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Global and Ethiopian Cereal Prices: Does the Law of One Price hold in the long run?

Heba Abbas, Annina Borgström

Abstract

Like many other countries in the world, Ethiopia is currently facing significant challenges with high food prices. The high food prices affect cereals such as teff, sorghum, and maize which are staple foods in the Ethiopian diet. This study investigates the relationship between cereal prices in Ethiopia and the world market price of cereals. To study the price relationship, the Law of One Price (LOP) is used, stating that prices in different markets should, in perfectly competitive markets with the absence of transportation costs, be equalized. The data used are the Consumer Price Index (CPI) of cereals in Ethiopia, the world market price index of cereals, and the exchange rate between Ethiopian birr (ETB) and US dollar (USD) between January 1998 and December 2022. The Engle and Granger cointegration analysis was used to test for the long-term relationship between domestic and international cereal prices. A key finding is that there are long-term relationships between domestic and international prices, indicating that the LOP holds in the long run.

Keywords: Ethiopia, cereal, food prices & LOP

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Tack!

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1. Introduction

Food prices have become a global concern, facing the reality of increasing inflation evident in recent years. While the population in developed countries, like Sweden, has expressed unwarranted concerns regarding rising food prices, several developing countries have experienced double-digit food inflation in the past decade (SVT, 2022; Ndikumana et al., 2022). Ethiopia, in particular, has experienced unusually high food prices recently (Kayamo, 2021).

The 2007-2008 global food crisis highlighted the challenge of escalating food prices, a concern echoed in Ethiopia due to various factors beyond the crisis. Alem & Söderblom (2011) explained the main driving factors to be the increased use of cereals for biofuels along with the depreciation of the USD. After the global food crisis in 2007-2008, Ethiopia faced additional challenges with increased food prices. One of the major challenges that arose was the outbreak of the civil war in Tigray in 2020 which resulted in significant asset losses for Ethiopia. Cereal production in conflict zones is generally limited, affected by topsoil degradation and irregular rainfall (USDA, 2022).

Following in 2021, food prices in Ethiopia gained renewed attention as prices increased. The Russian invasion of Ukraine in 2022 further worsened global supply issues for fuel and cereals, contributing to the upward trend in prices. Ethiopia's heavy reliance on Russia and Ukraine for wheat, oil, and agricultural inputs, like many other African countries, underscores the impact of instabilities in the food sector on enduring cereal price effects (Ndikumana et al., 2022; USDA, 2022).

The effects of food price hikes have gained attention from policymakers and researchers due to the impact on household purchasing power and overall welfare (Ndikumana et al., 2022). Low-income households, in particular, suffer from high food as prices have a harmful impact since the households spend a significant portion of their income on food. As highlighted by the Ethiopian Public Health Institute (2020), only 26% of Ethiopian households can afford a

nutritious diet, showing how sensitive Ethiopian households are to price hikes. Given that food is a basic need, rapid increases in food prices may force households to reduce food consumption, potentially leading to starvation in extreme cases (De Janvry & Sadoulet, 2016). Even during short-term price hikes, there are potential lasting effects on health, labor outcomes, and chances of survival (Jayne, 2012). Given the global concern that increasing food prices may lead to starvation and macroeconomic imbalances, research on food prices is an important and relevant topic to study.

Cereals are important as they are the primary component in the diets of Ethiopians and the major crops grown in Ethiopia include maize, teff, wheat, and sorghum (Admassie, 2013; Ofcansky & Berry, 1993). In developing countries like Ethiopia, cereals are commonly used as substitutes and not compliments. If the price of wheat increases, teff might be used instead (Loening, Durevall & Ayalew-Birru, 2009).

As a developing country, Ethiopia's agricultural sector is a crucial contributor to the nation's economy, accounting for around 35% of the country's GDP. This highlights the importance of agriculture in driving economic growth and development in the country. Additionally, around 72% of the population is employed in the agriculture sector (Central Intelligence Agency, 2023).

The prices of Ethiopian food are thought to be influenced by global food prices (Abebe et al. 2023). However, measures such as export bans on international food trade in Ethiopia are considered a mitigating factor, restraining the direct influence of world market prices on domestic cereal prices. While export bans aim to secure domestic food supplies and alleviate price increases, critics argue that they may lead to long-term developmental drawbacks, including reduced incentives for agricultural investment (AGRA, 2019). Until 2016, international food trade was limited compared to total agricultural production. However, post-2016, Ethiopia increased its agricultural exports and joint free trade agreements which affected possible deviations of LOP (USDA, 2022;). This study will include an examination

of whether these shifts in trade policies will alter the impact of world market prices on domestic cereal prices.

This study analyzes the factors contributing to the rise in prices, where trade is a main component. However, a political debate sparked when Minot (2010) suggested that Ethiopia is not dependent on food trade due to its relatively small trade in general. Other researchers like Admassie (2013) and Martin & Anderson (2012), along with more mentioned in the section of the literature review, suggest that trade and trade policies do have a big impact. As there is no consensus on the impact of trade on food prices, the subject is interesting to further study.

The objective of this study is to empirically investigate if there is a relationship between world market prices of cereals and domestic prices of cereals. Durevall et al. (2013) have found a relationship between 2000-2010, however, our analysis benefits from a more extensive dataset, incorporating recent years. The scientific relevance of studying this topic is given the global concern regarding increasing food prices along with recent data. Furthermore, while numerous studies such as Admassie (2013) and Minten et al. (2014) examine food prices in Ethiopia, only a few incorporate LOP in their analyses to explore the long-run relationship between global and domestic food prices. According to LOP, there should be a relationship between domestic and international prices, however, empirically the law rarely holds. To address this objective, the following research questions will be explored:

- Do world market prices of cereals influence domestic prices of cereals in Ethiopia?
- If they do, what is the magnitude of this impact in the short and long run?

This thesis will be organized as follows. The first section will introduce the subject of the thesis along with the aim and research questions. The second and third sections present previous research on food prices and the theoretical framework. Subsequently, the data and methods will be presented. The last sections will consist of the analysis of the research question and the concluding remarks with recommendations for future research.

2. Literature Review of Food Prices

Several studies have been conducted in response to unusually high food prices. This section reviews the most significant literature on food prices, food security, trade policies, and exchange rates in developing countries.

Global food price fluctuations have the potential to influence local food prices, however, Ethiopia has historically used trade restrictions to mitigate price hikes (Agra, 2019). Contrary to researchers like Dawe (2001), Admassie (2013), and Martin & Anderson (2012) thoughts on how free trade impacts domestic prices, a study by Minot (2010) suggested that Sub-Saharan countries such as Ethiopia have minimal dependence on global food trade and that the increasing world food prices have a minor effect on domestic food prices. The reason behind the minimal dependence is suggested to be due to domestic factors rather than external. Exchange rate manipulations and crop failures are examples of internal factors increasing food prices.

The consensus is that high food prices harm developing countries, making stabilizing food prices crucial for food security. Dawe's (2001) examination of the rice price stabilization in developing Asia highlighted the inherent conflict between global pursuits of free trade, as facilitated by international agreements. Dawe advocated for a policy favoring pure price stabilization for rice, aiming to foster macroeconomic stability and stimulate efficient investment. His analysis concluded that unrestricted free trade would be a threat to food price instability. However, when developing countries become less poor and the population is food secure, liberalized financial markets would be a reasonable policy.

In alignment with Dawe's analysis, Gouel and Jean (2013) delved into the important role of trade policies in this context. Their work raises questions about the combination of food storage and trade policies, particularly the implications of export restrictions. The authors underscored the intricate relationship between trade policy decisions and the overall stability of food prices in the global context.

Another study conducted by Martin & Anderson (2012) aligns with the perspectives of Dawe and Gouel & Jean on the significance of trade policies. The authors investigate the impact of trade policies, particularly export restrictions, on food price hikes of cereals. They emphasize problems of export restrictions, indicating that if all countries employ them, it would be ineffective in stabilizing domestic prices and could worsen international price instability during food market shocks.

The research conducted by Durevall et al. (2013) demonstrates the complexities of inflation and food prices in Ethiopia. The study's findings indicate that inflation in Ethiopia is closely tied to the significance of agriculture and food in the economy. Over the study period, inflation in Ethiopia was mainly driven by food prices. In the long term, external factors such as the exchange rate and international food prices play a crucial role in determining Ethiopia's food prices. However, in the short run, domestic agricultural supply shocks and seasonal fluctuations, likely influenced by expectations about future harvests, can cause deviations from the long-term relationship between domestic and international food prices. The mechanisms linking world food prices to domestic prices remain poorly understood due to limited arbitrage opportunities. Due to that reason, the authors suggest the need for further research.

Admassie (2013) investigates the political economy of food prices in Ethiopia after the global food crisis in 2007–08. According to the author, the price hike was not only due to external factors but also internal factors such as fluctuations in the exchange rate and trade policies. However, in response to the food price crisis, the Ethiopian government implemented various policy measures to decrease the high prices. Some of the policy measures included releasing emergency food cereal reserves, subsidies, export bans on cereals, eliminating VAT taxes on food items, and fiscal measures like tariff adjustments. These measures did mitigate the food prices in the short run, however, in the long run, the policies had a negative effect and increased prices again.

Minten et al. (2014) conducted a study on Ethiopian cereal markets from 2001 to 2011. The authors argue the significance of cereals as a staple food and a primary source of livelihood for many farmers. The study examines changes in cereal prices, attributing these changes to internal factors including economic growth, technological development, and urbanization. However, external factors such as trade policies are also a driving factor to price fluctuations.

Aragie et al. (2020) explore the impact of a cereal export ban in Ethiopia on various economic factors, including domestic prices and welfare. The authors argue that an export ban may stabilize domestic food prices, but it may not eliminate the price spike caused by external shocks. Their analysis suggests that implementing an export ban could help stabilize domestic food prices, although it may not fully alleviate the domestic price increases caused by external price shocks. A cereal export ban can not only hinder food production but also have distributional implications. The implications will most likely harm the welfare of rural households through income loss as the majority of the labor force is employed in the agricultural sector. The authors suggest that implementing a cereal export ban may offer short-term benefits during periods of high international food prices. However, the bans should be lifted once the shock mitigates. Additionally, the government can strengthen the economy by providing farmers with incentives for agricultural production, such as fertilizers or new technology.

Over the past decade, a notable increase in food prices has become a prominent topic in both political and economic discussions in Ethiopia. To address this, Ethiopia's Central Bank has devalued the ETB as a strategy to stabilize food prices, adjust the gap between the official exchange rate and the black exchange rate, and improve trade balance. Kayamo (2021) studied the effectiveness of this approach. The research delves into the impact of the real exchange rate on prices during the period from 1982 to 2019. The author argues that globalization and trade openness have made the exchange rate an important economic variable that determines the country’s economic performance. Fluctuation of the exchange rate directly affects production, consumer prices, exports, and imports. The study reveals that the real exchange rate has effects on prices in the short and long run. In particular, imbalances in the real exchange rate, whether due to depreciation or appreciation, can contribute to

higher food prices in the short term and long term. The analysis shows that in the short run, depreciations reduce high food prices and appreciations trigger price hikes. However, in the long run, the fluctuations of the exchange rate are the most triggering to Ethiopia's increasing food prices.

In a recent study, Ndikumana et al. (2022) empirically investigated the factors contributing to increasing food prices in Ethiopia between 1998 and 2020. The study examines the driving factors of inflation in the country, using four key measures; cereals, food, nonfood, and CPI inflation. While Durevall et al. (2013) identified imbalances in the monetary, cereal, and food sectors as having long-term effects on inflation, Ndikumana et al. (2022) extended the exploration of the fiscal sector's role in inflation modeling. In the short term, prices are affected by structural factors such as cereal output gaps and demand-side factors including increasing money supply and public sector borrowing. Even when confined to the post-2005 high-growth period after the IMF program, these outcomes remain consistent.

3. Theoretical considerations

The Law of One Price (LOP) is one of the key principles of economic theory. Ironically, As Miljkovic (1999) phrased it "Although it is a law, it has probably been violated more than any other economic law (on the results of numerous empirical studies)". However, the violations are not due to the failure of the theory, because LOP holds perfectly given assumptions. The theory's assumptions fall short of empirical evidence, leaving substantial uncertainty as to whether LOP holds or not.

In its simplest form, LOP states that identical goods, without transportation costs, should be sold at the same price in perfectly competitive markets across different countries when expressed in the same currency. Applied to cereal prices, LOP theoretically suggests that cereals should exhibit similar prices worldwide when expressed in the same currency, assuming free trade and the absence of transportation costs. However, in practice, various factors can contribute to deviations from LOP, especially in the case of a developing country like Ethiopia (Krugman, Obstfeld & Melit, 2012).

Put simply, LOP implies a link between the prices of goods and exchange rates (Krugman, Obstfeld & Melit, 2012). If P is domestic (Ethiopian) prices and PW is international prices which, in this thesis, will refer to the world market price index of cereals. E is the ETB/USD exchange rate.

$$P = E \times PW \quad (1)$$

The prices of identical or similar commodities traded in geographically separated markets tend to display similar movements and long-term trends, primarily influenced by international arbitrage (Mainardi, 2001). Arbitrage refers to the practice of buying goods from a low-cost location and selling them in a market where they hold a higher value, which would create a profit. The limits of arbitrage can be observed in reality, where arbitrage is conducted by a relatively small number of actors. Nevertheless, in perfect markets, arbitrage opportunities

are negligible, indicating that LOP holds. Transaction costs and arbitrage boundaries can hinder the smooth and linear establishment of long-term equilibrium relationships. If transportation costs exist, the prices are expected to differ by the expense of relocating the product from a low-priced location to a high-priced one. Empirically, LOP may face violations in the short run when transportation costs are not perfectly aligned, as noted by Clements et al. (2019). However, Mainardi (2001) argues the prices will move towards the long-term equilibrium as the price disparities can be partly mitigated through international trade.

If transportation costs get expensive because of longer travel to the commodity markets, farmers might trade at other markets. The increased expense of transportation costs can incentivize trade at black markets close by rather than official markets further away (Engel & Rogers, 2001). In the work of Engel and Rogers (1996), it was observed that borders influence official markets, emphasizing the significance of geographic considerations. It's essential to note the distinction between trade at black markets and official markets in this context.

When applying the framework of LOP, multiple factors may contribute to deviations from the ideal scenario where identical goods should be priced the same globally. For instance, Ethiopia, like most other countries, has frequently throughout the last 25 years used export bans as trade barriers (Ndikumana et al. 2022), disrupting a free market and hindering prices to be equalized. The concept of LOP, assuming free trade, faces challenges where trade restrictions disrupt the market equilibrium because trade, whether it involves importing or exporting, plays a crucial role in reducing the chances of arbitrage opportunities in the market (Krugman, Obstfeld & Melit, 2012).

When a country imposes an export ban on a specific good, it can lead to a shortage of supply in the global market, which can cause prices to rise in other markets. This can lead to a divergence in prices across different markets, potentially affecting the extent to which the

LOP holds. For instance, a study by Wibowo et al. (2023) analyzed the Indonesian government's decision to ban crude palm oil exports in April 2022 due to a scarcity of cooking oil in the domestic market that led to a shortage of crude palm oil supply in the global market. The outcome was a minimal increase in global palm oil prices and a sharp decline in global prices after the export ban policy was lifted.

Furthermore, the impact of export bans on LOP can also depend on the type of goods being exported and the degree of market integration. For instance, an export ban on a substitute good may have a more influential impact on LOP than an export ban on a less substitutable good (Wibowo et al. 2023).

If the government of firms yields significant market power, they may be able to set prices above competitive levels, leading to price disparities across markets. Government market power, when used through regulations, subsidies, or trade policies, can impact prices and the equalization of prices across different markets. Biswas et al. (2015) provided an example illustrating how government market power, when misapplied, can deviate from the LOP, citing the case during Yingluck Shinawatra's administration in Thailand.

In 2011, Shinawatra's strategy involved buying rice from Thai farmers at inflated prices, storing the rice to reduce global supply (thereby driving up global prices), and later selling the rice at a higher price. The intended goal was to boost the domestic price of rice and support Thai farmers. While Thailand may have been the largest rice exporter, controlling 30% of the market, they were not the only producer of rice. India and Vietnam increased their rice production at the time and filled the supply gap left by Thailand. Consequently, this resulted in Thailand storing 17.5 million metric tons of overpriced rice with diminishing quality, which they could not sell. The policy was strongly criticized for its negative impact on the Thai economy and the global rice market, as well as for its potential violation of World Trade Organization rules. Ultimately, the policy was abandoned in 2014 after causing significant losses to the Thai government and farmers.

Subsidies play an important role in shaping the dynamics of the LOP, influencing prices across diverse markets. Notably, agrochemical subsidies, such as those for fertilizers, can act as equalizers to adjusting the prices of agricultural products and providing adequate compensation for farmers. Nevertheless, subsidies can also serve consumer welfare if they are used as an instrument to mitigate prices, for instance, food stamps (Agra, 2019; Fuje, 2019).

Yet, this positive outcome may carry potential downsides. For instance, when consumers are incentivized to buy subsidized goods, it can lead to disparities in prices across markets which will complicate whether LOP holds. As the subsidies may lower prices for consumers, a trade-off between urban consumers and rural farmers appears. As subsidies lower prices for consumers, a trade-off emerges between urban consumers and rural farmers. If the subsidies are unevenly distributed, a “winners and losers” scenario unfolds. Urban consumers will gain from price decreases, but rural farmers will lose profit from their goods (Fuje, 2019).

This trade-off is also evident in the context of export bans. While urban households may benefit from export bans, rural households face lower prices, resulting in an overall net loss at the economy-wide level. The governments must balance between benefits for urban consumers and losses for rural households when making policy decisions (AGRA, 2019).

Indeed, in the context of discussing LOP in terms of cereal prices, it's crucial to consider the seasonal nature of cereal harvests. Cereal crops are typically harvested once a year, and the success of these harvests significantly influences prices. Depending on how good these crops are, the supply will differ. A bumper harvest, or bumper crop[1], tends to increase the supply and lower the prices while a bad harvest will be vice versa. It is important to note that what constitutes a good harvest in Ethiopia does not equal a good harvest in Ukraine. These disparities in harvest conditions can contribute to deviations between domestic prices and

[1] An unusually productive harvest.

international prices, violating the principle of LOP (Abbott & Battisti, 2011; Krugman, Obstfeld & Melit, 2012).

4. The Data

In this study, time series data is used to analyze the relationship between domestic prices and international prices, focusing on cereal price changes over time. The data covers the period between January 1998 and December 2022. The sources the data is taken from are officially recognized database sources such as governmental publications and international financial institutions. The choice of working with a large dataset consisting of 25 years of period lies behind the necessity of avoiding temporal bias, which occurs when the dataset is small or covers a short period of time. Another error that is taken into account to avoid is the measurement error, this type of error would be present when there are inaccuracies in how the data is collected or recorded, for that reason, it is crucial to modify and adjust the data before the analysis study part. More details of minimizing the risk of measurement bias are revealed in the next sections.

The data presented in the next two sections are in the index form. Indexes are used instead of prices since this study uses a basket of goods (cereals) rather than individual goods such as wheat. The international prices are analyzed by different countries, meaning that there is not only one price. Indexes provide standardized and simplified price levels that are comparable throughout different time periods and even in different markets, making it important for the aim of studying the relationships and economic trends among the domestic and global prices used in this study. To put it differently, this approach helps in understanding the relative price changes rather than the absolute values. Since the national average is of interest, the Consumer Price Index (CPI) is used.

4.1 Ethiopian CPI of Cereals

CPI measures the average change in prices paid by consumers over time. This study requires the Ethiopian CPI of cereals to understand the impact of the world market price of cereals on the Ethiopian prices of cereals. By analyzing this data, we can gain a better understanding of how changes in cereal prices affect the cost of buying cereals for consumers. This index

contains several types of cereals including; teff, rice, wheat, barley, sorghum, and maize (Central Statistical Agency, 2018; Ethiopian Statistical Service, 2023).

We used the data for the cereals CPI from the government agency of Ethiopia's website. The data was collected from 119 marketplaces and includes twelve general indexes of both food and non-food items. Cereals are one of the eleven food classes in the food CPI, which we will be using in our report (Central Statistical Agency, 2018; Ethiopian Statistical Service, 2023).

The data was manually filled in from the monthly CPI reports since not all data existed in one survey study ready to download. Some of the data had the base year of 2006, while others had the base year of 2011 and 2016. Having different base years results in inaccurate and inconsistent comparisons of prices over time, therefore, a transformation of the data was required in Excel to resolve this issue.

Besides the different base years, this study faced another challenge when gathering the data. Until 2016, the Central Statistical Agency (CSA) measured the Ethiopian CPI of cereals in their reports. After 2016, CSA changed the index to “Bread and Cereals”. Even if the main ingredient in bread is cereal, the addition of bread to the price index, of course, carries some weight. However, CSA (2018) emphasizes that selecting a representative basket of goods and services is crucial in constructing CPI and has carefully made the choice to include bread due to its small weight. With the support of CSA, we argue that the addition of bread should not result in a measurement error (Central Statistical Agency, 2018; Ethiopian Statistical Service, 2023).

4.2 World Market Price Index of Cereals

Since our interest is examining if there is any relationship between the domestic and the international price indexes, data on the world market prices of cereal is needed. The

international prices provided in this data are the primary input of the production of the cereals, which helps in tracking the changes in the cereal's prices, specifically in the world market. In other words, the changes in the international price index of cereals help in discovering if there is a link between international cereal prices and domestic Ethiopian cereal prices.

The data used in this study has been sourced from The World Bank Commodity Price data (2023). The dataset contains various monthly indexes of both food and non-food series, one of which is the cereal price index that has been specifically used in this study. The cereals series consists of nine types of cereal indexes; barely, maize, sorghum, rice (Thai 5%), rice (Thai 25%), rice (Thai A.1), rice (Vietnamese 5%), wheat (US SRW), and wheat (US HRW). Note that teff is not included in the World Bank's index of cereals as it is a locally grown cereal primarily used in Ethiopia.

As the reports are already fixed to be downloaded, there was no option to choose the base year or the currency of the values. The data found reflects the values with the base year of 2010 based on nominal USD, it is adjusted to have the base year of January 1998 in this study, as well as it will be presented in the domestic currency of ETB to ensure that the data is comparable over time.

4.3 Exchange rates

The third type of data that is used along with the Ethiopian prices of cereal and the world market prices of cereals is the currency exchange rate of the ETB against the USD. The data is extracted from the Food and Agriculture Organization of the United Nations website, which we argue to be not questionable, but trustworthy (FAO, 2023).

Another reason for the importance of having the exchange rate a part of the data is that the cereal market is global. Countries trade cereals internationally, and fluctuations in exchange rates can affect the domestic currency's inflation or deflation. This can influence the production costs of cereal, which can, in turn, impact the prices of cereals for consumers and their purchasing power.

For the 25 years we are examining, the ETB per USD data will, like the other two variables of data used, be adjusted to have a base year of January 1998. The value of the ETB has lost more than 6,5 times its value in the past 25 years relative to the USD value, on average, the ETB value has decreased against the USD by 31.12% each year between 1998 and 2022.

5. Empirical framework

In this section, we will describe the approach to analyze the relationship between the world market prices and the Ethiopian cereal prices along with the effect international prices have on domestic prices. Our methodology combines a descriptive analysis with a cointegration analysis based on a model of LOP.

5.1 Descriptive analysis

The first part of our analysis describes the period of our data, 1998-2022. To receive a clearer perspective of how international cereal prices might have affected Ethiopian cereal prices this approach was chosen. A descriptive analysis in economics does not directly prove if there is a relationship between domestic and international cereal prices. However, with this descriptive analysis (Science, 2023), we aim to showcase the objective outline of our data and provide some empirical explanations of economic events and policies affecting food prices in Ethiopia.

Descriptive analysis is an instrument for identifying patterns and trends in data, addressing questions about who, where, when, and to what extent. When identifying economic events, a descriptive analysis can also point toward causal understanding and to the mechanisms behind causal relationships. No matter how significant the findings of a study may be, they will only contribute to knowledge and practice if others read and understand the conclusions. As the goal of the descriptive analysis is to help the readers better identify and understand important trends in the data, visualization in the form of graphs can be utilized. Graphs should present all necessary content to meet the audience's information needs and be self-contained (Loeb et al. 2017).

5.2 Cointegration analysis

Starting with some background; Cointegration is a concept used in time series analysis to study the relationships between two or more non-stationary time series. If two or more time

series are cointegrated, it suggests a long-term relationship (Johansen, 1991). We have chosen the method to analyze the relationship between the Ethiopian cereal price index and the international price index of cereals because it measures a long-term relationship.

Harris (1995) explains the economic interpretation of cointegration that if two or more series are establishing a long-term relationship, even if the series themselves contain stochastic trends (i.e. they are non-stationary), they will closely move together over time, and the difference between them will be stable (i.e. stationary[2]). Stochastic trends refer to the long-term behavior of a time series that is not deterministic but rather random or unpredictable. Stochastic trends can arise due to changes in long-run factors such as technological improvements and various economic shocks which can have a significant impact on economic fluctuations. A specific form of a stochastic trend is the random walk where future values of a variable are inherently unpredictable, following a sequence of random steps (King et al., 1987).

The Engle and Granger test is chosen to be performed in this thesis to investigate if there is a long-term relationship between the domestic cereal price index in Ethiopia and the world market price index of cereals. Also called the three-step procedure, the Engle and Granger test, is a commonly used method for detecting cointegration between two or more time series. As we can understand by the name, it involves three main steps. First, the Dickey-Fuller (D-F) test is implemented to test the variables of Ethiopian cereal prices and world market prices of cereals in ETB. The D-F test is a statistical test used to determine whether a time series data set is stationary. The main objective is to evaluate whether unit roots are present in a time series, potentially indicating non-stationarity; I(1). If the time series are non-stationary, then one continues with a statistical OLS regression, and lastly tests the residuals for a long-run relationship between the variables. If the residuals are stationary; I(0), the time series is implied to be cointegrated (Engle & Granger, 1987).

[2] Stationary data has a constant mean and variance over time.

Harris (1995) suggests the easiest way of the D-F test involves estimating the equations below. The variables included are the first difference series at time t presents as ΔY, the intercept as α, the coefficient of the lagged level of the series Y_{t-1} as γ, the deterministic time trend as $ß_t$, and the error term as ε_t.

Test for a unit root with constant:

$$\Delta Y = \alpha + \gamma Y_{t-1} + \varepsilon_t \quad (2)$$

Or with a unit root with constant and deterministic time trend:

$$\Delta Y = \alpha + ß_t + \gamma Y_{t-1} + \varepsilon_t \quad (3)$$

The null hypothesis for the D-F test states that a unit root is present in the time series, implying that the series is non-stationary. To test the null hypothesis, the p-value and the T-statistics are compared against the significance levels of 1%, 5%, and 10% and their critical values. If the data does not provide enough evidence to conclude that the time series is stationary, then the null hypothesis cannot be rejected. In the case of non-stationarity, the resulting statistic does not adhere to a standard t-distribution but, rather, a D-F distribution (Harris, 1995).

After the D-F test, a simple OLS regression is estimated. To test if there is a long-term relationship between world market prices of cereals and domestic prices of cereals we later used the basic LOP equation.

Focusing on the process of the cointegration analysis, as explained earlier in the theory section, LOP may not align well with empirical applications. To test if LOP holds, we need a more advanced model. The model is used to statistically test whether there is a relationship between world market prices of cereals and domestic prices in Ethiopia, initially using a simple logarithmic expression and later refining it to address observed deviations. The equation is consequently presented as:

$$ln\,P = \alpha + \beta\, ln(\,E \cdot PW\,) + \varepsilon \quad (4)$$

Rewritten to:

$$p = \alpha + \beta\,(\,e \cdot pw\,) + \varepsilon \quad (5)$$

Where lowercase letters are used instead of the natural logarithms (*ln*). In the equation, p is the log of the cereal price index in Ethiopia, e is the log of the ETB/USD exchange rate, pw is the log of the world market price index of cereals, and ε is the residuals. Natural logarithms are used to capture the percentage changes in the price index rather than the absolute changes, to simplify the analysis. The ln transformation can also help stabilize the variance of the errors in the data to reduce heteroscedasticity and can mitigate the impact of extreme values or outliers. The dependent variable in this case is p, and the independent variable is $(\,e \cdot pw\,)$.

Moving to the third part of the Engle and Granger test, after regressing y on x using the OLS regression model, we tested for the presence of stationary errors in the residuals of that relationship using D-F test (Ari, 2021). If y and x are both *I*(1) (non-stationary) and ε is *I*(0) (stationary), Engle and Granger define this cointegration of order *CI*(1,1) (Harris, 1995).

In simpler terms, we tested if the residuals were stationary. If ε is stationary, one can conclude cointegration and indicate that LOP holds. The assessment of cointegration serves as an indicator of whether LOP holds in the context of the specified variables.

When the long-term cointegration is confirmed, it is possible to incorporate the short-term dynamics and adjust for any deviations from the long-term equilibrium by using the error correction mechanism (ECM) (Engle & Granger, 1987). As presented in the formula below, the first differenced value of p is denoted as Δp_t, the first differenced values of p and

$(e \cdot pw)$ at lags 1 to 4 are donated as Δp_{t-n} and $\Delta(e \cdot pw)_{t-n}$, the coefficients that measure the impact of each lagged term are donated as a and β, the error term is ε_t. and the error correction term (ECT) presents the cointegrated residuals in long-term lagged by one period while γ indicating the speed of the adjustments. A way to conclude this model is to test the statistical significance by comparing if the p-values are less than the significance values;

$$\Delta p_t = \alpha + a_1 \Delta p_{t-1} + a_2 \Delta p_{t-2} + a_3 \Delta p_{t-3} + a_4 \Delta p_{t-4} + \beta_1 \Delta(e \cdot pw)_{t-1}$$

$$+ \beta_2 \Delta(e \cdot pw)_{t-2} + \beta_3 \Delta(e \cdot pw)_{t-3} + \beta_4 \Delta(e \cdot pw)_{t-4} + \gamma\, ECT_{t-1} + \varepsilon_t \qquad (6)$$

6. Results

In this section, we will analyze the empirical events that caused fluctuations in prices and explore the mechanisms causing both deviations from LOP and the mechanism for LOP to hold. Furthermore, a cointegration analysis will be performed to investigate a positive relationship between domestic and world market prices.

6.1 Descriptive analysis

The purpose of this study is to empirically investigate if there is a long-term relationship between domestic and international prices, as well as to understand if the international markets affect the domestic cereal market.

Figure 1 shows our data from the period 1998 to 2022, displaying the logarithms of the cereal index in Ethiopia, the ETB/USD exchange rate, as well as the world market prices of cereals in USD. Even if we can see some periods where domestic and world market prices deviate from each other, the overall trend indicates a positive relationship between the prices.

Unlike the other graphs, Figure 1 illustrates the ETB/USD exchange rate. Figure 1 displays an increase in the exchange rate during 2008-2011, indicating a devaluation of the ETB. More exactly, in September 2010, the ETB was devalued by 16% against the USD to enhance trade and competitiveness (Durevall & Sjö, 2012). After increasing steadily, around 2017 another devaluation happened. However, this study do not further analyze why the government of Ethiopia devalued the ETB, just mentioning that it can enhance trade and impact arbitrage opportunities.

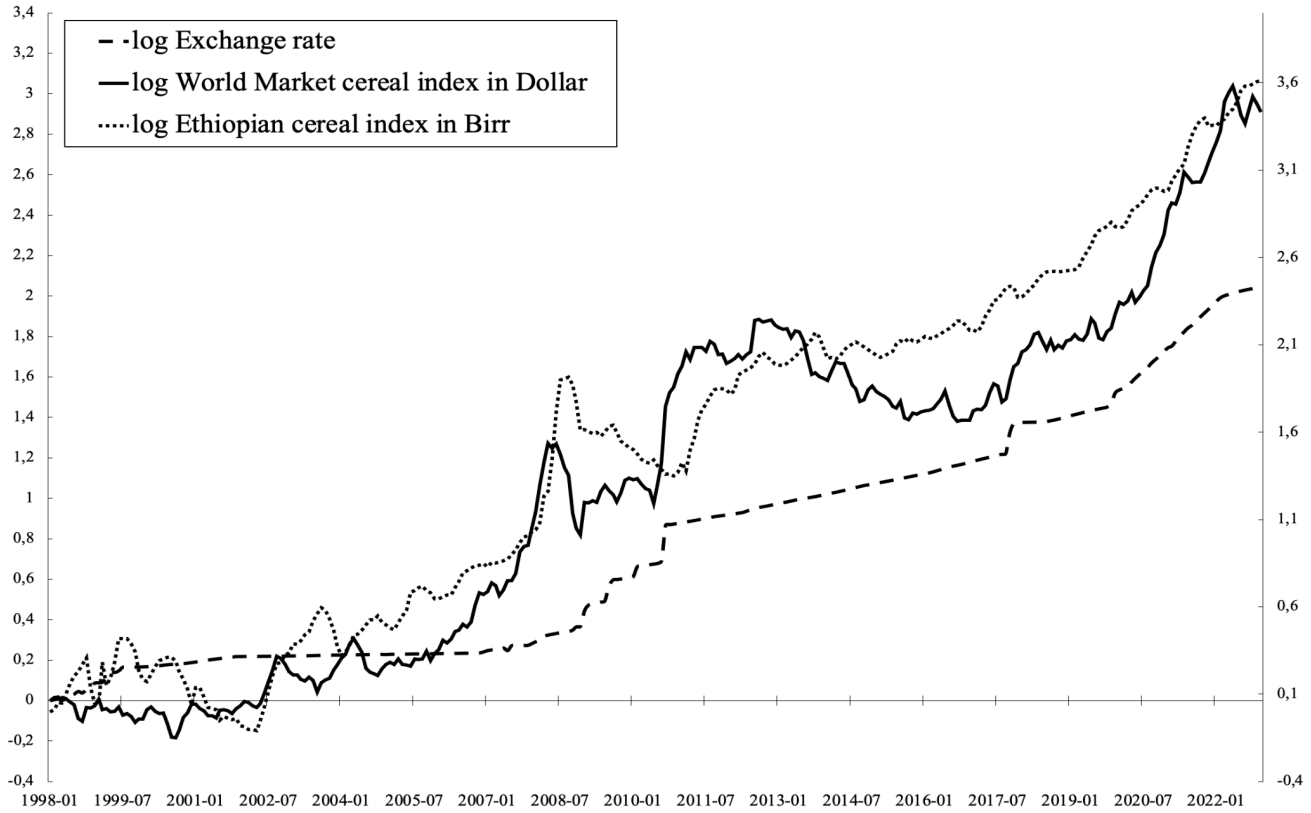

Fig. 1. Cereal Index Comparison in Ethiopia and the world market. The x-axis shows the monthly periods between January 1998 and December 2022. Furthermore, the y-axis shows the logarithmic indexes.

Between 1998 and 2008, the Ethiopian cereal prices and the world market prices of cereals periodically moved with similar trends as presented in Figure 2. Durevall et al (2013) provide some key explanations as to why this happened from 2000-2010. Moving forward, a report by Rashid and Negassa (2011) explains that the government, at the end of the 1990s, focused on price stabilization and supporting food security to support the citizens and mitigate food prices. Price stabilization policies used to mitigate food prices will cause domestic prices to differ from the world market prices.

During 2000-2002, Ethiopia received bumper crops, initially leading to a decrease in cereal prices, especially for maize, which decreased by 80% in early 2002. In response, the government purchased maize to support farmers. However, the situation turned around in

mid-2002 due to droughts, resulting in lower cereal production and a food security crisis. The poor crops suggested a decrease in supply and consequently an increase in prices. As Figure 2 shows, the domestic and international prices moved with similar trends around 2002 which can be explained by Ethiopia importing more after the poor bumper crop around that time (Abbott & Battisti, 2011).

Between 2005 and 2008, the Ethiopian Grain Trade Enterprise faced a different challenge. Despite good harvests, cereal prices increased rapidly from late 2005 due to high inflation rates. For instance, in 2008 inflation reached close to 40 % in Ethiopia due to several factors such as increasing money supply and rising world commodity prices (IMF, 2020). The price hike resulted in a decline in the national cereal reserves, reducing the subsidies for poor households (Fuje, 2019; Rashid & Negassa, 2011).

In 2008, there was a visual hike in the domestic prices of cereal in Figure 2. The price increase was mainly fueled by the global food crisis in 2007-2008. The Ethiopian government responded to mitigate the increasing prices through various policy measures, including an export ban on cereals, removing VAT taxes on cereals, and price controls such as price ceilings (Admassie, 2013). These government-initiated policies, exerting market power, resulted in a deviation of domestic prices from international prices, as presented in Figure 2. Furthermore, in 2008 a ban on maize export was implemented, however, it was later lifted in 2014. According to USDA (2022), Ethiopia has historically applied de facto bans on cereal exports to ‘stabilize domestic cereal prices, which indicates deviations between domestic and world market prices, enabling arbitrage.

One perspective suggests that due to the private sector, the government, and donors, there have been imbalances in the cereal market during 2000-2010. The actors were responsive to fluctuations in harvests, by adjusting the levels of cereal export and import, as well as providing food aid. This strategic approach aimed to constrain the influence of local supply shocks on domestic food prices (Durevall et al. 2013).

Geographic considerations and transportation costs play a significant role in understanding the variations in cereal prices in Ethiopia. The country's geographical location, coupled with potentially expensive transportation costs can contribute to disparities in cereal prices. Even if cereals are identical, the expenses associated with moving them within the country or exporting them may introduce pricing differences among them. However, if transportation costs are constant and if LOP holds, there should be no difference in the index. Therefore, the indexes should be equalized when comparing them without transportation costs (AGRA, 2019; Engel & Rogers, 2001).

Ethiopia, with its nine official states, experiences differences in prices among them (AGRA, 2019; Engel & Rogers, 2001). Some of these states face increased transportation costs due to longer travel to the commodity markets, which can incentivize trade at black markets close by rather than official markets further away (Engel & Rogers, 2001). Furthermore, Durevall et al. (2013) also recognized the unofficial trade with neighboring countries. Although there is no official information regarding the size of the unofficial trade, it is important to highlight that it might affect prices. If the neighboring countries unofficially trade cereals with each other, the prices will consequently be similar. The unofficial trade can be seen as an additional explanation as to why the domestic cereal prices during 1998-2008 moved with a similar trend as the world prices, indicating fewer arbitrage opportunities.

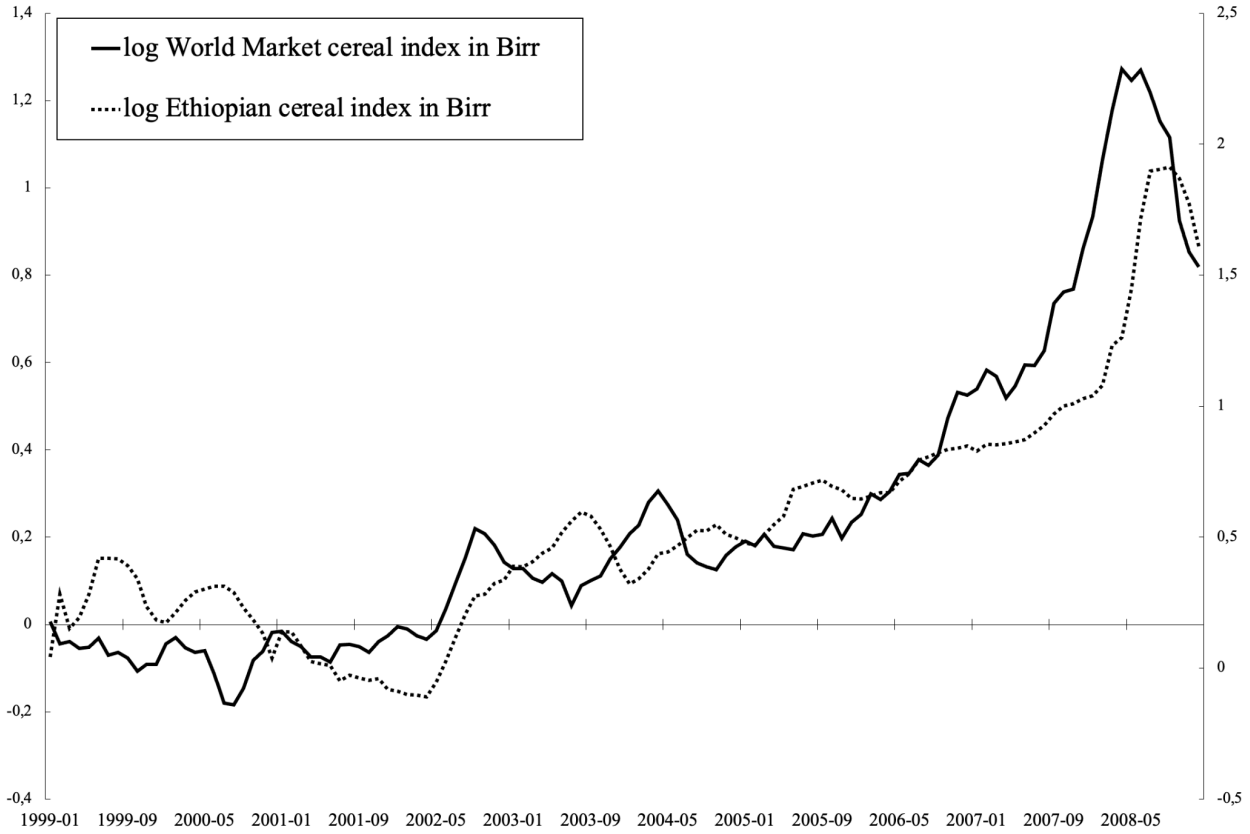

Fig. 2. Cereal Price Index Comparison from January 1998 to December 2008. The x-axis shows the monthly periods between 1998 and 2022. The y-axis shows the logarithmic indexes.

As illustrated in Figure 3, following the global food crisis, both the Ethiopian and the world market prices decreased in 2009, indicating that the arbitrage opportunities were reduced. The decline in Ethiopian prices was a result of bumper crops in 2009. However, by the end of 2010, prices started to rise again, making the Ethiopian government implement food price stabilization such as price ceilings and export restrictions (Admassie, 2013).

The global food price increase from 2010 to 2011 was triggered by several factors similar to the ones that started the 2007-2008 global food crisis. Contributing factors to the crisis included shifts in dietary patterns in developing countries, increased ethanol production, restricted expansion of agricultural land, weather conditions, exchange rate fluctuations, rising oil prices, and the Arab Spring (Coulibaly, 2013). Due to the global food crisis,

Ethiopia imported more cereals in 2012, accounting for almost 18 times more than the prior year, indicating more trade and less arbitrage (TrendEconomy, 2023).

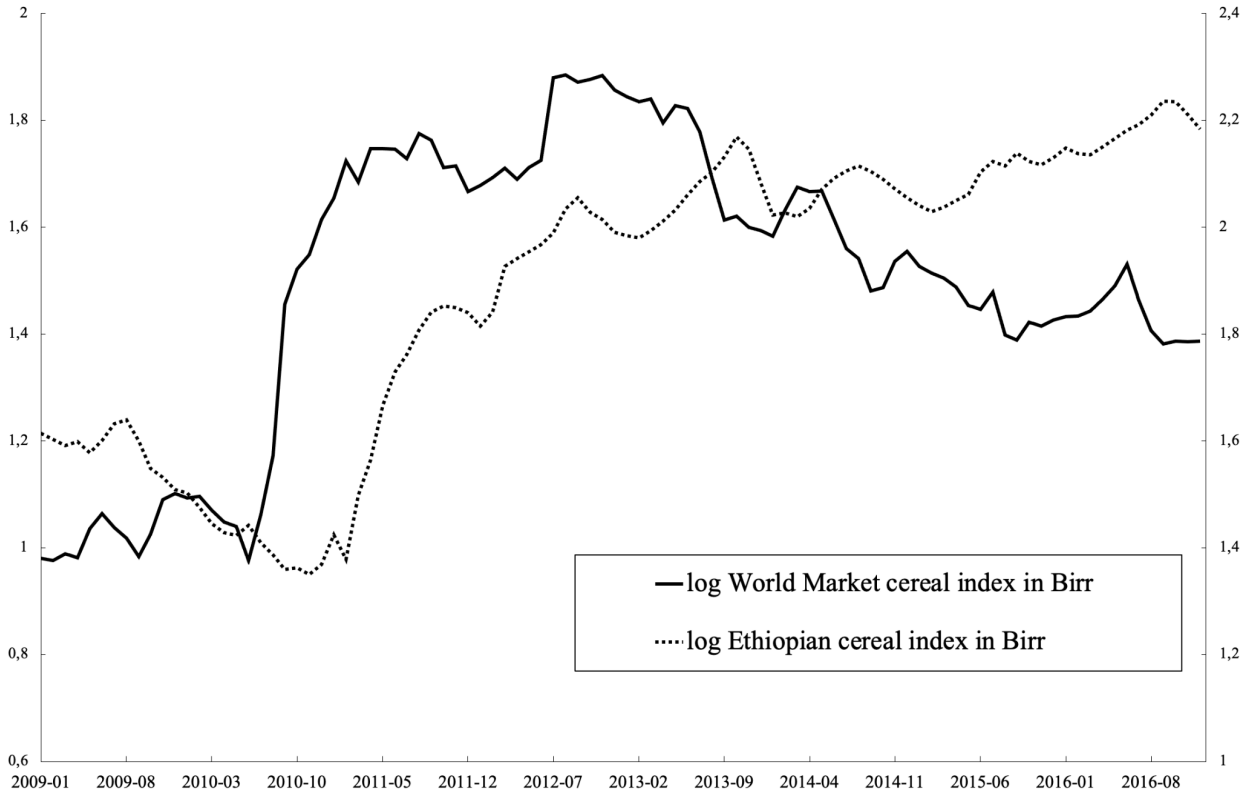

Fig. 3. Cereal Price Index Comparison from January 2009 to December 2016. The x-axis shows the monthly periods between 1998 and 2022. The y-axis shows the logarithmic indexes.

Ethiopia has a history of severe droughts that have significantly impacted cereal output. Following the bumper crops in 2009, droughts affected the cereal output negatively in 2012 (Ndikumana et al. 2022). The occurrence of El Niño since 2015 has further intensified the impact of droughts on crops. The droughts have led to reduced cereal output and a loss of income in the rural parts of the country. As the supply decreased, the prices increased, indicating deviations between domestic and world market prices. In an attempt to mitigate the expensive cereal prices, the Ministry of Trade and Industry announced a temporary export ban in 2013 on some agricultural commodities, including cereals (AGRA, 2019). Despite the struggles Ethiopia faced with droughts, the rest of the world had better crop yields, leading to

a decrease in international prices, however, domestic prices remained high (UN, 2014). Figure 3 indicates that the bans did not have a direct decreasing effect on domestic prices, however, there might be an indirect effect mitigating the increase. Even though the international price index declined after 2013, the prices of cereal in Ethiopia continued to increase.

Figure 4 illustrates that between 2017 and 2022, the domestic cereal price index in Ethiopia and the world market price index of cereals moved in a similar fashion, indicating fewer arbitrage opportunities. It is reasonable for the similar movement to reoccur, after years of trade restrictions, because the Ethiopian government implemented “Homegrown Economic Reform” in 2018. The reform aimed to increase the government’s efficiency and liberalize the economy (Ayele & Raga, 2023). The LOP, as presented in the theory section, holds under the assumption of perfect competitive markets. By liberalizing the country’s economy and dropping export bans, Figure 4 indicates visually that LOP holds. Furthermore, Ethiopia recently entered the World Trade Organization's (WTO) agreement Continental Free Trade Area (AfCFTA) to boost intra-Africa trade (Ayela & Raga, 2023).

In 2020, Ethiopia was classified at high risk of debt distress by the IMF and the World Bank. As a response, the government of Ethiopia shifted its aim to enhance export performance, intending to generate foreign currencies (Ayele & Raga, 2023). As a result, Ethiopia increased its cereal exports by almost 300% in 2020 compared to 2019. Not only did the cereal export increase, the import of cereals went from around $255,000 in 2019 to around $3,342,000 in 2020 to around $4,942,000 in 2022 (TrendEconomy, 2023). The increased trade reduces the arbitrage opportunities, shown in Figure 4, where the prices move with similar trends.

In recent times, Ethiopia has faced new challenges arising from both domestic and external shocks. The global economy felt the impact of the COVID-19 pandemic, leading to inflation in 2020. In 2022 Russia invaded Ukraine, consequently impacting the cereal prices, both

domestically and internationally. The droughts and the conflict in Tigray have also affected Ethiopia's economy (Ayele & Raga, 2023). As Figure 4 illustrates, both Ethiopian cereal prices and world market prices have experienced a gradual increase during the last couple of years and moved with similar trends, indicating a minimal chance for arbitrage.

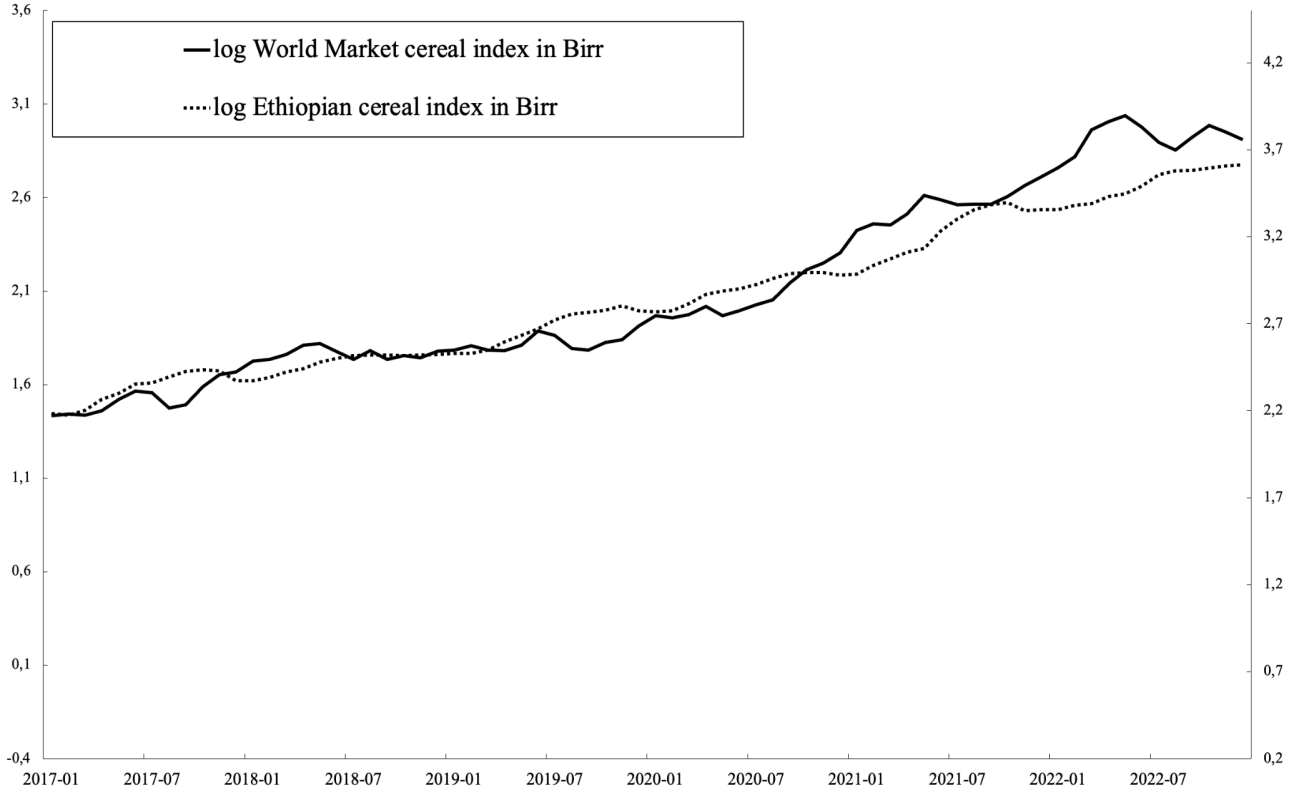

Fig. 4. Cereal Price Index Comparison from January 2017 to December 2022. The x-axis shows the monthly periods between 1998 and 2022. The y-axis shows the logarithmic indexes.

6.2 Cointegration analysis

The analysis starts by testing if the time series of p and $(e \cdot pw)$ are non-stationary. Using the D-F test, the optimal number of lags used for testing the time series data is determined by looking at the lowest value of the Akaike Information Criterion (AIC) is 6 lags for p and 10 lags for $(e \cdot pw)$. AIC is a measure used for model selection in statistics, as it balances simplicity and fits as well as prevents overfitting. When testing variables with and without

trends, analyzing test statistics, critical values, and p-values for different numbers of lags can help to conclude (Bevans, 2023).

Table 1 presents the implementation of the D-F tests on p and $(e \cdot pw)$ for the time series of January 1998 until December 2022. It can be concluded from these four tests that the time series of the variables p and $(e \cdot pw)$ time series are non-stationary; I(0), this decision is based on comparing the values of the test statistics and the p-values with the critical values and the significance levels.

As seen in Table 1, the test statistics values are higher than the critical values and the p-value of each variable is larger than the significance levels. That indicates, examining the long-term period of 25 years by testing with D-F with and without trend while using six lags for p and ten lags for $(e \cdot pw)$, there is sufficient proof to conclude that neither p nor $(e \cdot pw)$ is stationary, and the null hypothesis cannot be rejected for both variables. In other words, the variables do not have a constant mean nor variance over time and there are unit roots present in the time series.

Table 1: D-F tests on time series.

Variable	Lags	Trend	Test Statistics	P-value	Critical values			Stationarity	Integration Order
					1%	5%	10%		
p	6	With	-2.288	0.4407	-3.988	-3.428	-3.130	Non - Stationary	I(1)
p	6	Without	0.918	0.9933	-3.457	-2.878	-2.570	Non - Stationary	I(1)
$(e \cdot pw)$	10	With	-2.018	0.5918	-3.988	-3.428	-3.130	Non - Stationary	I(1)
$(e \cdot pw)$	10	Without	0.270	0.9759	-3.457	-2.878	-2.570	Non - Stationary	I(1)

The second step of the Engel and Granger model is to run an OLS regression, and subsequently test the residuals by implementing the D-F test without intercept or trend, displayed in Figure 5. However, it is important to examine the results of the test on the residuals before analyzing the OLS model result. This helps to avoid the issue of spurious regression, where the time series may seem to be related to each other, indicating that the variables are statistically significant when they may not be. For this reason, testing and confirming that the residuals are stationary implies that the relationship between the time series is not spurious.

The residuals graph as shown in Figure 5 suggests that the model is performing well over the 25 years of interest. The horizontal line in the middle at zero shows the equilibrium point where the domestic Ethiopian cereal prices align with the international cereal prices. The residuals are fluctuating above and below the horozontal line indicating oscillation of the positive and negative values of the residuals. Since the fluctuations visually do not present a clear long-term movement in the graph, there are no non-stationary issues in the model, as well as suggesting that the mean of the residuals over time is consistent.

The results of the D-F test on residuals are presented in Table 2. The t-statistics are compared to the outcomes of the three critical values to assess the stationarity of the residuals. In the test, twelve lags are used, just like in the previous D-F tests. The number of lags is determined by the AIC. As shown in Table 2, the t-statistics are more negative, which indicates that the null hypothesis of the presence of a unit root is rejected. The result confirms that the residuals are stationary; I(0), then it is verified that there is a long-term cointegration. The residual can be rewritten, using the OLS model from equation (5), as follows:

$$p - \alpha - \beta\,(e \cdot pw) = \varepsilon \qquad (7)$$

Table 2: D-F test for residuals.

Residual Integration	Lags	Test Statistics	Critical values			Stationarity	Integration Order
			1%	5%	10%		
Residual	12	-2.954	-2.580	-1.950	-1.620	Stationary	I(0)

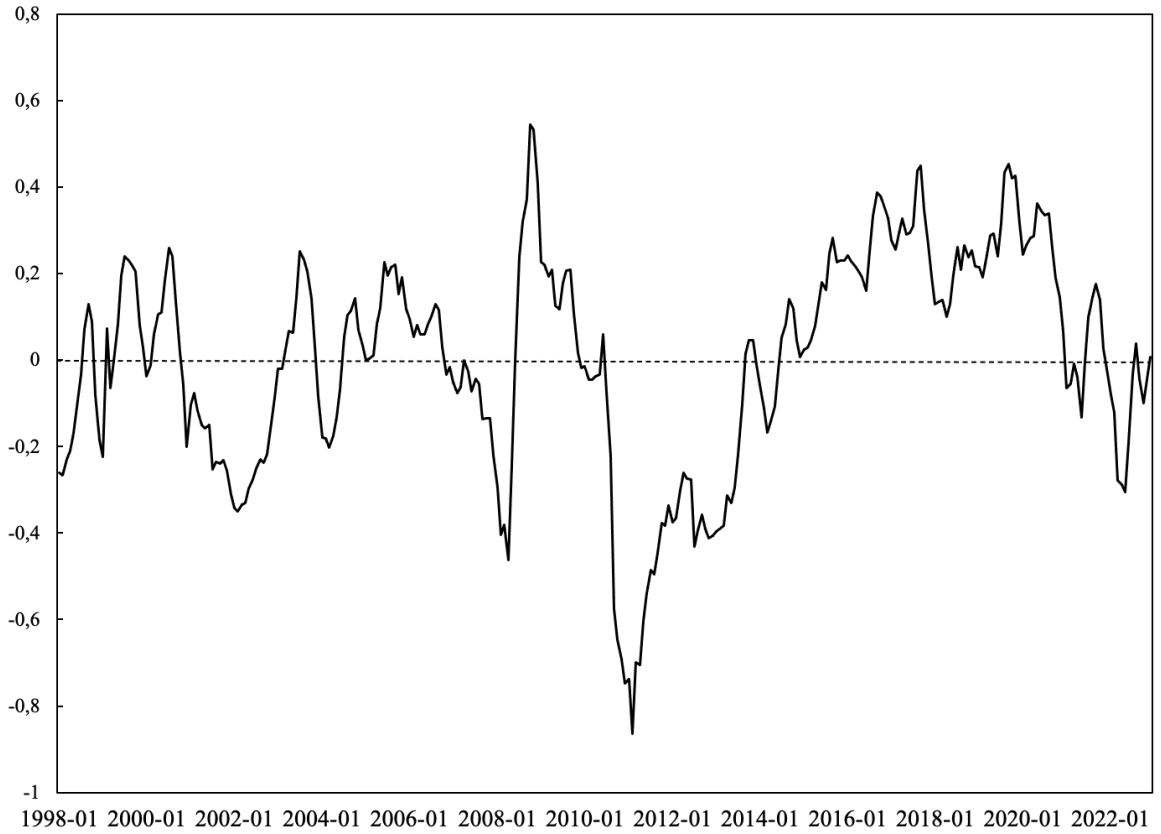

Fig. 5. Residuals of *p* and *(e· pw)* during 1998-2022.

Referring to the second step previously mentioned, the OLS regression model is carried out as displayed in Table 3, which is used to direct the attention to two main elements of interest; the R^2-value, which indicates how well the variance of the *p* is explained by $(e \cdot pw)$ and the coefficient value, which is interpreted after confirming the stationarity of the residuals.

As seen in Table 3, the R^2 value of 0.9405 reflects the variation of the cereal prices in Ethiopia is 94.05% explained by the model. This very high of R^2 value in the OLS regression suggests a strong relationship between the variables in the model. In addition, the coefficient $(e \cdot pw)$ is 1.1502, suggesting a positive relationship between the Ethiopian cereal prices and the world market prices of cereals in ETB. An increase of 1% in the world market prices of cereals in ETB tends to increase Ethiopian cereal prices by about 1.1502%, meaning a 1% decrease in the world market prices causes a decrease in Ethiopian cereal prices by about 1.1502%.

In order for LOP to hold, the coefficient should be equal to one in the long term. The most suitable approach to test LOP is to conduct a D-F test on a new time series equivalent to the differentiation between the Ethiopian cereal prices and the world market prices shown in equation (8). Table 4 shows the results of the D-F test with and without trend for eleven lags determined by the AIC. It can be concluded that testing with trend, the null hypothesis of a unit root can be rejected at the significance level of 5% and 10%. The test indicates that the new time series of the differentiated variables may be stationary. Despite the coefficient being higher than one, the deviation from value one vanishes with the trend.

$$p - (e \cdot pw) \tag{8}$$

Table 3: OLS Regression Results.

p	**Coefficient**	**T-statistic**
Constant	0.2599964	11.13
$(e \cdot pw)$	1.15021	68.66
Model Summary		
R^2	0.9405	
Number of Observations	300	

Table 4: D-F tests on $p - (e \cdot pw)$.

Variable	Lags	Trend	Test Statistics	P-value	Critical values			Stationarity	Integration Order
					1%	5%	10%		
p - (e·pw)	11	With	-3.461	0.0438	-3.988	-3.428	-3.130	Stationary	I(0)
p - (e·pw)	11	Without	-2.526	0.1092	-3.457	-2.878	-2.570	Non - Stationary	I(1)

The ECM displayed in Table 5 provides details about the relationship between each of the differentiated values of both p and $(e \cdot pw)$ denoted as *D.p* and *D.*$(e \cdot pw)$ at different lags (L_n) and the differentiated p variable. The model examines the effect of global cereal prices on Ethiopian cereal prices by analyzing the coefficients' size, while the number of lags signifies short-term effects. For instance, the coefficients of D.$(e \cdot pw)$ at lags one, three, and four are 0.1079, 0.1167, and 0.1489 indicating a positive relationship with *D.p* representing a significant short-term effect at a specific point in time.

The correlation coefficient of ECT is -0.0279. This indicates that the variables are being adjusted towards long-term equilibrium for maintaining a stable relationship. Explaining this further, any deviations in the long-term are fixed with approximately 2.97% of the deviation in each period, that being said, it also indicates the speed of 2.97% per period for the variables to be adjusted back to equilibrium after a short-term shock. Moreover, the significant value of ECT validates the cointegration between Ethiopian cereal prices and the world market prices of cereals, along with the statistically significant model based on the F-value of 13.28, indicating that EMC is stationary.

Table 5: ECM.

D.p	**Coefficient**	**Standard Error**	**t-Statistic**	**P-value**
D.p				
L_1	0.3327	0.0571	5.82	0.000
L_2	0.0685	0.0598	1.15	0.253
L_3	-0.0712	0.0598	-1.19	0.235
L_4	0.1017	0.0557	1.83	0.069
D.$(e \cdot pw)$				
L_1	0.1079	0.0542	1.99	0.048
L_2	-0.0105	0.0576	-0.18	0.856
L_3	0.1167	0.0576	2.03	0.044
L_4	0.1489	0.0562	2.65	0.008
ECT	-0.0279	0.0101	-2.76	0.006
Constant	0.0032	0.0026	1.23	0.220
Model Summary				
R^2	0.2954			
F-value	13.28			
Number of Observations	295			

7. Concluding remarks

Food prices are a global concern all over the world. However, in some parts of the world increasing food prices harm more than others. Poor developing countries like Ethiopia are more sensitive to price hikes than others, due to the majority of the household income being spent on food. Ensuring food security for the population is crucial, however, there is a trade-off between price stabilization for the urban population and the rural farmers. Price controls to decrease prices for the urban population will decrease the profit of cereal output for the farmers. By increasing international trade, domestic prices will follow the global market prices which have been shown to increase.

The first years of our analysis were characterized by bumper crops decreasing domestic cereal prices, although, the 2008 global food crisis led to an increase in both domestic and international prices. However, government interventions mitigated the impact on domestic prices.

In the second part of our analysis, domestic prices differed from international prices due to stricter trade policies, indicating more arbitrage opportunities. However, from 2017 to 2022 Ethiopia faced a war in Tigray, the COVID-19 pandemic, and a global shortage of cereals due to Russia's invasion of Ukraine. Meanwhile, the Ethiopian government joined free trade agreements increasing exports, indicating fewer arbitrage opportunities.

In conclusion, using the Engle and Granger model, we have been able to show that even though the time series might not appear to be related over short periods due to their non-stationarity, there is a stable relationship in the long term. The result goes along with the descriptive analysis and the expectations regarding the theory of the LOP. Prices should be equalized to reduce arbitrage opportunities in the long run. Consistent with the findings of Durevall et al. (2013), we have shown a positive relationship between Ethiopian cereal prices and the world market prices of cereals in ETB.

While our study identified a long-term relationship between the Ethiopian and world market price indexes of cereals, indicating that LOP holds in the long run, there remain several matters to study within this subject. Our analysis did not extensively explore the influence of the exchange rate on Ethiopian cereal prices, nor did we delve into the specific importance it might carry in shaping these prices. Neither did the analysis explore how fluctuations in other prices, both domestically and internationally, can generally impact cereal prices. These two matters will be interesting for future research.

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