	Auction price	Producer price	Auction price	Producer price	Auction price	
Mean	0.045	0.179	0.190	0.179	0.107	-0.025	0.103	0.119	0.189	0.282	0.203
Median	0.587	0.000	0.299	0.095	-0.461	-0.590	0.080	-0.040	0.000	-0.142	-0.774
Minimum	-59.533	-35.786	-73.760	-63.393	-67.481	-70.616	-42.505	-32.306	-59.324	-30.632	-19.066
Maximum	78.392	49.232	87.960	41.654	41.278	67.947	44.558	38.849	48.691	49.506	47.499
Std. Dev.	16.338	11.425	21.901	10.578	16.039	11.676	13.131	8.660	13.653	10.887	8.032
Skewness	-0.018	0.388	-0.114	-0.737	-0.462	-0.276	-0.034	0.306	-0.404	0.847	1.168
Kurtosis	5.854	5.867	5.122	8.643	4.802	13.404	4.260	7.539	7.079	6.702	7.406
Jarque-Bera	87.6	94.9	49.0	365.7	44.1	1167.0	17.1	225.5	185.9	178.2	267.4
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
# obs.	258	258	258	258	258	258	258	258	258	258	258
	Returns correlations										
AC (lag=1)	-0.164*	-0.082	-0.253*	-0.001	-0.186*	-0.158*	-0.298*	-0.026	-0.067	-0.089	0.177*
AC (lag=2)	0.015*	-0.056	-0.106*	0.011	0.028*	0.034*	0.074*	-0.005	-0.087	-0.018	0.140*
LB (6)	14.470*	7.477	27.301*	15.871*	11.616	20.505*	32.466*	9.057	7.159	5.952	24.994*
LB (12)	25.736*	15.832	45.358*	22.256*	15.843	30.606*	36.626*	15.596	15.576	21.383*	33.070*
	Squared returns correlations										
AC (lag=1)	0.049	0.068	0.0792	0.1175	0.183*	0.171*	0.231*	0.074	0.307*	0.193*	0.109
AC (lag=2)	-0.053	0.070	0.0610	0.0685	0.214*	0.041*	0.1930*	-0.010	0.223*	0.124*	0.262*
LB (6)	3.756	3.398	11.666	36.803*	26.717*	10.625	40.263*	8.218	53.198*	16.109*	22.185*
LB (12)	6.110	11.699	20.471*	37.496*	31.246*	58.279*	53.816*	11.754	55.135*	60.571*	24.453*
	Tests for stationarity										
ADF (lag=6)	-7.096*	-6.561*	-7.534*	-5.744*	-7.546*	-5.866*	-6.869*	-7.296*	-8.067*	-7.235*	-5.901 *
KPSS (lag=6)	0.039	0.047	0.043	0.056	0.035	0.060	0.023	0.036	0.039	0.040	0.060

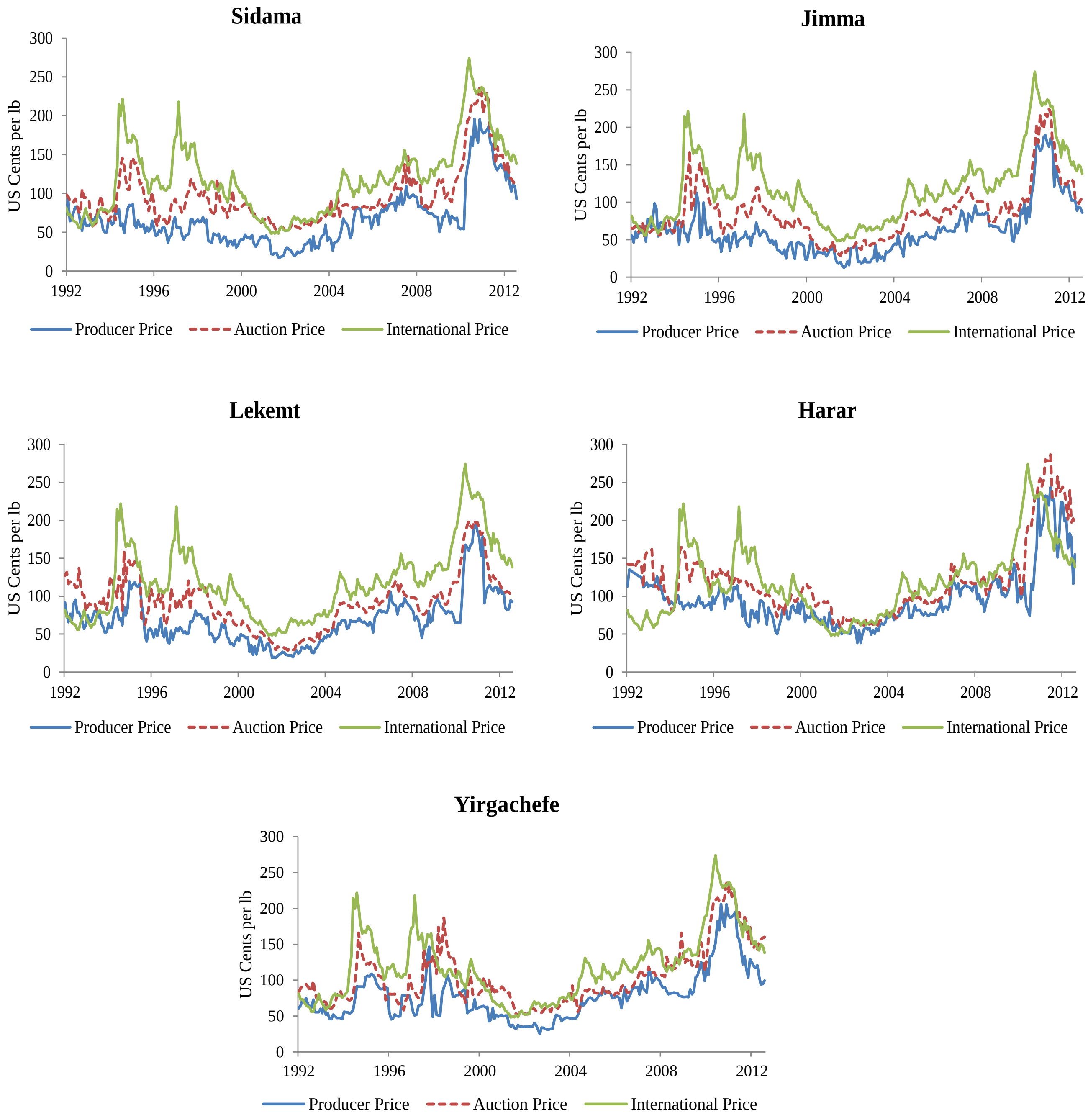
Note: The symbol (*) denotes rejection of the null hypothesis at the 5% significance level. AC is the autocorrelation coefficient; LB is the Ljung-Box autocorrelation test; ADF is the Augmented Dickey-Fuller test; and KPSS is the Kwiatkowski-Phillips-Schmidt-Shin test for stationarity.

Table 4. Average conditional correlations for different subperiods based on T-DCC model

Correlation	Jan1992-Dec 1995	Jan 1996-Dec 2004	Jan 2005-Dec 2008	Jan 2009-Jun 2013	Full sample
			Sidama		
Producer-Auction	0.041	0.080	0.055	0.091	0.070
	(0.035)	(0.039)	(0.025)	(0.040)	(0.041)
Producer-International	0.042	0.052	0.058	0.054	0.052
	(0.037)	(0.037)	(0.024)	(0.026)	(0.033)
Auction-International	0.420	0.416	0.420	0.440	0.423
	(0.061)	(0.035)	(0.022)	(0.025)	(0.039)
			Jimma		
Producer-Auction	0.028	0.028	0.028	0.028	0.028
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Producer-International	0.108	0.108	0.108	0.108	0.108
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Auction-International	0.266	0.266	0.266	0.266	0.266
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			Lekemt		
Producer-Auction	0.203	0.148	0.153	0.177	0.165
	(0.084)	(0.114)	(0.037)	(0.049)	(0.089)
Producer-International	0.114	0.110	0.138	0.134	0.121
	(0.090)	(0.111)	(0.046)	(0.054)	(0.088)
Auction-International	0.201	0.336	0.417	0.441	0.348
	(0.101)	(0.088)	(0.037)	(0.069)	(0.115)
			Harar		
Producer-Auction	0.189	0.189	0.189	0.189	0.189
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Producer-International	0.085	0.085	0.085	0.085	0.085
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Auction-International	0.116	0.116	0.116	0.116	0.116
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			Yirgachefe		
Producer-Auction	0.275	0.227	0.249	0.265	0.248
	(0.027)	(0.024)	(0.021)	(0.029)	(0.032)
Producer-International	0.065	0.055	0.098	0.090	0.072
	(0.025)	(0.025)	(0.023)	(0.021)	(0.030)
Auction-International	0.192	0.226	0.239	0.238	0.225
	(0.027)	(0.045)	(0.034)	(0.023)	(0.040)
# obs.	48	107	49	54	258

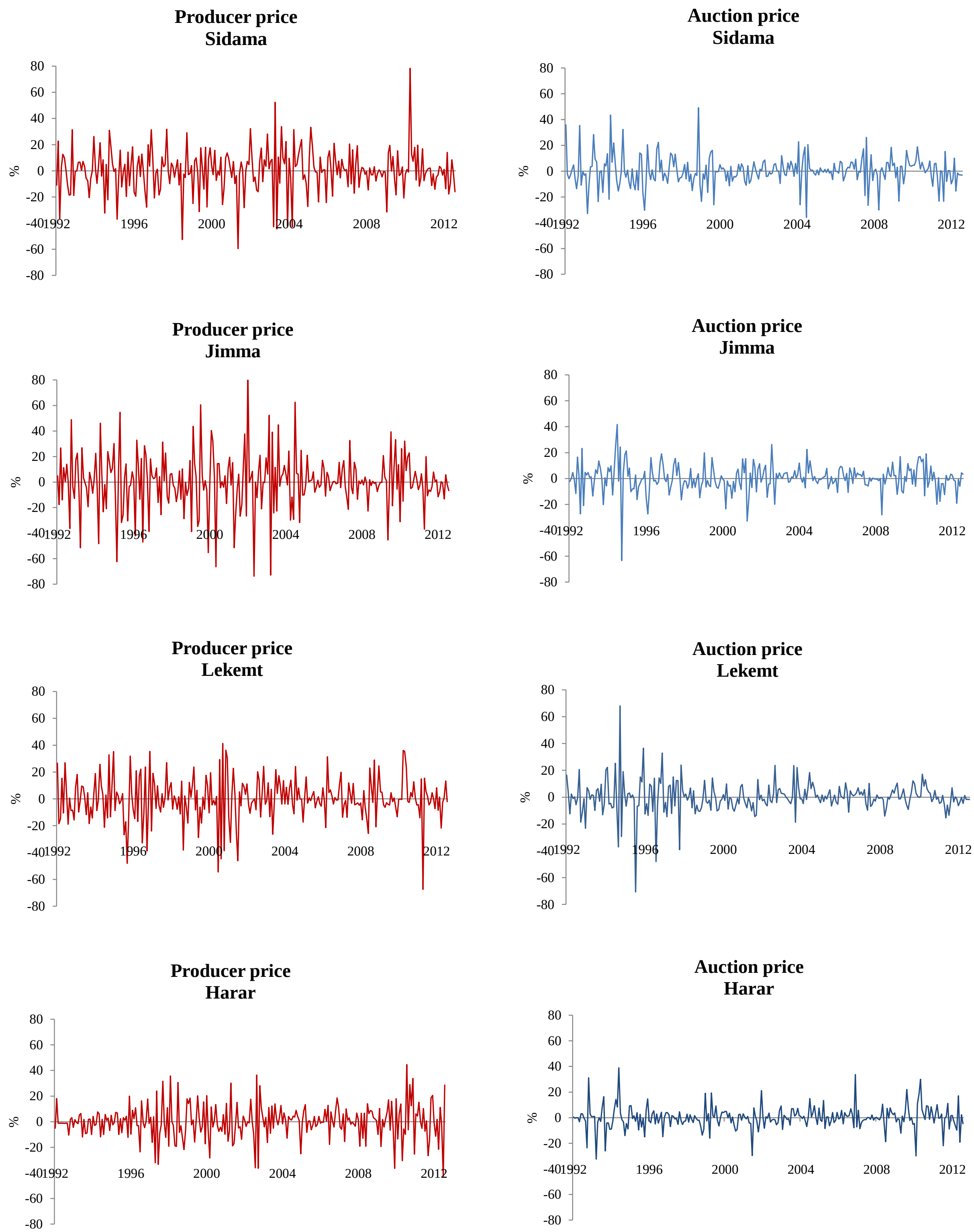
Note: The conditional correlations are derived from the estimation results of the T-DCC model. Standard deviations reported in parentheses.

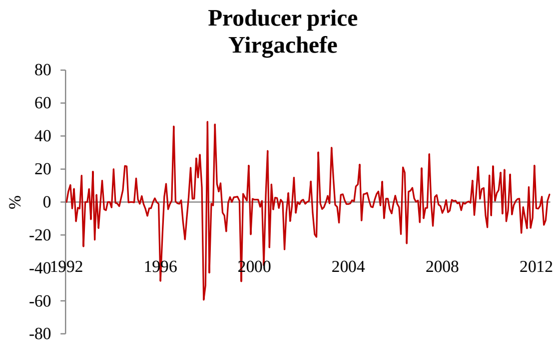
Figure 1. Producer, auction and international prices

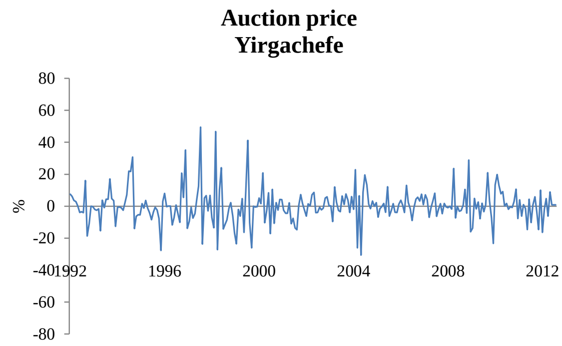


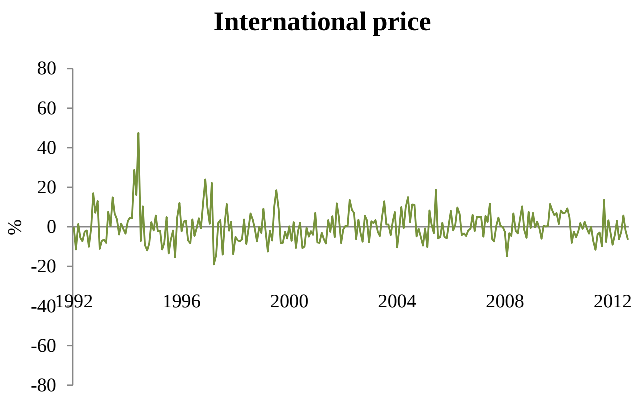
Note: Producer prices obtained from the Central Statistical Agency (CSA), auction prices from the Ministry of Agriculture and Rural Development (MoARD) and the Ethiopian Commodity Exchange (ECX, and international price from the International Coffee Organization (ICO).

Figure 2. Producer, auction and international price returns







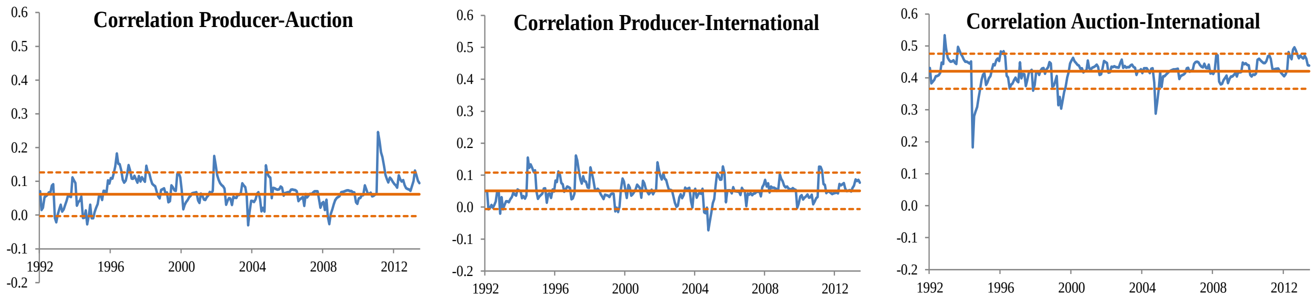


Note: Producer prices obtained from the Central Statistical Agency (CSA), auction prices from the Ministry of Agriculture and Rural Development (MoARD) and the Ethiopian Commodity Exchange (ECX, and international price from the International Coffee Organization (ICO).

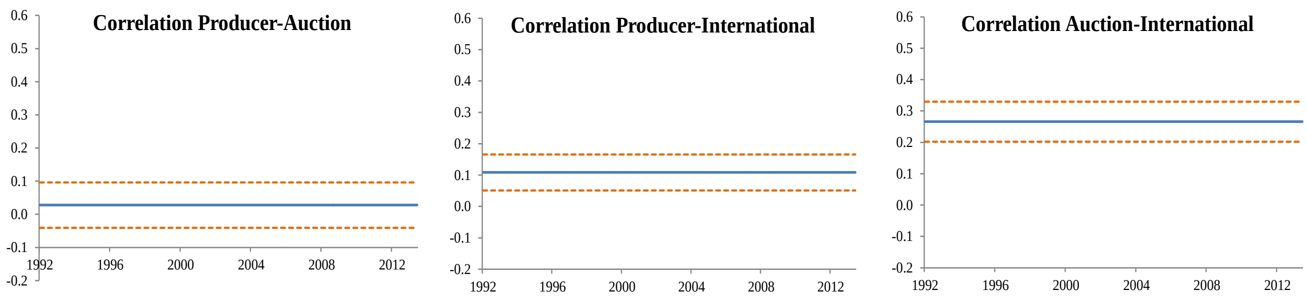
Figure 3. Three-year moving correlation coefficients of price returns

Figure 4. Dynamic conditional correlations based on T-DCC model

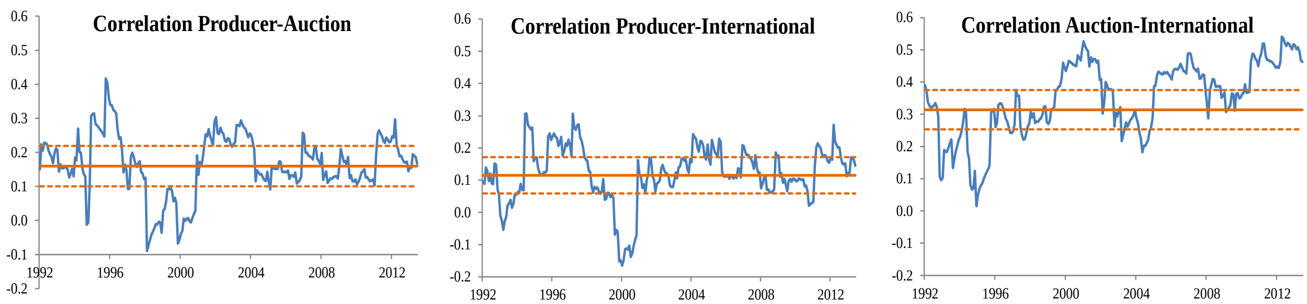
Sidama



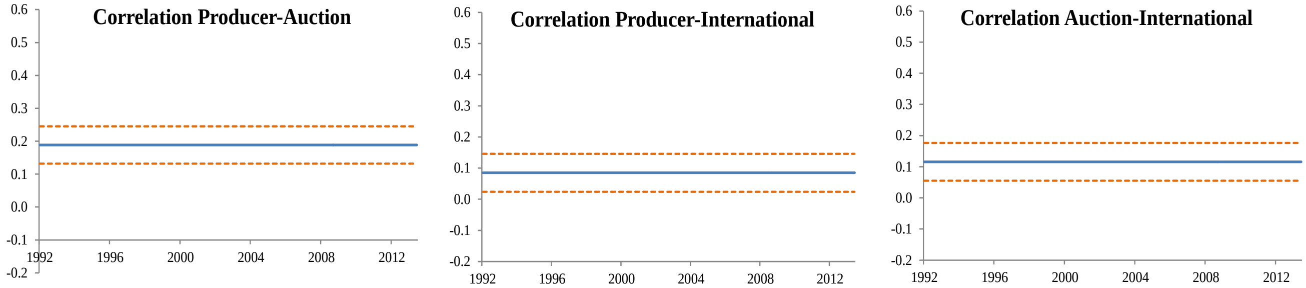
Jimma



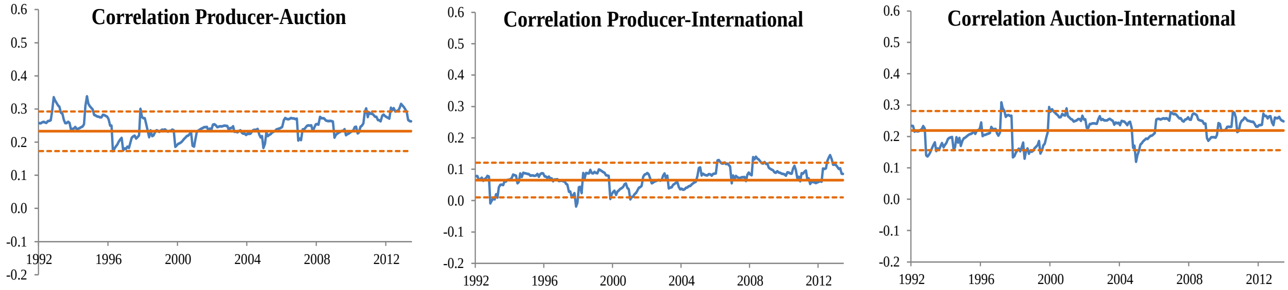
Lekemt



Harar

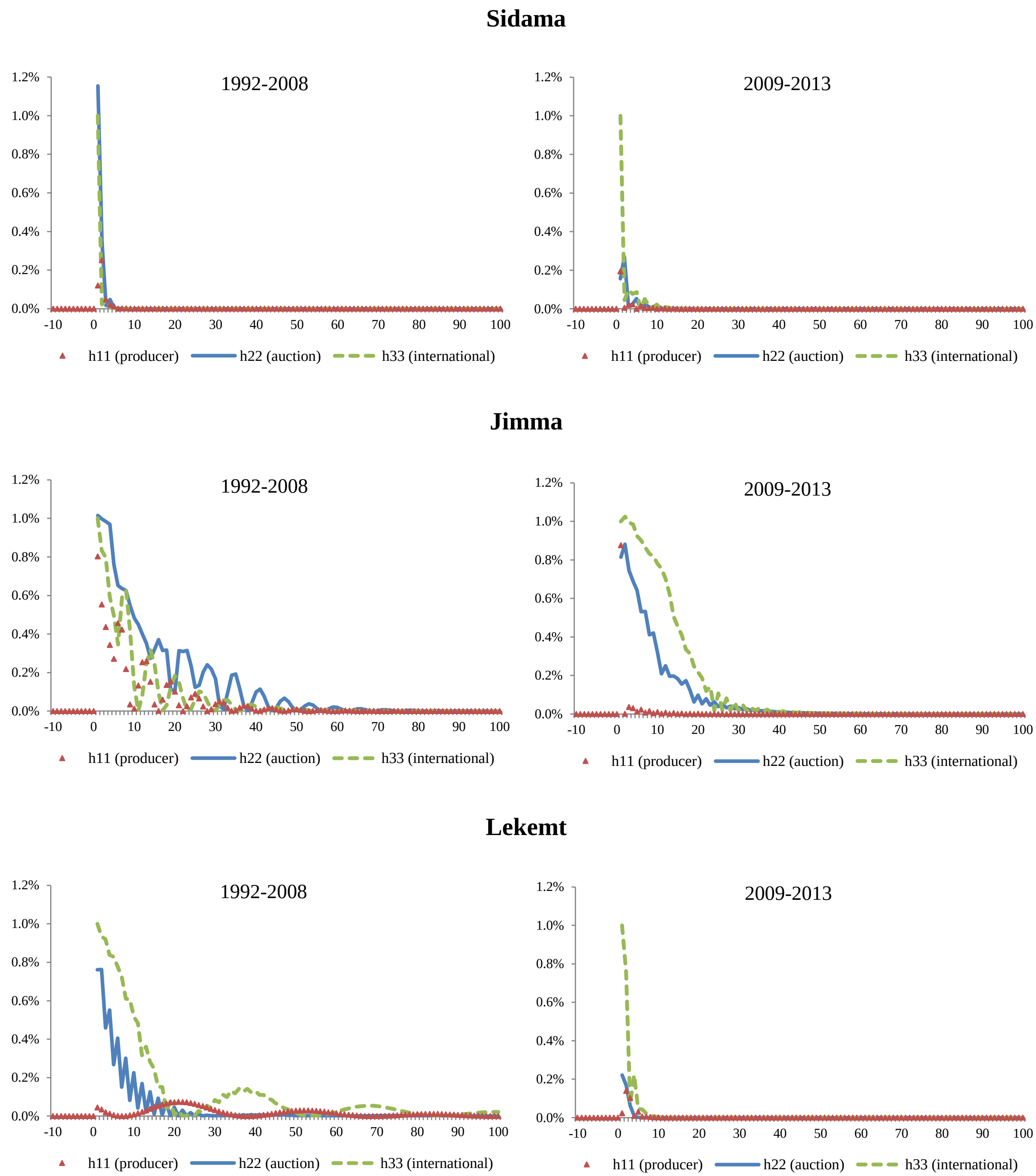


Yirgachefe

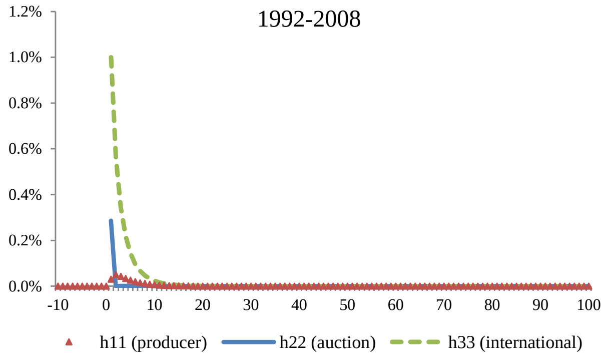


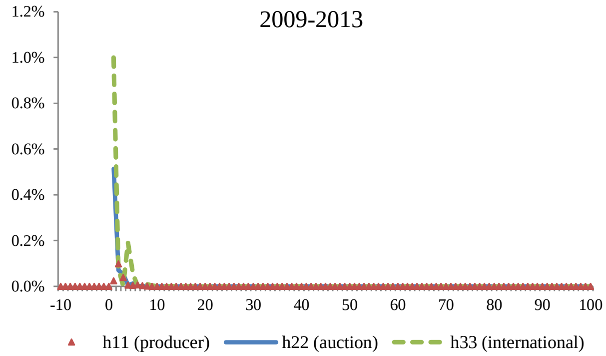
Note: The dynamic conditional correlations are derived from the estimation results of the DCC model. The solid line is the estimated constant conditional correlation following Bollerslev (1990), with confidence bands of one standard deviation.

Figure 5. Impulse-response functions on conditional volatility after a shock in the international market, based on T-BEKK model

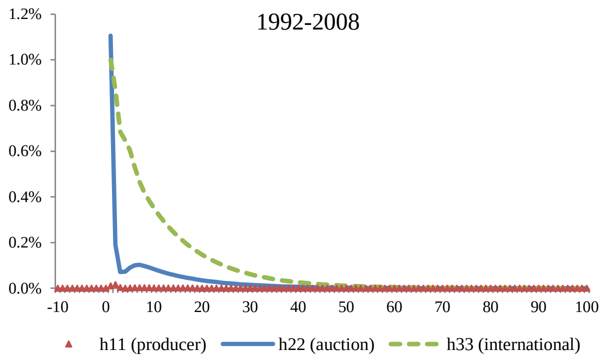


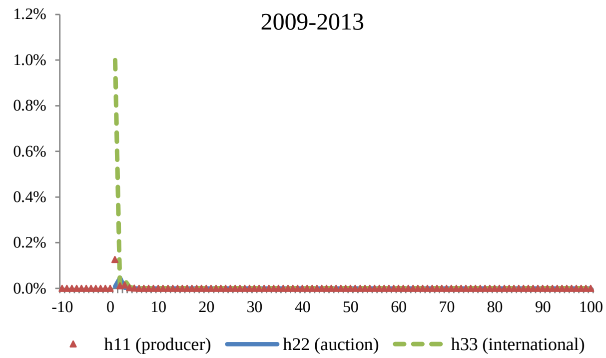
Harar





Yirgachefe





Note: The responses are the result of an innovation equivalent to a 1% increase in the own conditional volatility of the international market. The responses in each market are normalized by the size of the original shock

Appendix

Table A.1. Commodity exchanges in Africa

Country	Exchange	Abbreviation	Established	Commodities traded
South Africa	South African Future Exchange	SAFEX	1995	Maize and Wheat
Nigeria	Abuja Securities and Commodity exchange	ASCE	2001	Cotton, Cassava and Coffee
Kenya	Kenya Agricultural Commodity	KACE	1997	Coffee
Malawi	Malawi Agricultural Commodity	MACE	2004	Rice, Wheat
Uganda	Uganda Commodity Exchange	UCE	2002	Coffee, Sesame, Maize, Beans
Ethiopia	Ethiopian Commodity Exchange	ECX	2008	Coffee, Sesame and Beans
Zambia	Zambian Agricultural Commodity	ACE	1994	Maize, Wheat, Soya Beans
Zimbabwe	Zimbabwe Agricultural Commodity	ZIMACE	1994	Maize

Note: Information obtained from United Nations Conference on Trade and Development (UNCTAD), www.unctad.org.

Table A.2: Average farm gate coffee prices pre and post the Ethiopian Commodity Exchange

Region/zone	Average Coffee Price (US$/Kg)			t-test for mean difference (p-value)
	2005-2008	2009-2013	Combined	
Oromiya	1.08	1.58	1.39	0.000
Lekemt	0.94	1.50	1.28	0.000
Jimma	0.86	1.37	1.21	0.000
Harar	1.74	2.62	2.17	0.000
SNNP	0.96	1.19	1.12	0.000
Kaffa	0.96	1.13	1.08	0.000
Sidama	0.88	1.19	1.00	0.000
Yirgachefe	1.06	1.45	1.36	0.000

Note: Prices based on producer prices collected by the Central Statistical Agency (CSA) between 2005 and 2013. Prices are collected by CSA on selected 119 rural and urban markets on a monthly basis.

Table A.3. Summary statistics for price returns, different subperiods

Statistic	Sidama		Jimma		Lekemt		Harar		Yirgachefe		International price
	Producer price	Auction price	Producer price	Auction price	Producer price	Auction price	Producer price	Auction price	Producer price	Auction price	
	Jan 1992-Dec 1995 (48 observations)										
Mean	-1.008	0.262	-0.209	0.676	-1.162	-0.818	-0.530	-0.558	0.808	0.441	0.415
Std. Dev.	15.860	15.564	24.450	15.902	16.397	18.882	6.153	11.804	9.935	9.342	11.361
	Jan 1996-Dec 2004 (108 observations)										
Mean	-0.240	0.200	-0.515	-0.256	0.302	-0.023	-0.215	-0.383	-0.413	-0.416	0.020
Std. Dev.	18.476	10.682	25.951	9.881	18.192	11.788	14.831	6.695	17.524	13.455	7.877
	Jan 2005-Dec 2008 (48 observations)										
Mean	1.525	-0.324	2.371	0.709	0.424	0.333	0.441	0.981	0.809	1.619	0.189
Std. Dev.	13.110	10.851	14.435	5.044	9.983	5.359	8.574	6.909	10.284	6.491	6.558
	Jan 2009-Jun 2013 (54 observations)										
Mean	0.235	0.511	0.015	0.139	0.563	0.360	1.000	0.962	0.291	0.349	0.392
Std. Dev.	15.052	9.108	15.676	9.888	15.832	6.165	17.079	10.245	10.057	9.584	5.901

Table A.4. Estimation results of T-DCC model

Coefficient	Sidama			Jimma			Lekemt			Harar			Yirgachefe		
	PP (i=1)	AP (i=2)	IP (i=3)	PP (i=1)	AP (i=2)	IP (i=3)	PP (i=1)	AP (i=2)	IP (i=3)	PP (i=1)	AP (i=2)	IP (i=3)	PP (i=1)	AP (i=2)	IP (i=3)
	Conditional mean equation														
g_0	-0.048	0.714	-0.227	-0.880	-0.231	-0.227	0.017	0.108	-0.227	-0.349	-0.071	-0.227	0.278	0.543	-0.227
	(1.071)	(0.805)	(0.492)	(1.524)	(0.610)	(0.492)	(0.902)	(0.576)	(0.492)	(0.629)	(0.464)	(0.492)	(0.801)	(0.569)	(0.492)
	Conditional variance-covariance equation														
w_i	46.180	11.234	21.213	22.159	39.524	21.213	102.875	1.633	21.213	8.921	20.445	21.213	8.990	8.681	21.213
	(57.299)	(7.555)	(6.596)	(37.240)	(12.598)	(6.596)	(35.836)	(1.402)	(6.596)	(7.717)	(21.516)	(6.596)	(10.941)	(9.340)	(6.596)
α_i	0.013	0.143	0.180	0.182	0.291	0.180	0.258	0.104	0.180	0.192	0.180	0.180	0.057	0.117	0.180
	(0.033)	(0.086)	(0.094)	(0.213)	(0.135)	(0.094)	(0.126)	(0.044)	(0.094)	(0.082)	(0.219)	(0.094)	(0.035)	(0.075)	(0.094)
β_i	0.812	0.778	0.478	0.789	0.358	0.478	0.345	0.884	0.478	0.778	0.577	0.478	0.893	0.816	0.478
	(0.214)	(0.068)	(0.102)	(0.234)	(0.142)	(0.102)	(0.136)	(0.033)	(0.102)	(0.107)	(0.383)	(0.102)	(0.085)	(0.136)	(0.102)
α			0.025			0.000			0.039			0.000			0.015
			(0.024)			(0.000)			(0.012)			(0.000)			(0.018)
β			0.733			0.006			0.900			0.605			0.884
			(0.462)			(1.186)			(0.025)			(4.734)			(0.089)
V			4.940			5.031			6.000			5.338			4.397
			(0.657)			(0.800)			(0.961)			(0.733)			(0.530)
Wald joint test for adjustments coefficients ($H_0 : \alpha = \beta = 0$)															
Chi-sq			16.409			0.576			1,765.850			0.036			154.720
p-value			0.000			0.750			0.000			0.982			0.000

(*Cont.*)

Coefficient	Sidama			Jimma			Lekemt			Harar			Yirgachefe		
	PP	AP	IP	PP	AP	IP	PP	AP	IP	PP	AP	IP	PP	AP	IP
	(*i*=1)	(*i*=2)	(*i*=3)	(*i*=1)	(*i*=2)	(*i*=3)	(*i*=1)	(*i*=2)	(*i*=3)	(*i*=1)	(*i*=2)	(*i*=3)	(*i*=1)	(*i*=2)	(*i*=3)
Ljung-Box test for autocorrelation (H_0: no autocorrelation in squared residuals)															
LB(6)	3.164	2.205	16.180	1.735	4.540	13.271	1.202	7.920	16.361	6.575	9.852	12.122	3.182	7.127	16.696
p-value	0.788	0.900	0.013	0.942	0.604	0.039	0.977	0.244	0.012	0.362	0.131	0.059	0.786	0.309	0.010
LB(12)	5.007	5.390	18.142	10.732	6.576	16.190	2.869	19.158	19.658	13.337	12.969	16.676	12.147	32.951	19.560
p-value	0.958	0.944	0.111	0.552	0.884	0.183	0.996	0.085	0.074	0.345	0.371	0.162	0.434	0.001	0.076
Lagrange multiplier (LM) test for ARCH residuals (H_0: no serial correlation in squared residuals)															
LM(6)	2.751	2.416	16.834	1.751	4.692	13.335	1.237	6.498	15.839	7.049	9.293	12.070	2.716	5.818	17.628
p-value	0.839	0.878	0.010	0.941	0.584	0.038	0.975	0.370	0.015	0.316	0.158	0.060	0.843	0.444	0.007
LM(12)	4.278	4.578	17.420	10.101	6.266	15.196	2.613	14.234	19.479	14.033	13.836	15.012	12.460	30.812	19.289
p-value	0.978	0.971	0.134	0.607	0.902	0.231	0.998	0.286	0.078	0.299	0.311	0.241	0.409	0.002	0.082
Hosking Multivariate Portmanteau test for cross-correlation (H_0: no cross-correlation in squared residuals)															
M(6)			49.273			62.872			71.216			58.039			68.806
p-value			0.657			0.191			0.058			0.329			0.085
M(12)			71.285			124.321			118.736			97.560			126.974
p-value			0.998			0.135			0.226			0.755			0.103
Log likelihood			-2,906.6			-2,957.2			-2,867.4			-2,779.4			-2,835.1
SBIC			22.919			23.311			22.615			21.933			22.365
# obs.			258			258			258			258			258

Note: Standard errors reported in parentheses. PP, AP and IP stand for producer, auction and international market. ν is the degrees of freedom parameter. LB, LM and M stand for the corresponding Ljung-Box, Lagrange Multiplier and Hosking test statistics.

Table A.5. Estimation results of T-DCC model across coffee varieties

Coefficient	Producer Price					Auction Price				
	Sidama (i=1)	Jimma (i=2)	Lekemt (i=3)	Harar (i=4)	Yirgachefe (i=5)	Sidama (i=1)	Jimma (i=2)	Lekemt (i=3)	Harar (i=4)	Yirgachefe (i=5)
	Conditional mean equation									
g_0	-0.048	-0.880	0.017	-0.349	0.278	0.714	-0.231	0.108	-0.071	0.543
	(1.071)	(1.524)	(0.902)	(0.629)	(0.801)	(0.805)	(0.610)	(0.576)	(0.464)	(0.569)
	Conditional variance-covariance equation									
w_i	46.180	22.159	102.875	8.921	8.990	11.234	39.524	1.633	20.445	8.681
	(57.299)	(37.240)	(35.836)	(7.717)	(10.941)	(7.555)	(12.598)	(1.402)	(21.516)	(9.340)
a_i	0.013	0.182	0.258	0.192	0.057	0.143	0.291	0.104	0.180	0.117
	(0.033)	(0.213)	(0.126)	(0.082)	(0.035)	(0.086)	(0.135)	(0.044)	(0.219)	(0.075)
b_i	0.812	0.789	0.345	0.778	0.893	0.778	0.358	0.884	0.577	0.816
	(0.214)	(0.234)	(0.136)	(0.107)	(0.085)	(0.068)	(0.142)	(0.033)	(0.383)	(0.136)
a					0.058					0.055
					(0.033)					(0.027)
b					0.416					0.204
					(0.217)					(0.349)
v					5.651					3.856
					(0.841)					(0.281)
Wald joint test for adjustments coefficients (H_0: a=b=0)										
Chi-sq					40.183					12.976
p-value					0.000					0.002
Ljung-Box test for autocorrelation (H_0: no autocorrelation in squared residuals)										
LB(6)	3.513	1.102	1.380	6.160	3.845	0.784	4.159	10.010	9.530	5.581
p-value	0.742	0.981	0.967	0.405	0.698	0.993	0.655	0.124	0.146	0.472
LB(12)	5.013	10.054	3.692	11.922	12.251	2.832	9.259	25.994	12.577	29.751
p-value	0.958	0.611	0.988	0.452	0.426	0.997	0.681	0.011	0.401	0.003

(*Cont.*)

Coefficient	Producer Price					Auction Price				
	Sidama (i=1)	Jimma (i=2)	Lekemt (i=3)	Harar (i=4)	Yirgachefe (i=5)	Sidama (i=1)	Jimma (i=2)	Lekemt (i=3)	Harar (i=4)	Yirgachefe (i=5)
Lagrange multiplier (LM) test for ARCH residuals (H_0: no serial correlation in squared residuals)										
LM(6)	3.060	1.073	1.360	6.932	3.319	0.781	4.395	9.026	8.901	5.052
p-value	0.801	0.983	0.968	0.327	0.768	0.993	0.623	0.172	0.179	0.537
LM(12)	4.188	9.592	3.340	12.967	12.140	1.445	8.223	19.517	13.714	27.212
p-value	0.980	0.652	0.993	0.371	0.434	1.000	0.767	0.077	0.319	0.007
Hosking Multivariate Portmanteau test for cross-correlation (H_0: no cross-correlation in squared residuals)										
M(6)					121.765					155.213
p-value					0.944					0.326
M(12)					297.777					281.790
p-value					0.493					0.742
Log likelihood					-5,274.5					-4,609.3
SBIC					41.598					36.441
# obs.					258					258

Note: Standard errors reported in parentheses. ν is the degrees of freedom parameter. LB, LM and M stand for the corresponding Ljung-Box, Lagrange Multiplier and Hosking test statistics.

Table A.6. Estimation results of T-BEKK model, period 1992-2008

Coefficient	Sidama			Jimma			Lekemt			Harar			Yirgachefe		
	PP (i=1)	AP (i=2)	IP (i=3)	PP (i=1)	AP (i=2)	IP (i=3)	PP (i=1)	AP (i=2)	IP (i=3)	PP (i=1)	AP (i=2)	IP (i=3)	PP (i=1)	AP (i=2)	IP (i=3)
	Conditional variance-covariance equation														
c_{i1}	12.497	-2.994	-3.688	3.998	-0.062	5.263	-0.002	0.002	0.002	3.405	0.569	4.766	1.625	4.359	-5.240
	(3.276)	(1.730)	(4.252)	(7.065)	(0.053)	(2.019)	(0.034)	(0.055)	(0.041)	(1.074)	(7.120)	(0.943)	(1.771)	(1.422)	(1.801)
c_{i2}		-0.002	-0.002		0.000	0.005		0.003	0.000		6.078	0.707		0.024	-0.026
		(0.040)	(0.068)		(0.038)	(0.021)		(0.023)	(0.021)		(0.952)	(5.772)		(0.298)	(0.122)
c_{i3}			-0.001			0.005			0.000			0.000			0.002
			(0.060)			(0.009)			(0.029)			(0.058)			(0.046)
a_{i1}	0.312	0.070	0.053	0.263	-0.026	0.170	0.123	-0.103	0.037	0.652	0.017	0.099	0.650	-0.005	-0.025
	(0.169)	(0.096)	(0.050)	(0.448)	(0.085)	(0.096)	(0.080)	(0.061)	(0.022)	(0.130)	(0.139)	(0.103)	(0.228)	(0.126)	(0.088)
a_{i2}	-0.099	0.299	-0.190	0.350	0.268	-0.209	0.018	0.269	-0.154	0.099	-0.510	0.302	-0.041	0.926	-0.283
	(0.204)	(0.119)	(0.088)	(0.366)	(0.225)	(0.112)	(0.048)	(0.073)	(0.038)	(0.203)	(0.325)	(0.185)	(0.199)	(0.227)	(0.188)
a_{i3}	-1.130	0.038	-0.152	-0.109	0.111	0.190	-0.171	-0.261	0.177	-0.242	-0.261	-0.565	0.132	0.104	-0.043
	(0.240)	(0.160)	(0.183)	(0.161)	(0.142)	(0.102)	(0.109)	(0.094)	(0.086)	(0.188)	(0.141)	(0.173)	(0.128)	(0.111)	(0.144)
g_{i1}	-0.128	-0.480	-0.254	0.817	0.183	0.064	0.966	-0.039	-0.052	0.802	0.086	-0.038	0.601	0.060	-0.055
	(0.233)	(0.108)	(0.149)	(0.150)	(0.021)	(0.061)	(0.019)	(0.071)	(0.014)	(0.078)	(0.103)	(0.068)	(0.182)	(0.130)	(0.060)
g_{i2}	0.596	0.575	0.082	-0.946	0.871	0.143	-0.354	-0.725	0.315	-0.064	0.078	0.035	-0.712	0.398	0.223
	(0.290)	(0.134)	(0.157)	(0.580)	(0.096)	(0.183)	(0.255)	(0.149)	(0.183)	(0.428)	(0.152)	(0.180)	(0.167)	(0.198)	(0.094)
g_{i3}	0.072	-0.396	0.665	-0.545	-0.089	0.574	0.386	0.951	0.817	-0.278	-0.001	0.701	0.655	0.512	0.754
	(0.956)	(0.400)	(0.298)	(1.272)	(0.142)	(0.346)	(0.146)	(0.170)	(0.141)	(0.085)	(0.086)	(0.101)	(0.249)	(0.130)	(0.152)
N			4.995			4.438			6.597			4.214			3.164
			(0.983)			(0.952)			(1.580)			(0.796)			(0.524)
Wald joint test for cross-volatility coefficients (H_0: $a_{ij}=g_{ij}=0, \forall i \neq j$)															
Chi-sq			255.295			1737.751			337.627			44.105			127.233
p-value			0.000			0.000			0.000			0.000			0.000

(*Cont.*)

Coefficient	Sidama			Jimma			Lekemt			Harar			Yirgachefe		
	PP	AP	IP	PP	AP	IP	PP	AP	IP	PP	AP	IP	PP	AP	IP
	(*i*=1)	(*i*=2)	(*i*=3)	(*i*=1)	(*i*=2)	(*i*=3)	(*i*=1)	(*i*=2)	(*i*=3)	(*i*=1)	(*i*=2)	(*i*=3)	(*i*=1)	(*i*=2)	(*i*=3)
Ljung-Box test for autocorrelation (H_0: no autocorrelation in squared residuals)															
LB(6)	5.759	1.963	15.511	4.570	11.230	4.111	23.415	5.520	18.461	2.983	22.124	11.483	2.101	2.993	23.566
p-value	0.451	0.923	0.017	0.600	0.082	0.662	0.001	0.479	0.005	0.811	0.001	0.075	0.910	0.810	0.001
LB(12)	10.315	7.056	16.911	7.001	14.182	8.290	26.837	10.597	20.796	7.249	24.702	15.531	3.568	17.917	25.634
p-value	0.588	0.854	0.153	0.858	0.289	0.762	0.008	0.564	0.053	0.841	0.016	0.214	0.990	0.118	0.012
Lagrange multiplier (LM) test for ARCH residuals (H_0: no serial correlation in squared residuals)															
LM(6)	4.874	1.356	15.109	4.078	10.845	3.580	17.461	5.607	18.303	3.271	18.098	11.703	2.497	3.519	22.875
p-value	0.560	0.968	0.019	0.666	0.093	0.733	0.008	0.469	0.006	0.774	0.006	0.069	0.869	0.741	0.001
LM(12)	8.968	4.374	15.403	7.563	12.717	5.538	21.618	9.074	18.307	7.968	31.458	16.006	4.169	20.520	23.111
p-value	0.706	0.976	0.220	0.818	0.390	0.938	0.042	0.697	0.107	0.788	0.002	0.191	0.980	0.058	0.027
Hosking Multivariate Portmanteau test for cross-correlation (H_0: no cross-correlation in squared residuals)															
M(6)			58.992			67.272			77.067			60.453			59.595
p-value			0.298			0.106			0.021			0.254			0.279
M(12)			87.327			111.411			103.478			91.541			90.283
p-value			0.928			0.392			0.605			0.872			0.891
Log likelihood			-2,315.9			-2,349.3			-2,288.6			-2150.5			-2243.6
SBIC			23.356			23.684			23.089			21.735			22.648
# observations			204			204			204			204			204

Note: Standard errors reported in parentheses. PP, AP and IP stand for producer, auction and international market. ν is the degrees of freedom parameter. LB, LM and M stand for the corresponding Ljung-Box, Lagrange Multiplier and Hosking test statistics.

Table A.7. Estimation results of T-BEKK model, period 2009-2013

Coefficient	Sidama			Jimma			Lekemt			Harar			Yirgachefe		
	PP	AP	IP	PP	AP	IP	PP	AP	IP	PP	AP	IP	PP	AP	IP
	(i=1)	(i=2)	(i=3)	(i=1)	(i=2)	(i=3)	(i=1)	(i=2)	(i=3)	(i=1)	(i=2)	(i=3)	(i=1)	(i=2)	(i=3)
	Conditional variance-covariance equation														
c_{i1}	3.986	3.930	3.843	-2.891	0.985	1.519	7.614	2.518	0.745	7.599	5.934	-1.638	4.941	3.383	3.383
	(5.762)	(1.617)	(1.100)	(1.980)	(1.772)	(1.131)	(2.845)	(1.438)	(1.423)	(1.796)	(1.428)	(1.018)	(4.121)	(1.911)	(1.470)
c_{i2}		0.001	0.000		0.000	0.000		0.000	0.000		-0.014	-0.001		0.000	0.000
		(0.188)	(0.155)		(0.180)	(0.056)		(0.128)	(0.088)		(0.056)	(0.030)		(0.156)	(0.048)
c_{i3}			0.000			0.000			0.000			0.002			0.000
			(0.267)			(0.095)			(0.110)			(0.052)			(0.096)
a_{i1}	-0.065	0.460	0.138	0.278	-0.183	-0.183	-0.812	-0.037	-0.044	-0.514	0.197	0.070	-0.083	0.216	0.213
	(0.214)	(0.135)	(0.093)	(0.272)	(0.217)	(0.107)	(0.384)	(0.201)	(0.135)	(0.126)	(0.095)	(0.045)	(0.746)	(0.408)	(0.135)
a_{i2}	-0.151	-0.161	0.177	0.899	0.196	0.066	-1.233	-0.062	-0.138	0.576	0.309	0.321	0.655	0.177	0.054
	(0.169)	(0.205)	(0.158)	(0.634)	(0.200)	(0.051)	(0.519)	(0.307)	(0.223)	(0.202)	(0.126)	(0.077)	(0.568)	(0.369)	(0.131)
a_{i3}	0.662	1.170	0.449	1.086	-0.020	-0.196	1.037	-0.466	-0.294	-0.786	0.132	0.447	0.342	-0.527	0.600
	(0.453)	(0.302)	(0.325)	(0.756)	(0.346)	(0.181)	(0.846)	(0.606)	(0.261)	(0.481)	(0.149)	(0.129)	(0.526)	(0.627)	(0.207)
g_{i1}	-0.464	-0.268	0.175	-0.066	0.088	0.126	-0.020	0.006	-0.372	0.553	0.189	0.092	-0.475	-0.380	0.096
	(0.145)	(0.172)	(0.145)	(0.166)	(0.169)	(0.179)	(0.167)	(0.106)	(0.106)	(0.163)	(0.071)	(0.053)	(0.848)	(0.683)	(0.279)
g_{i2}	1.330	0.008	0.107	0.462	-0.681	0.276	-0.254	-0.583	-0.098	-0.456	0.011	0.328	0.660	-0.291	-0.425
	(0.378)	(0.949)	(0.507)	(0.386)	(0.335)	(0.195)	(0.814)	(0.350)	(0.287)	(0.277)	(0.016)	(0.091)	(0.395)	(0.248)	(0.214)
g_{i3}	-1.865	0.417	0.197	0.995	1.430	0.427	-0.381	0.835	0.536	1.101	-0.903	0.197	-0.727	-0.628	0.203
	(0.814)	(0.853)	(0.548)	(0.686)	(0.267)	(0.719)	(0.309)	(0.259)	(0.199)	(0.302)	(0.226)	(0.147)	(0.816)	(1.120)	(0.508)
v			6.807			20.178			4.919			815.858			6.289
			(4.035)			(45.520)			(2.239)			(197.076)			(2.860)
Wald joint test for cross-volatility coefficients (H_0: $a_{ij}=g_{ij}=0, \forall i \neq j$)															
Chi-sq			1023.340			361.019			658.147			365.035			343.127
p-value			0.000			0.000			0.000			0.000			0.000

(*Cont.*)

Coefficient	Sidama			Jimma			Lekemt			Harar			Yirgachefe		
	PP (*i*=1)	AP (*i*=2)	IP (*i*=3)	PP (*i*=1)	AP (*i*=2)	IP (*i*=3)	PP (*i*=1)	AP (*i*=2)	IP (*i*=3)	PP (*i*=1)	AP (*i*=2)	IP (*i*=3)	PP (*i*=1)	AP (*i*=2)	IP (*i*=3)
Ljung-Box test for autocorrelation (H_0: no autocorrelation in squared residuals)															
LB(6)	0.454	5.776	4.391	9.361	6.369	4.031	1.244	1.573	6.510	4.020	4.736	4.846	3.294	3.228	12.173
p-value	0.998	0.449	0.624	0.154	0.383	0.672	0.975	0.955	0.369	0.674	0.578	0.564	0.771	0.780	0.058
LB(12)	0.958	7.941	13.608	15.704	9.030	5.357	6.415	3.180	14.438	9.708	7.187	11.458	4.384	7.192	19.332
p-value	1.000	0.790	0.326	0.205	0.700	0.945	0.894	0.994	0.274	0.642	0.845	0.490	0.975	0.845	0.081
Lagrange multiplier (LM) test for ARCH residuals (H_0: no serial correlation in squared residuals)															
LM(6)	0.417	5.602	6.332	7.676	8.790	4.108	1.041	2.134	6.681	3.678	3.843	3.943	3.044	2.742	5.229
p-value	0.999	0.469	0.387	0.263	0.186	0.662	0.984	0.907	0.351	0.720	0.698	0.684	0.803	0.840	0.515
LM(12)	0.857	8.477	15.587	9.630	11.985	6.341	4.916	3.081	12.689	8.990	5.922	12.112	8.904	17.229	13.266
p-value	1.000	0.747	0.211	0.648	0.447	0.898	0.961	0.995	0.392	0.704	0.920	0.437	0.711	0.141	0.350
Hosking Multivariate Portmanteau test for cross-correlation (H_0: no cross-correlation in squared residuals)															
M(6)			37.895			52.704			65.190			39.425			49.142
p-value			0.953			0.524			0.142			0.932			0.662
M(12)			99.662			91.079			107.970			81.075			109.468
p-value			0.704			0.879			0.483			0.975			0.442
Log likelihood			-555.6			-573.8			-536.8			-584.0			-547.9
SBIC			22.423			23.100			21.728			23.478			22.140
# observations			54			54			54			54			54

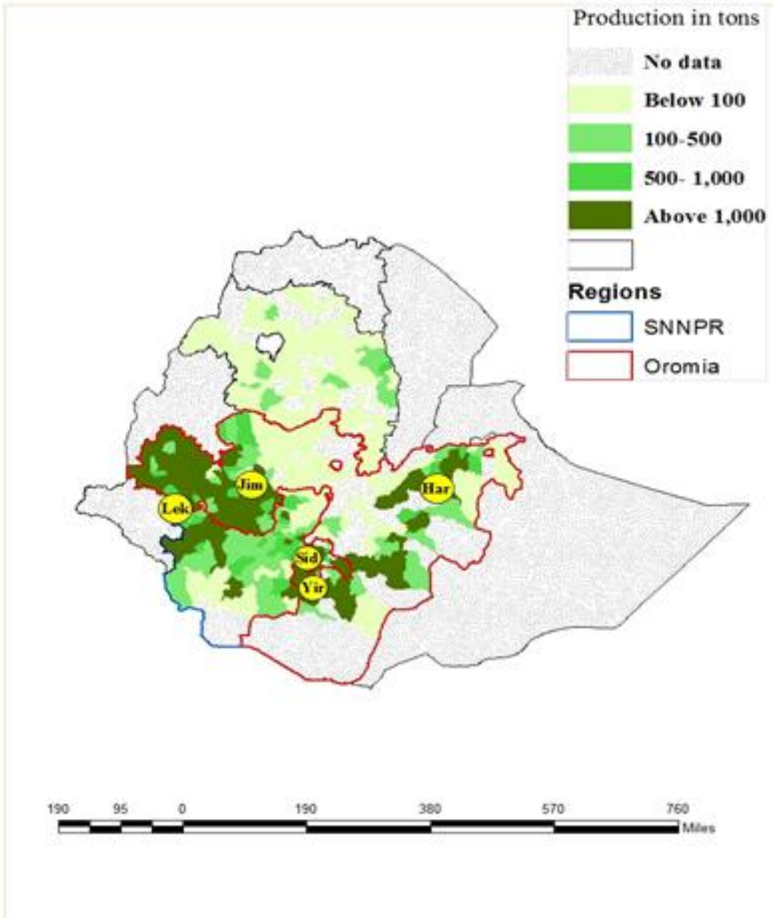
Note: Standard errors reported in parentheses. PP, AP and IP stand for producer, auction and international market. ν is the degrees of freedom parameter. LB, LM and M stand for the corresponding Ljung-Box, Lagrange Multiplier and Hosking test statistics.

Table A.8. Estimated break dates for price returns and squared price returns

Market	Returns	Squared returns
Sidama		
Producer price	Dec 2010	Dec 2010
Auction price	May 1994	Feb 1999
Jimma		
Producer price	May 2002	Jul 2003
Auction price	Jun 1994	Sep 1994
Lekemt		
Producer price	Dec 2010	Oct 2000
Auction price	Aug 1995	Sep 1994
Harar		
Producer price	Apr 2011	Dec 2002
Auction price	Apr 1994	May 1994
Yirgachefe		
Producer price	Feb 2012	Jan 1998
Auction price	Aug 1997	Sep 1997
International price	Apr 1994	Apr 1994

Note: The estimated break dates are based on Lavielle and Moulines (2000) test for structural breaks on the mean of price returns and the squared of price returns as a proxy of volatility. Minimum length of a segment is 2 months.

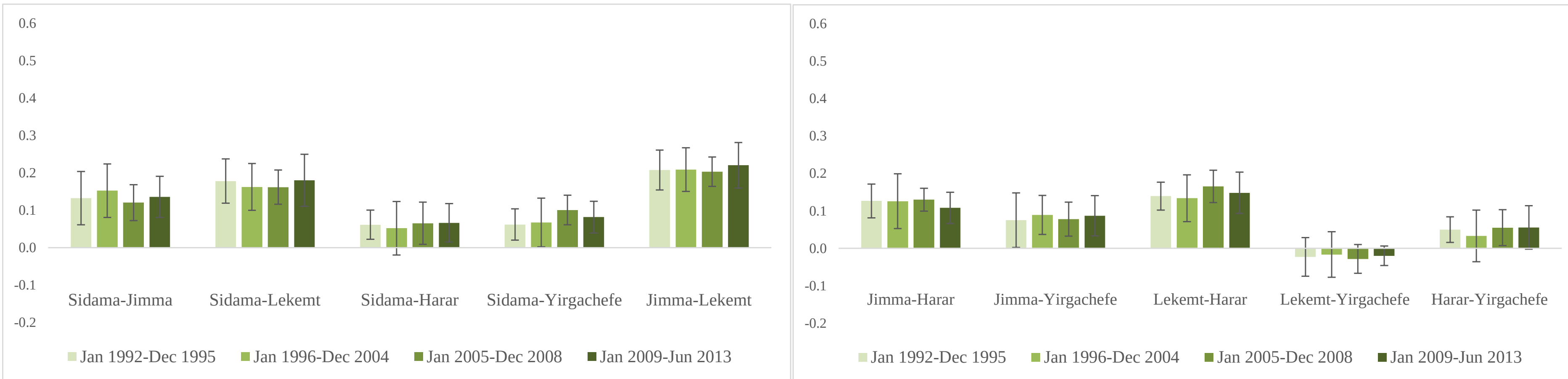
Figure A.1. Growing areas of Arabica coffee in Ethiopia, 2009-2013



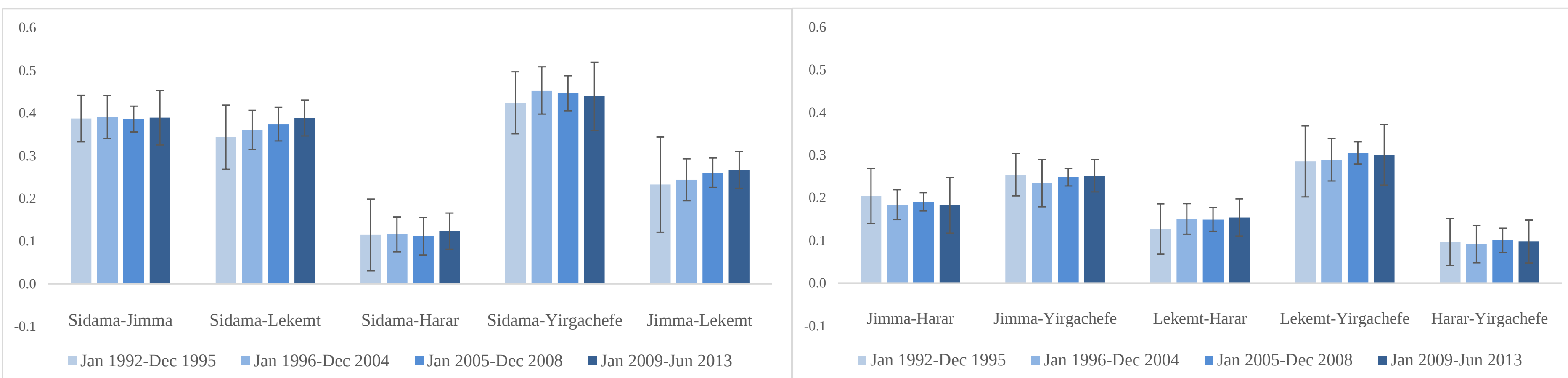
Note: Map based on weighted production average period 2009-2013. Volume of production obtained from Central Statistical Agency (CSA). Sid=Sidama; Jim=Jimma; Lek=Lekemt; Har=Harar; Yir=Yirgachefe; SNNPR= Southern Nations Nationality Peoples region.

Figure A.2. Average conditional correlations for different subperiods based on T-DCC model across coffee varieties

Producer level



Auction level



Note: The conditional correlations are derived from the estimation results of the T-DCC model. The vertical lines are confident bands of one standard deviation.