MANUAL ON THE BASIC ANALYSIS OF AGRICULTURAL PRICES FOR DECISION-MAKING

OIMA/MIOA

ORGANIZACIÓN DE INFORMACIÓN DE MERCADOS DE LAS AMÉRICAS

MARKET INFORMATION ORGANIZATION OF THE AMERICAS

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Foreword

For the last fifteen years, national institutions involved in the management and operation of agricultural market information systems (MIS) have played a role, with varying impact, in the agricultural development of Latin America and the Caribbean (LAC). Their main tasks, which are to collect data and process and disseminate information, have served primarily as a catalyst for increasing agricultural productivity, but have also promoted the economic development of the countries through their respective productive sectors.

That same period saw the establishment of the Market Information Organization of the Americas (MIOA), a network conceived and supported from the outset by the Agricultural Marketing Service (AMS) of the U.S. Department of Agriculture (USDA). One of the main objectives of the AMS is to facilitate the efficient marketing of agricultural products in national and international markets, and it was this that prompted the network's creation.

The MIOA has also become an important network for cooperation on training, comprised as it is of government and government-linked institutions whose chief responsibilities or objectives are the compilation, processing and dissemination of data related to agricultural markets and products. The institutions that are currently members of the MIOA network represent 33 LAC countries.

As part of its constant efforts aimed at innovation and the continuous improvement of processes, the Market Information Organization of the Americas (MIOA) is pleased to announce the publication of the "Manual on the Basic Analysis of Agricultural Prices for Decision-making" and make it available to its member countries. Its aim in doing so is to update and enhance the knowledge and technical expertise of officials responsible for operating trade information systems, to enable them to more effectively influence decisions taken by different market players and thereby make agricultural business activities more transparent. The manual is also designed to permit university students from different disciplines to study the basic concepts and gain a better understanding of the tools available for the analysis of agricultural prices, learn more about how markets function, and be better equipped to interpret the transmission of prices between products and markets.

Throughout this manual, the MIOA presents and analyzes different instruments and techniques of analysis that make it possible to better appreciate and understand the structure, behavior and operation of markets, particularly agricultural ones. It also considers the factors that determine the supply and demand for goods, the formation of prices, especially prices linked to agricultural products, and the types of market structure that exist and their main implications for decision-making.

The reader will also find the sources that explain price variations and learn about the concepts of trend, cycle, seasonality and volatility that apply to all time series, the basic techniques used to decompose and analyze these components separately, and their principal uses and/or practical applications. Finally, users of this manual will be able to recognize and understand some basic tools for conducting technical analyses of prices, and gain a grasp of the origin and importance of bilateral and multilateral trade in agricultural products, having studied the main variables that have to be taken into account to better understand the links between the prices of agricultural products, as well as the level of integration of different markets.

In the particular case of this manual, an effort has been made at the end of each chapter to show the practical applications and immediate uses of the information that will enable readers to perform their daily tasks better once they become familiar with the technical material presented in the document.

Acronyms

LAC	Latin America and the Caribbean
AMS	Agricultural Marketing Service
AR	Autoregressive Model
ARIMA	Autoregressive Integrated Moving Average Model
ECLAC	Economic Commission for Latin America and the Caribbean
CNP	National Production Council of Costa Rica
CWT	Hundredweight or centum weight
USA	United States of America
FAO	United Nations Food and Agriculture Organization
GATT	General Agreement on Tariffs and Trade
GIEWS	Global Information and Early Warning System
RSI	Relative Strength Index
IICA	Inter-American Institute for Cooperation on Agriculture
INCOTERMS	International Commercial Terms
INEGI	National Institute of Statistics and Geography of Mexico
CPI	Consumer Price Index
MAD	Median Absolute Deviation
MAPE	Mean Absolute Percentage Error
OLS	Ordinary Least Squares
MINAGRI	Ministry of Agriculture of Argentina
OCDE	Organization for Economic Co-operation and Development
MIOA	Market Information Organization of the Americas
DPO	Detrended Price Oscillator

MA	Moving Average
CMA	Centered Moving Average
SAGARPA	Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food of Mexico
SIAP	Agricultural and Fisheries Information Service of Mexico
MIS	Agricultural Market Information System
TS	Tracking Signal
TEU	Twenty-foot Equivalent Unit
USD	United States dollar
WTO	World Trade Organization

Table of Contents

List of Tables

List of Figures

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In order to identify, define, and design the technical content for each chapter in the manual, a workshop was held in July 2017 at IICA Headquarters where a number of experts and institutions contributed their guidance, knowledge, and professional experience. The group of experts included Joaquin Arias, Specialist in Sectoral Analysis and Public Policies; Hugo Chavarria, Specialist in Sectoral Analysis; Guillermo Zuñiga, Specialist in Agricultural Business and Value Chains; Eugenia Salazar, Specialist in Sectoral Analysis; Ana Bustamante, Specialist in Virtual Learning Environments; Helena Ramirez, Coordinator of the MIOA program; Edgar Cruz, Specialist in Trade and Markets; and all personnel of the Inter-American Institute for Cooperation Agriculture (IICA). Additionally, a number of university professors and researchers provided their expertise for this manual: Govind Seepersad of the University of the West Indies in Trinidad and Tobago; Prakash Ragbir, Manager of Information and Communication Technology at the National Agricultural Marketing and Development Corporation (NAMDEVCO); Wolfgang Baudino Pejuan Ucles of the Zamorano University in Honduras; Roger Castellon of EARTH University in Costa Rica; Anabel Then of ISA University in the Dominican Republic; Joao Gomes Martines of the Luiz de Queiroz College of Agriculture (ESALQ) in Brazil; and Victor Rodriguez Lizano and Mercedes Montero Vega, both from the University of Costa Rica.

Most of the technical content of this manual was developed based on the extensive work conducted by IICA's Center for Strategic Analysis for Agriculture (CAESPA) in this area at the hemispheric level, as part of its commitment to capacity building. The material was thoroughly examined during the workshop and later facilitated by Joaquin Arias and Hugo Chavarria for this initiative.

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CHAPTER 1

Introduction to price analysis in agriculture

Introduction

The years 2005 to 2008 were witness to one of the biggest across-the-board increases in food prices in modern history. The price of maize more than doubled due to growing demand for biofuels, as maize is the main input used to produce ethanol in the United States. Burgeoning demand for food in emerging countries with large populations also sparked a trend toward higher maize prices (ECLAC/FAO/IICA 2012).

Furthermore, the price of wheat rose strongly during the same period, by an average rate of 28.6% per year, driven by growing demand. Some of the peaks in wheat prices were also due to lower production in Russia, Ukraine and the United States, mainly for weather-related reasons. This, in turn, resulted in unusually low inventories, largely accounting for the excessive volatility of prices during the period.

Global rice prices also increased, at an average rate of 17.5% per year. In this case, the rise was mainly due to smaller harvests in the world's principal rice producing countries in the 2006-2007 farming year, especially in the United States, where some farmers switched to producing maize, coupled with steady growth in the demand for imports among the Asian countries, particularly Indonesia. The implementation of specific policies by countries in the region, such as Guyana's restriction on exports, led to a reduction in global rice supplies that also contributed to the price increases.

Other events occurred that depressed food prices, however. For example, the World Bank reported that global food prices fell 14% between August 2014 and May 2015, to a five-year low. One of the main reasons for this decline was lower oil prices, which cut the cost of transportation and agrichemicals, impacting the cost structure of producers and, as a result, wholesale and retail prices (World Bank 2015).

The above examples demonstrate how prices respond to changes in economic variables and, in a simple way, how the two elements are interrelated. But, what factors determine the agricultural supply and demand? How does the market structure influence price setting? How do the basic relationships in an agricultural chain function? To answer these questions, the main objective of this chapter is to provide a holistic explanation of how prices are formed and how they serve as one of the main indicators of the operation of a market or economy.

The price of a product is affected by countless factors that are determined, to a greater or lesser degree, within the different segments of an agricultural chain. Cases will be cited throughout this chapter that demonstrate key concepts of price formation, in order to enable the reader to arrive at a better understanding of the cause and effect relationships between different variables and the price.

The chapter begins with an exploration of elements that influence price formation. Among other aspects, it describes how a price changes as its passes through the different links in the chain, and explains the concept of markup and its influence over the price observed. This is followed by an introduction to the concepts related to the formation of the prices of products traded internationally. This distinction is made given the particular complexity of price formation in the case of imported and exported products.

Three other aspects are then addressed. An analysis of the determinants of supply and demand is followed by examples of price setting under different market structures. The way in which prices vary in response to changes in their determinants is then explained, in order to introduce the concept of elasticity.

1.1 An initial overview of price formation

Thus far, the word "price" has been used in a general sense, without alluding to a specific link in the production chain. In fact, it is possible to identify various prices at different points in the chain. The mostly widely disseminated time series are those dealing with farm, wholesale and retail prices, so when speaking about prices it is important to consider the point in the chain involved. For example, in 2014 the farm price of limes in Mexico was 1.1 pesos but the end consumer price was 8 pesos per unit (Chavez 2014). The reason for this has to do with the concept of markup in agricultural chains. Middlemen purchase a product lower down the chain and resell it at a higher price further along. In the case of limes, the percentage of markup between the price paid to the producer and the price paid by the end consumer was 86% (Table 1.1).

Table 1.1. Lime prices and percentage of markup in pesos in Mexico.

Item	Value
Farm price (pesos per unit)	1,1
End consumer price (pesos per unit)	8
Percentage of markup on farm price	627%
Percentage of markup on end consumer price	86%

Source: prepared based on Chavez 2014.

It should be noted that the markup margin, in this case 6.9 pesos (8-1.1), does not represent the profit made by the intermediary, since transaction, costs are incurred when a product passes along the agricultural chain, from one link to another. The main expenses incurred by the intermediary are **transaction, transportation and refrigeration costs**.

Consider the following case, which highlights the importance of these costs in the formation of the final price of a product.

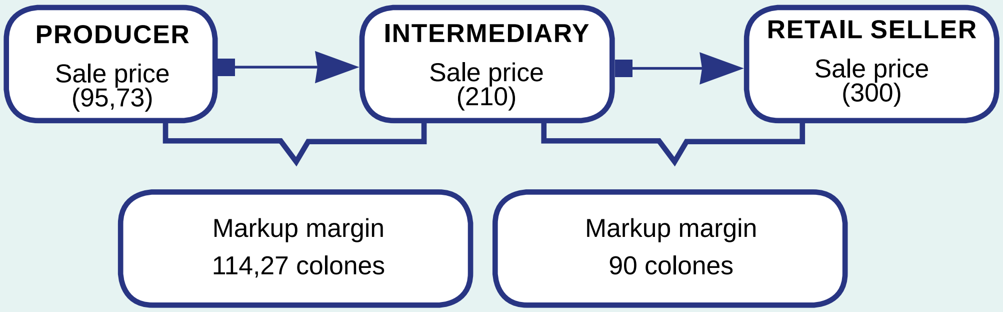
A case of domestic price formation in Costa Rica

In Zarcero, Costa Rica, a producer estimates that the cost of producing a bunch of cilantro is roughly 95.73 colones. To obtain a 25% return on her investment, she needs to sell each bunch for around 120 colones.

An intermediary pays the farmer 120 colones per bunch, but then incurs a series of costs, such as freight, travel, loading and unloading, and other expenses. If the intermediary aims to sell the bunches of cilantro to a retailer in the local markets held weekly, he will have to take into account the 120 colones paid for each bunch, plus markup costs and a percentage of profit. If the markup costs total 20 colones per bunch, the intermediary would so far have invested 140 colones per bunch of cilantro.

If the intermediary aims to make a 50% profit on his investment, he will sell each bunch to the retail seller for 210 colones (140 x 1.5). The retailer purchases each bunch of cilantro for 210 colones, but must factor in right of sale and other costs incurred in running a market pitch. Thus, the retail seller estimates his expenditure to be 20 colones per bunch of cilantro. If the retailer wishes to obtain a 30% return on his investment, he will need to sell each bunch of cilantro to the end consumer for roughly 300 colones (230 x 1.3).

A summary of the process is shown in the following diagram:



The above example provides a general explanation of price formation throughout a chain; however, there are distinctive features in the countries that also influence the price formation process throughout the chain. To gain a better understanding of this process, a study was carried out to examine the behavior of agricultural prices in Latin America, focusing on the price formation process of 54 agricultural products in 12 regions. The factors that have an important impact on prices were found to include the regions' agricultural structures, the conditions for accessing them, and the technologies used to grow crops.

One of the main conclusions of the study was that price formation depended intrinsically on the characteristics of the different regions and products. Broadly speaking, it is important to consider:

- farm structure
- the level of diversification of farm production and the existence of local markets
- domestic freight costs
- links with other regions
- access to information
- the prices of agricultural inputs (which account for 20%-60% of the total costs of the factors of production). However, these also depend on the prices of the technology available (IICA 2014).

Given the major differences that can exist among the aforementioned factors, it is necessary to conduct a specific analysis in each region, even within each country or territory. For example, a study of this kind carried out in Peru focused on three regions with three different types of territories (the coastal, highland and rainforest regions) and differences with regard to the use of technology, access to water, target markets and ease of transportation, factors that have a major impact on the selection of crops and the return on production. The data for the three regions gives an overview of the behavior of price formation in accordance with the characteristics of each one (Paz-Cafferata 2010).

The example cited above explains the price formation process of an item produced and sold within a country; however, Latin America and the Caribbean's agricultural balance of trade has historically been positive (a trade surplus), which means that, in economic terms, the region exports more than it imports.

Given the major contribution that the region makes to international agricultural trade, it is especially important to understand the price formation process of products that are traded internationally. The price at which an imported product is sold can be influenced by variables other than the ones that impact the price of a good produced and sold within the country, since the marketing chain tends to be less complex in local markets. International markets, on the other hand, involve a greater number of players, leading to higher costs when the payment of tariffs, licenses, permits, etc., has been factored in.

Some of the most important variables related to transportation that affect the price of an imported product are the following costs:

1. Freight
2. Insurance
3. Lost product
4. Storage
5. Import and export duties

For an in-depth analysis of these and other variables, and of the concept of Incoterms, see Frank (2006).

The following example shows some of the costs that have to be taken into account when an agricultural product is exported or imported, as they play a key role in the price formation of such products.

Price formation process in the case of imports

An exporter needs to ship a container full of agricultural product “X”, having agreed to deliver it on board a ship in the final port of destination. This means the exporter will have to defray the cost of road freight from the plant to the port of shipment, and then the cost of sea freight to the port of destination.

To calculate the costs of this operation, one of the first variables that must be taken into account is the distance, as well as the container’s size (20’ or 40’ – 1 or 2 TEU) and type (dry, refrigerated or frozen).

The following illustrative, but not exhaustive list, shows some of the pertinent costs:

The shipping and export and import costs would amount to USD 2150, broken down as follows:

- Road freight to port: 110
- Sea freight: 1120
- Documentation, destination 50
- Disembarkation, destination 150
- Documentation, place of origin 65
- Export from Veracruz (border/port compliance): 400
- Export documentation 60
- Importation into Acajutla (border/port compliance): 128
- Import documentation: 67

Assuming that roughly 1400 boxes fit into a container of this kind, the cost per box would be USD 1.54.

The above is an estimate of the real cost, calculated using the IDB’s transport cost estimator tool (IDB 2017). Numerous trade agreements between countries currently exist that establish tariff conditions for specific products, so this aspect must be taken into account within the price formation process of products traded on the international market.

As has been shown, the agriculture sector is highly complex and has prices that serve as market "thermometers," reflecting not only a product's relative abundance or scarcity, but also the trends in other variables. One thing that all the aforementioned variables have in common is that they affect the supply or the demand, either directly or indirectly. Therefore, the next step is to analyze the determinants of the supply and demand in an agricultural market, in order to gain a better understanding of price formation in agriculture.

1.2 Determinants of supply and demand

The price of an agricultural product is determined mainly by the interaction between the supply and the demand, which are influenced by a series of factors.

The determinants of the supply and demand for agricultural products that influence price behavior are analyzed in the following sections. For example, the agronomic requirements of some crops mean that they can only be harvested at certain times, so that supplies vary over the course of the year. These changes in the supply lead to variations in prices, which follow a similar pattern every year.

1.2.1 Price determinants of supply

In the case of the agriculture sector, the supply may include not only fresh produce and/ or processed products but also agricultural inputs and machinery, technical assistance, agricultural loans and land, and many other elements. Given the highly complex and wide-ranging nature of the subject, this section will only address the supply of fresh produce, under the premise that the main generator of the supply are producers and certain variables that they do not control but which directly affect their production decisions and yields. The following example is by way of an introduction to the concept of supply.

Understanding supply

In 2008, the six fruits that accounted for the lion's share of fruit production in the United States were, in descending order of importance, grapes (an estimated 22.3%), apples (14.0%), strawberries (11.3%), cherries (4.0%), cranberries (3.9%), peaches (3.3%) and pears (2.3%). It is worth noting that the above percentages can vary from year to year due to changes in market conditions. In 2006, the grape harvest declined by approximately 8.3%, due to adverse climatic conditions in California, which was one of the main reasons why prices were higher than in 2005. On the other hand, strawberry and cherry production increased during 2007, by 14.8% and 25.5% respectively. Weather patterns and changes in agricultural support policies have driven the increase in fruit production in Canada (24.6%) and the European Union (7.3%) over the last five years. An important point to bear in mind is that U.S. supplies of strawberries can no longer keep up with demand for the fruit in the winter months, due to labor costs.

Domestic production supplies the U.S. fresh strawberry market but, in addition to being the world's largest producer, the country is the leading consumer (more than one million tons per year). Most domestic supplies (nearly 90%) are produced in California. However, in Canada the supply of domestic strawberries is weaker, so that most of the fruit is imported.

The above data was taken from a SAGARPA study carried out in 2009 to garner information about the supply of fruit, especially strawberries, in the United States and Canada with a view to identifying market opportunities. As can be seen from this case study, domestic supplies of a product can be affected by the phenological state of plantations, climatic events, import and export levels, support policies, labor costs, the price of the product, and other variables that will be addressed in greater depth in this module.

Source: prepared based on SAGARPA 2009.

There is a direct causal relationship between the quantity of a product that is available and its price: the higher the price, the bigger the supply, as rising prices are an incentive for producers to sell more produce.

Unlike its industrial counterpart, agricultural production depends on the production cycles of plants and animals, which means that one of the biggest limitations to the supply of agricultural products is the availability of products for immediate marketing, since they may have been planted but are not ripe enough to be of interest to the market. More produce is available around harvest times and prices are usually low. On the other hand, when production is low, little product is available and prices are high. Unlike other sectors, the production cycle of crops is one of the determinants, since detailed planning is required to be able to supply a product on a specific date.

It is important to remember that agricultural products have different types of cycles and can be divided into:

1. Short-cycle crops
2. Semi-permanent crops
3. Perennial crops

Farmers who are familiar with the cycle of a given product will have access to information about harvest cycles and forecasts, and be able to:

- Program the marketing of agricultural products according to the demand
- Predict the qualities of an agricultural product
- Identify production areas
- Identify markets for each product

In addition to the cycle, several other factors affect the supply and, consequently, the price of a crop. The price of an agricultural product can therefore be expressed as a function of different variables:

$$P=f(Q,P_{inp},T,Cl,P_c,P_a,R,N,G,Exp)$$

Where:

P= price of the product

Q= quantity

P_{inp}**=** price of inputs (seeds, fertilizers, labor, etc.)

T= technology

Cl= climate, pests and diseases

P_c**=** price of products competing for the same resources

P_a**=** prices of associated crops

R= existing inventories, stocks, reserves

N= number of hectares (area) or production structure of crops

G= government policies (marketing, state intervention, plant health standards, legal problems with land tenure)

Exp= expectations and attitudes of producers

According to the law of supply, an increase in the **price** of an agricultural product results in an increase in the quantity supplied. When the price drops, the opposite occurs. This phenomenon is closely linked to **producers' expectations and attitudes.** For example, small-scale and low-income producers tend to be more risk averse, so they reduce or cease production when faced with a drop in prices or climate risks.

If the price of a product has been rising during recent production cycles, more producers are likely to produce that good, thus increasing the **number of hectares** planted with the crop and, as a result, the supply. In this regard, it should be borne in mind that failure to control the production of a good usually results in an oversupply, mainly during peak harvest times, which instead depresses prices.

A case in point was what occurred with sugarcane between 2011 and April 2013. During that period, sugar production responded to the stimulus of the good prices paid in previous years, resulting in significantly higher sugarcane harvests in key producer countries like

Brazil, Thailand, Australia and Mexico, and a global sugar surplus. Over that period, the price of sugar was 30.1% below the long-term trend, mainly because of the oversupply. China also reduced its overseas purchases of sugar due to larger domestic supplies, which shows how **stocks or inventories** also play an important role in price formation (IICA 2014).

Another price determinant is the technology available for production, as the higher the technological level, the more efficient the production system. Efficiency translates into the use of fewer inputs per unit. Thus, to a large extent, the agricultural supply depends on the **development and adoption of technolog**y.

In the case of Mexico, and the Puebla region specifically, the timely implementation of recommended technology made it possible to achieve experimental yields of up to five, seven and eight tons of maize per hectare (Aceves et al. 1993). However, the National Institute of Statistics and Geography reported that over the period 1993-2004, the yield was 2.6 tons per hectare (INEGI 2007), and 2.54 tons per hectare in 2008 (SIAP 2009). According to Osorio-García et al. (2012), the failure to adopt the technology generated was the main reason for this low productivity.

Climatological factors, pests and diseases determine the availability of the supply of agricultural products. For example, between 2011 and 2013 the international price of coffee rose by an average of 36%, due to outbreaks of rust in Central America, Colombia and Peru that reduced the supply and drove up the price. During the same period, the United States suffered the worst droughts in its history, resulting in higher international maize prices and a 30.6% deviation from the long-term trend (IICA 2014).

The **existence of other products that compete for the same resources** is another price determinant. It should be remembered that land, labor and capital are the principal factors of production. The supply of crop A in a given area can be affected by the introduction of another crop (B) that also requires labor, land or capital. Thus, the larger the number of hectares planted with crop B, the smaller the quantity of factors of production available for crop A, and the smaller the supply.

The way in which information about **the level of inventories** is managed can cause sharp changes in agricultural prices in the short term. One study carried out in the region suggests that incomplete information on the availability of inventories can trigger abrupt changes in prices, and also explains that good inventory management is regarded as part of risk management. Hence, price volatility is less of a problem in economies that have sound inventory management policies, and such countries are less vulnerable to the vagaries of the international market.

This shows how sensitive prices can be to inventory levels. It is also suggested that storable (non-perishable) products are subject to less price volatility than perishable ones whose inventories are kept to a minimum (ECLAC/FAO/IICA 2011).

Related concept: price elasticity of supply

As has been discussed in this section, there is an important relationship between the price and the quantity supplied of a good. It is due to the importance of this relationship that the concept of elasticity is introduced, which indicates the responsiveness of the quantity supplied to changes in prices. As is to be expected, higher prices stimulate production, which means that a positive relationship is maintained between the price and the quantity supplied. For example, if the elasticity of supply is 1.3, it means that if the price changes by one percent, the quantity supplied will change by 1.3%.

Another determinant of the supply of a product is **state intervention**. For example, in Costa Rica the price of rice is regulated throughout the chain. Such regulation makes for greater price stability, but the price of rice does not necessarily respond efficiently to scenarios in which production is small or input costs increase. This can be a disincentive for producers when they come to sell the product, since the price may not reflect the true cost of producing the rice or the true supply situation. For more in-depth information about the system used to regulate the price of rice in Costa Rica, see León-Sáenz and Arroyo-Blanco (2011).

Por último, es de importancia entender que existen factores que afectan el coFinally, it is important to bear in mind that there are factors that affect the behavior of prices in the short, medium and long run. This makes it easier to understand the behavior of prices, since it provides information that makes it possible to differentiate between temporary or short-term factors and structural ones, both of which affect the behavior of the price.

A short-term factor refers to the behavior of economic variables, given specific natural or market situations that arise and temporarily affect variations in the production and consumption of agricultural goods. (Salinas-Callejas 2016). Political decisions are usually a response to temporary situations, as in most cases they are designed to stabilize prices after an event of some kind has occurred. Examples of temporary situations are droughts or the appearance of a pest that causes major production losses.

Structural changes, on the other hand, explain the behavior of prices in the medium and long terms (the trend). For example, technological innovation, higher productivity, lower costs, variations in cultivated area and changes in the alternative uses of agricultural goods are some of the variables that can be classed as structural. This means they have a permanent effect on variations in the production and consumption of agricultural goods, as long as the conditions persist.

1.2.2 Price determinants of demand

Consumption decisions are influenced by a series of factors that are known as determinants of demand. Consumption patterns can vary depending on consumer tastes and preferences, product perishability, and the evolution of consumer income over time as it shapes consumption. It should be noted that these factors affect the demand, and also influence the price.

For example, there are documented accounts of vegetable growing and consumption dating back to 8000 B.C., when mainly peas, beans and lentils were consumed. While these crops continue to be key in combating malnutrition, reducing poverty and contributing to human health, the evolution of vegetables has been very different from the increase in the production and consumption of other crops such as maize, wheat and rice. Since the Green Revolution (around the 1960s), all these products have seen production increases of between 200% and 800%, while vegetable production has grown by only 59%. In this regard, production and consumption decisions are interconnected; producers grow crops for which they are certain there will be most demand, and it is in order to understand these consumption patterns that the determinants of demand are analyzed (FAO 2016).

Agricultural prices are influenced by variables that influence demand for the product. The main variables are shown below:

$$P=f(Q, I, TP, G, P_e, S_s, P_r)$$

Where:

P= price of the product

Q= quantity

I= income of consumers

TP= tastes and preferences of consumers

G= government policies (sales tax,subsidies)

P_e= perishability of the products

S_s= socioenvironmental specifications

P_r= prices of related (complementary and substitute) products

Both developed and developing countries continue to increase their consumption of maize, wheat, rice, dairy products and meat; however, no changes are foreseen in the pattern of vegetable consumption, which is expected to remain at 7 kg per person per year. This pattern is due to both **consumer tastes and preferences** and consumer income. It has been observed that as income rises, consumer diets change: the population consumes fewer plant proteins and more expensive proteins, such as dairy products and meat. Thus, the greater the purchasing power, the smaller the proportional consumption of vegetables (certain types of food replace others). Products of this kind, whose consumption decreases when **consumer income** increases, are known as inferior goods.

There is another type of product (e.g., organic and fresh products, products with fair trade seals or some other kind of guarantee) that offer consumers greater value added and, as such, reflect a positive relationship between consumption and consumer purchasing power. In the search for a healthier lifestyle, consumption of organic products has been increasing at around two to three percent worldwide. This leads to changes in production systems that are the result of pressure from consumers who have opted for foodstuffs that do not contain chemicals, contributing not only to human health but also to a reduction in agricultural production's impact on natural resources. For example, although no official figures on the performance of the country's organic market are available, the Organic Agriculture Group of Chile estimates that the domestic organic market generates around USD 35 million per year. It is a new market enjoying 20% annual growth, even though organic products usually cost about 25% more than products grown and harvested using conventional agricultural methods (USDA 2010).

Food consumption has increased across the globe as consumer incomes have risen more than prices. In regions with developing countries, food consumption has increased considerably, especially if there have been substantial increases in income. However, in Sub-Saharan Africa, higher agricultural prices meant that food consumption in 2012 was 11% lower than in 2000, despite a population increase of 38% over the same period (World Bank 2017). In both Europe and North America, on the other hand, food consumption has remained constant, because consumers with sustained high incomes are not going to increase their food consumption in the same proportion as changes in their income, since food is a basic need that is already covered (FAO 2012).

In the two cases mentioned above, the patterns of behavior of both vegetables and organic products reflect **tastes and preferences**, as well as **consumer incomes,** which are some of the price determinants.

As most agricultural products are perishable, they need to be bought and sold within a short period of time. Unlike other products, in most cases farmers and merchants cannot store them, especially if fresh produce is involved. **Consumer tastes and preferences** are one of the variables that must be considered when studying price formation. Although one refers to agricultural products in general, there are significant differences between fresh produce and storable products, which have a much longer shelf life.

One problem with vegetables, for example, is that they must be consumed within a very short period of time, as many are consumed fresh. As much as 45% of global fruit and vegetable production is wasted. Fruits and vegetables are the group of products with the highest wastage rate, and their short shelf life is the main reason (FAO 2012).

Products with a distinctive seal are a clear example of how the demand for products varies according to consumer tastes, preferences and income. In this regard, all quality seals, such as certifications of organic products like Fairtrade and Global Gap, are designed to demonstrate that products meet a series of specifications for which the consumer is willing to pay. This type of consumer is willing to pay a premium price to ensure that the products are of a higher quality or meet socioenvironmental specifications in the production systems within which they are produced. The quality of a product depends on the elements that are regarded as defining that quality. The market establishes quality based on the value that consumers assign to a product, linked to a set of properties or characteristics they rate or perceive as being superior to the other products in the market (Arvelo et al. 2016).

Like the organic products mentioned previously, the consumption of certified products has also been on the rise in recent years, reflecting the demand in some niche markets. Global consumption of Fairtrade certified coffee is a case in point. Six percent more volume was produced in 2013-2014, with the total reaching 150,800 metric tons (Fairtrade 2015). The production and marketing of certified cacao has also grown considerably, mainly due to the chocolate industry's responsiveness to the demands of consumers. In 2012, 150,000 tons of cacao were produced with the Fairtrade seal, 98,400 tons with the Rainforest Alliance label, 214,000 tons certified by the UTZ program and 45,000 tons with the organic seal (Arvelo et al. 2016). However, these consumption trends are heavily dependent on consumer incomes and, as already mentioned, on the market niches in which the product is sold.

Adopting a similar approach to the one employed for the section on supply, we shall now turn to the concept of elasticity of demand.

Concept of elasticity of demand:

Spending on food makes up only a small part of the total budget of high-income consumers, such as those in the OECD countries. As a result, consumers of this kind are relatively indifferent to even quite sharp fluctuations in agricultural prices. This relationship between the change in the quantity consumed and price swings is known as the **price elasticity of demand**.

In economic terms, this kind of consumer is more inelastic[1] with respect to prices than poor consumers living in developing countries, who purchase mostly basic foodstuffs with less value added. This means that the prices of basic agricultural products account for a bigger proportion of the final price they pay for food, and food is an important part of household expenditure (CFS 2011).

In addition to variations in prices, changes in income are another factor that may lead consumers to alter their consumption patterns. This relationship is known as **income elasticity of demand.** Consider the following example, which contains an analysis of changes in milk consumption in the Central American countries related to income and cheese prices.

[1]*Inelastic behavior is the term used to describe a situation in which the proportional change in income is bigger than the proportional change in food consumption.*

Price elasticity and income elasticity: cheese in Central America

In 2012, a study was conducted to analyze the behavior of fluid milk and cheese consumption in Central America, with a view to identifying the consequences of the entry into force of the Free Trade Agreement between Central America and the United States. Some of the results of this study are shown in the following table. With respect to price elasticity, it suggests that a one percent change in the price of cheese leads to a change in consumption of 0.212% in Costa Rica, -0.937% in El Salvador, 0.233% in Guatemala, 0.564% in Honduras and 0.591% in Nicaragua. Consumption falls as the price of cheese increases but the proportional change is less than one percent; because of this, cheese is regarded as an inelastic good.

Price elasticity is negative in all of the countries except Costa Rica, suggesting that as the prices of products rise, consumption will fall. The behavior with regard to income elasticity indicates that the higher the income, the greater the consumption

Variable	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua
Price elasticity	0,212	-0,937	-0,233	-0,564	-0,591
Income elasticity	0,150	1,204	0,309	0,715	0,417

The above table shows that El Salvador's elasticity is greater than that of the other countries: consumption declines by 0.937% in response to a one percent increase in the price, while the figure for Guatemala is only 0.233%. Analyzing the behavior of income elasticity, cheese consumption in El Salvador rises 1.204% in response to a one percent change in income, while in Costa Rica the figure would be only 0.15%.

The level of consumer income is one of the determinants of demand. In the case of foodstuffs, the higher the income level, the greater the inelasticity of demand, in terms of both price elasticity and income elasticity. For example, in the European Union the price elasticity of cheese is -0.18 and income elasticity is 0.03 (FAPRI 2017), which means that when there are changes in the price, consumption will remain much more constant than in Central America.

Estimating price elasticity and income elasticity is useful for predicting how a market is going to react to changes in these variables, thus making it possible to anticipate the socioeconomic changes that such variations in consumption can trigger.

Source: prepared based on Huang and Durón-Benítez 2015.

The diets of all human beings are formed of combinations of agricultural products; however, the combination of foodstuffs is linked to the prices of products, and to the other determinants of demand. As a result, the price of a product is also determined by the **prices of related products**, whether substitutes or complementary products. If two products complement one another, they are referred to as **complements**. In this case, if the price of one good increases, consumption of the other is going to fall, since they are consumed together.

If, on the other hand, two products are substitutable, they are known as **substitute products.** In this case, if the price of one good increases, an increase in the consumption of the other is to be expected, as consumers begin replacing one with the other. The concept of **cross elasticity** is used to analyze the relationship between related goods; that is, the behavior of consumption of one good (A) in response to changes in the price of another good (B).

Cross elasticity: substitute products and complements

Data on the consumption and prices of black tea and coffee in the United States was analyzed to determine the behavior of the consumption of both between 1990 and 2008. According to the price elasticity of tea, tea is an inelastic good, while coffee is elastic. This means that if prices begin to fall, coffee consumption is going to replace tea consumption. As coffee is a more elastic product, when prices fall there will be a bigger increase in the quantity demanded and, therefore, in consumption. Assuming that the size of the market remains constant, people are going to consume more coffee in place of tea.

Variable	Black tea	Coffee
Black tea	-0,393	0,125
Coffee	0,599	-1,022
Income elasticity	0,837	1,008

Source: adapted from FAO 2011.

In the case of complements, an analysis of consumption habits related to groups of products in Japan estimated that the cross elasticity between rice and oil is –0.228, meaning that when the price of one of these goods increases, consumption of the other decreases. This situation occurs because if the price increases and consumers eat less rice, consumption of the oils used to cook it also decreases (FAO 2003).

In the case of both the vegetables and organic products already mentioned, such movements in the demand curve cannot necessarily be adjusted by means of local production, since the rate of growth of the total population is greater than the rate of agricultural production. As a result, in many cases countries are forced to import these products, thereby increasing the volume of international agricultural trade. All these changes in consumption patterns are directly related to the price formation process of the agricultural products that are the main focus of study in this manual.

Another element that has a major impact on price formation is the structure of the market in which a good is traded. The various dimensions of this subject are worth analyzing separately, so the way in which market structures influence the formation of agricultural prices will be addressed in the next section.

1.3 Market structures and price formation

As explained in the previous section, the price formation process is influenced by a series of national and international variables. The latter include trade liberalization, the size of the economy, the degree of self-sufficiency and tariffs, quotas and other trade barriers. For example, the extent to which the domestic price of a product is influenced or determined by the international price is directly dependent on trade liberalization.

Market structures also influence price formation. Therefore, this section focuses on the influence of market structures in determining agricultural prices.

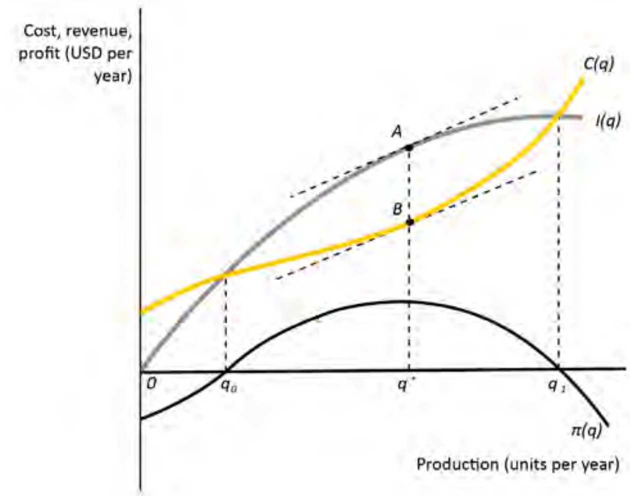
1.3.1 Perfect competition

A market is competitive when there are many buyers and many sellers, and the product traded is homogeneous. Precisely because firms have little market power, none of them can influence pricing on their own. Since one of the assumptions of perfect competition is product homogeneity, the differentiation of products is one of the reasons why conditions of perfect competition are rarely seen. Even in the case of the agriculture sector and fresh produce, certain differentiation exists in terms of quality. Markets fulfill most of the assumptions of perfect competition, however, as there are a large number of suppliers of fairly homogeneous products and both producers and consumers have access to price information.

Agricultural markets are designed to enable buyers to have direct contact with farmers, and are a commonly used mechanism for buying and selling, especially in the case of fresh produce. For example, agricultural and farmers' markets have long existed in Argentina but in the mid-1990s farmers engaged with rural development organizations in the province of Misiones to establish family farmers' markets, or ferias francas. A typical feria has an average of 12 pitches, with around 20 families involved. However, a very wide variety of products is sold and the number of pitches varies from 3 to 120, depending on the market concerned (Goldberg 2010).

In markets, all farmers try to maximize profits and this occurs when the difference between producers' revenue and costs is the maximum, as can be observed in the following figure (Figure 1.1). The maximum distance is observed when the distance between total income and total costs is the greatest; that is, the distance between A and B.

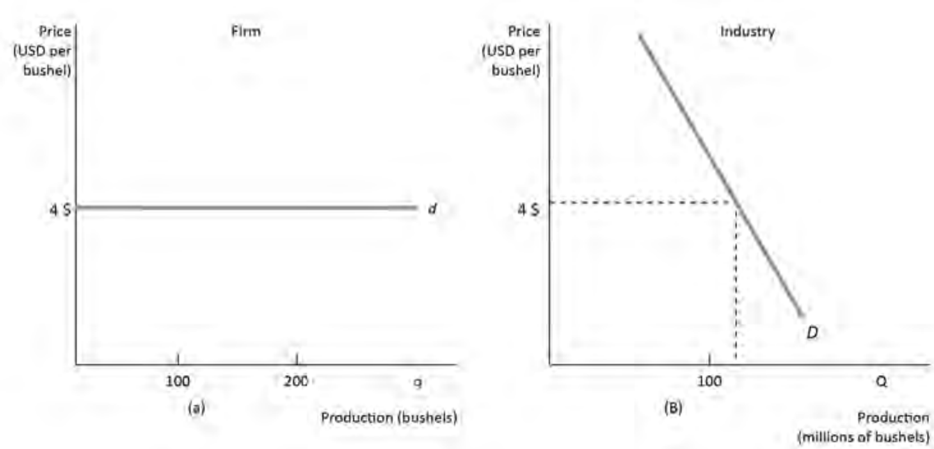
Figure 1.1. Cost, revenue and profit curve



Source: taken from Pindyck and Rubinfeld 2009.

However, in a market of this kind no single farmer can influence the demand curve or product pricing, since each one has a very small slice of the market. Therefore, they are all faced with a given price, in which the cost of producing an additional unit (marginal cost) is equal to the additional revenue per unit sold (marginal revenue) and to the product price, as can be observed in the next figure (Figure 1.2).

Figure 1.2. Demand curve of the farmer (a) and the market (b)



Source: taken from Pindyck and Rubinfeld 2009.

Therefore, under conditions of perfect competition, to avoid incurring losses farmers would have to sell their products at a price that ensures that at least the marginal cost is equal to sale price; i.e., that the cost of producing an additional unit is at least equal to the product's sale price. This means that producers produce and sell only if the sale price covers their costs and provides the expected profit. If, on the other hand, they incur a loss or their expectations are not met, they will not produce the same products during the next growing season and the total supply in the marketplace will decrease.

1.3.2 Imperfect competition

In an efficient market, all the economic agents affect price formation but none has the power to set prices on its own. However, if any kind of control over product prices exists, the market is said to be imperfect or not perfectly competitive. Market power affects the pricing process, because the bigger the firm, the more it can influence the market price. The bigger a firm is, the more it can take advantage of economies of scale and, as a result, reduce unit costs and offer a product at a lower price.

In Costa Rica, the leading producer of milk and dairy products is the Cooperativa de Productores de Leche Dos Pinos, RL, which has long dominated the domestic market. In 2016, this cooperative had an 89% share of the fluid milk and milk-based fluid products market. As a result, smaller dairy producers may be obliged to adopt the same retail prices as Dos Pinos; were they to charge a higher price, they would be squeezed out of the market. The cooperative has a vertically integrated business model, which allows it to achieve consolidated economies of scale (Euromonitor 2015).

There are many reasons for imperfect competition, but firms' power to set prices depends on the behavior of product elasticity and the number of firms in the marketplace and the relationship among them. A brief description of the price formation process and its characteristics in the case of both monopolies and oligopolies and monopolistic competition is provided below.

1.3.2.1 Monopoly

A monopoly is said to exist when a single firm accounts for all domestic production. The monopolist controls the market. The reasons for the existence of a monopoly include: a) legal barriers, such as a decision by a national government, or the existence of a patent whereby a single firm owns the intellectual property of a product, b) natural barriers: one firm owns all the natural capital of the inputs needed to produce a good; and c) the size of the investment required to enter the market is prohibitive, ruling out the entry of new competitors.

In the agriculture sector, as in other segments of the economy, providing an example of a monopoly is no easy matter, since most governments and the rules of international organizations promote competition. However, agrichemical patents can be considered a monopoly. If a firm designs and patents a new formula, no competitor can offer the same product, which means that a monopoly exists, at least as long as the patent lasts.

The characteristics of pricing in a competitive market is as follows: when firms raise the price of their products without product differentiation of any kind, they lose market share, since buyers are going to prefer to buy the same product from other firms that offer better prices. However, a monopolist can set higher prices than is possible in a competitive market because it is the sole supplier. The monopolist endeavors to maximize profits (revenue minus costs) by determining the quantity it can produce. For further details of pricing in a monopoly market, see Annex 1.

1.3.2.2 Oligopoly

A number of research projects have addressed in depth the question of market concentration in agrifood chains. However, the degree of market concentration also depends on the competitive context of the agricultural chain concerned and the influence of the international market on domestic economies. Several examples of the price formation process in Latin America are presented below, under different market structures and various levels of market concentration.

In Argentina, four firms control 68.6% of the oilseed industry; nonetheless, the global supply and demand are the main determinants of the domestic supply and demand (Baffes and Gardner 2003). This is the case because there are many independent oilseed buyers that farmers can use to access the international market. The commercial process is in the hands of large firms that process and export crude oil. Roughly 80% of Argentina's oil production is exported, and no oil is imported. There is little commercial competition in the domestic market, which can mean that consumers pay prices higher than the international ones (Petrecolla 2009).

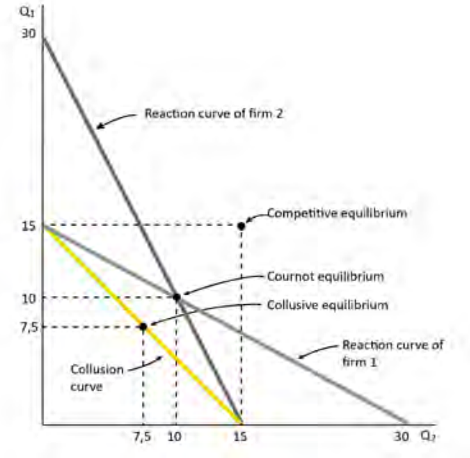
Despite the existence of a large number of producers, there is not usually strong competition for the purchase of fruit and vegetable harvests. A case in point is the citrus fruit industry in Sao Paulo, Brazil, where four processors account for 80% of production. In addition to processing operations, these firms have their own plantations, which means they are guaranteed a certain level of supply. Producers in the area sell almost all their production to these processors, but account for only 70% of the total supply, with the other 30% coming from the firms' own plantations (Petrecolla 2009). This situation means that the processors enjoy greater negotiating power with producers.

Hence, the price formation process is linked to the conditions of the industry, not the free market or international prices. If all these firms decide to pay the same prices to farmers, they can have both a positive and a negative impact on the way in which international prices influence domestic prices, since, in this case, the oligopoly's power means that the companies can set consumer prices higher than those that might apply if there were perfect competition.

The pricing process in an oligopoly depends on firms' strategic behavior. In an oligopoly, companies are bound to respond to their competitors' decisions, so the analysis of the oligopoly is linked to the non-cooperative strategic analysis. This means that, in part, firms base their production decisions on those of their competitors, because if oligopolies produce more than the market can buy, the supply overhang depresses prices, hitting firms' revenues.

Assuming that a good is homogenous, which is the case of most agricultural products (and of fresh produce, especially), and that firms decide how much to produce simultaneously, according to the **Cournot model** a company maximizes profits when the quantity produced by its rival does not change. Under the Cournot model, each firm regards its competitor's level of production as fixed when deciding how much it is going to produce. This means that the level of production that maximizes the profits of firm 1 is a decreasing function of the quantity that it thinks firm 2 will produce. This relationship between a firm's production level and the quantity it believes its competitor is going to produce is known as the reaction curve. Thus, each firm is going to produce the quantity indicated at the point where the reaction curves intersect (Figure 1.3).

Figure 1.3. Cournot equilibrium



Source: taken from Pindyck and Rubinfeld 2009.

If firms do not take their production decisions simultaneously, the firm that takes a decision first is regarded as the leader firm and the other as the follower. In this case, the **Stackelberg model** establishes that one of the firms decides how much to produce after observing the production level of its competitor.

The Cournot and Stackelberg models are alternative representations of oligopolistic behavior. The best one to use to analyze a given industry will depend on the characteristics of the industry concerned. If one firm has a great deal of market power, the Stackelberg model is the most appropriate, but if two firms have similar market power, the Cournot model is the most suitable.

Example: Cournot model

As previously mentioned, the milk market in Costa Rica behaves like an oligopoly. If firm 1 controls around 80% of the country's fluid milk, and the demand curve for the market is given by:

Q=100-0.75P, where the price is given in USD and the quantity in kg per capita per year.

The production costs are: $TC_1=80+5Q_1$ and $TC_2=100+10.2Q_2$

What quantity would be produced by firm 1 if both firms decide on the level of production at the same time?

The revenue of the leader firm would be given by: $R_1=P*Q_1$

$R_1=(133,33-1,33Q)*Q_1$

As in this case it is a question of a duopoly, $Q= Q_1+Q_2$

$R_1= (133,33-1,33Q)*Q_1$

$R_1= (133,33-1,33)*(Q_1+Q_2)*Q_1$

$R_1= 133,33Q_1-1,33Q_1^2-1,33Q_1 Q_2$

Assuming that *MgR=MgC* for the firms to maximize profits,

$Mg_1 R= Mg_1 C$

$133,33 - 2,67Q_1 - 1,33Q_2= 5$

$$Q_1= \frac{133,33 - 5 - 1,33Q_2}{2,67}$$

As the firms' level of production is based on what they estimate their competitors are going to produce, the quantity that Q_1 produces is linked to what Q_2 produces, and vice versa. These curves are known as **reaction curves**.

$Q_1 = 48,06 - 0,5Q_2$

Similarly, $Mg_2R = Mg_2C$

$133,33 - 1,33Q_1 - 2,67Q_2 = 10,2$

$$Q_2 = \frac{133,33-10,2-1,33Q_1}{2,67}$$

$Q_2 = 46,11-0,5Q_1$

$Q_1 = 48,06-0,5(46,11-0,5Q_1)$

$Q_1 = 33,34$ and $Q_2 = 29,44$

Example: Stackelberg model

If Company 1 is considered to be the market leader and is therefore the first to set its quantity produced, Company 2 sets its quantity after observing what Company 1 does. In this case, the leading company is always the one that produces the greatest quantity, as illustrated by the following example.

The leading company sets its production level based on what it believes Company 2 will produce; in other words, it takes into account the reaction curve of Company 2. Therefore, its income is determined by:

$$I_1 = 133,33Q_1 - Q_1^2 - 1,33Q_1\ (46,11 - 0,5Q_1)$$

$$I_1 = 71,9Q_1 - 0,665Q_1^2$$

$$IMg_1 = 71,9-1,33Q_1 = 5$$

$$Q_1 = 50,21 \text{ y } Q_2 = 21,18$$

It has been observed that both the Stackelberg and Cornout models are based on a firm's power when it operates in a market with little competition. As was explained at the beginning of this section, when there are many suppliers with a homogeneous product, none of them has sufficient market power to influence the price; conversely, the bigger a firm's market share, the greater its power. This means that market concentration is an important economic indicator that needs to be measured. **Market concentration** measures the power (or market share) of the leader firms of a given industry. This is one of the indicators that governments use to decide whether they should intervene to prevent the formation of monopolies by promoting competition. Some examples of market concentration in Brazil can be seen in Table 1.2, which shows the level of concentration of several agricultural inputs. These market concentration indexes can range between 0 and 100. For example, if a firm's market concentration is 0, it means there is no market concentration of any kind. If, on the other hand, a firm scores 100% it means that all production is in its hands.

Table 1.2. Market concentration of industries in Brazil

Market	Market concentration index*
Agrichemicals	89% (C2)
Agricultural machinery	94% (C4)
Seeds	78% (C4)
Fertilizers	60% (C4)

** C2 and C4 correspond to the concentration indexes of the market shares of 204 leader firms.*

Source: adapted from Petrecolla 2009.

As can be seen in the above table, the industry with the greatest market concentration is that of agricultural machinery, in which the four firms with the biggest market share account for 94% of the national industry. The most commonly used indicator is the **Herfindhal-Hirschman** index.

1.3.2.3 Monopolistic competition

Monopolistic competition occurs even when there are a large number of suppliers in the market, as limited product differentiation means that products do not compete directly for the same market. For example, the assortment of brands of the same product found in supermarkets is a form of monopolistic competition. The availability of a number of brands of the same product means that consumers have access to small differences for which they are willing to pay a differentiated price.

After analyzing the main factors that affect the price formation of an agricultural product, each chapter of this manual concludes with a case study highlighting some of the principal points discussed. The example chosen for this chapter is the formation of potato prices in the United States.

Practical example: Introduction to price analysis in agriculture, a case study of potatoes

Potato consumption is an integral part of the diet and culture of the average global citizen, who, according to FAO, consumes 33 kg of potatoes every year. The United States Department of Agriculture (USDA) calculates that a 100-gram serving of fresh potato contains 87 calories and 20.13 grams of carbohydrates. This shows the important nutritional contribution that potatoes can make to the diet, as well as to food security and food sovereignty.

Until the early 1990s, potatoes were mostly produced in Europe, North America and the former Soviet Union. Since then, however, production has increased in Asia, Africa and Latin America. By 2014, the world's main potato producers and consumers were China (95,515,000 tons produced), India (46,395,000 tons), Russia (31,501,354 tons), Ukraine (23,693,350 tons) and the United States (20,056,500 tons) (FAO 2014). The United States is the only country in the Americas to figure among the world's principal potato producers and consumers, which means that any change in the determinants of the domestic supply or demand can have an impact at the international level.

The global supply is characterized by marked seasonality, mainly due to climate change. This is true of both North and South America but not Central America, where the climatic conditions are much more constant all year round. Figure 1.4 shows the seasonality of potato production in the United States and its bearing on prices.

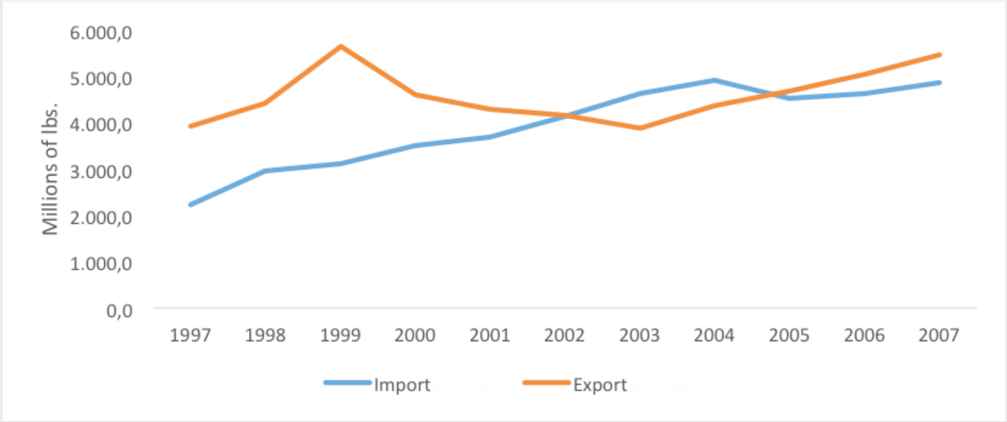
Figure 1.4. Production and price of potatoes in the United States. 1997-2007

Source: Prepared with data from USDA 2017.

The harvest peaks in autumn and falls in winter can be observed clearly in Figure 1.4, followed by upswings each summer. The way in which prices fall around the harvest peaks is also evident. This information confirms the close relationship that exists between climatic factors and the supply of an agricultural product, and how the supply is a determinant in price formation.

As mentioned throughout this chapter, higher demand for a product can push up prices. In the particular case of the United States, domestic demand grew somewhat during the period analyzed. For example, in the case of potatoes used for processing, the quantity demanded in 1997 was 268,352 (*1000* cwt), with the figure rising to 278,271 (*1000* cwt) by 2007. However, the United States could import potatoes from other countries, which would ease the demand and depress prices. The country could also export some of its production, meaning that there would be less potatoes available for the domestic market and the effect would be the opposite (possible higher prices). Given this situation, U.S. potato exports for the period in question were analyzed and the results are shown in Figure 1.5.

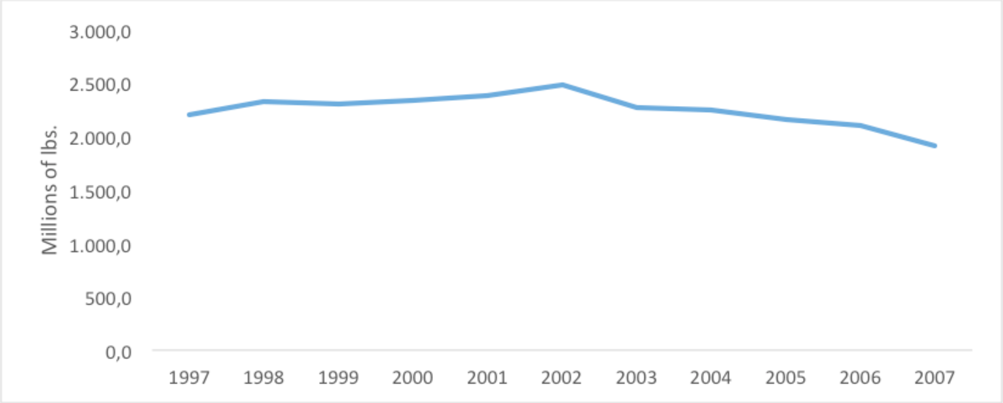
Figure 1.5. U.S. potato imports and exports.



Source. Prepared with data from USDA 2017.

As can be seen in Figure 1.5, imports are usually lower than exports, suggesting that more potatoes leave the United States than enter the country. The next figure shows the trends in potato stocks during the period analyzed, under the premise that low stocks create pressure for higher prices, and vice versa. Figure 1.6 shows the trends in potato stocks at the start of each year.

Figure 1.6. Trend in U.S. potato stocks.

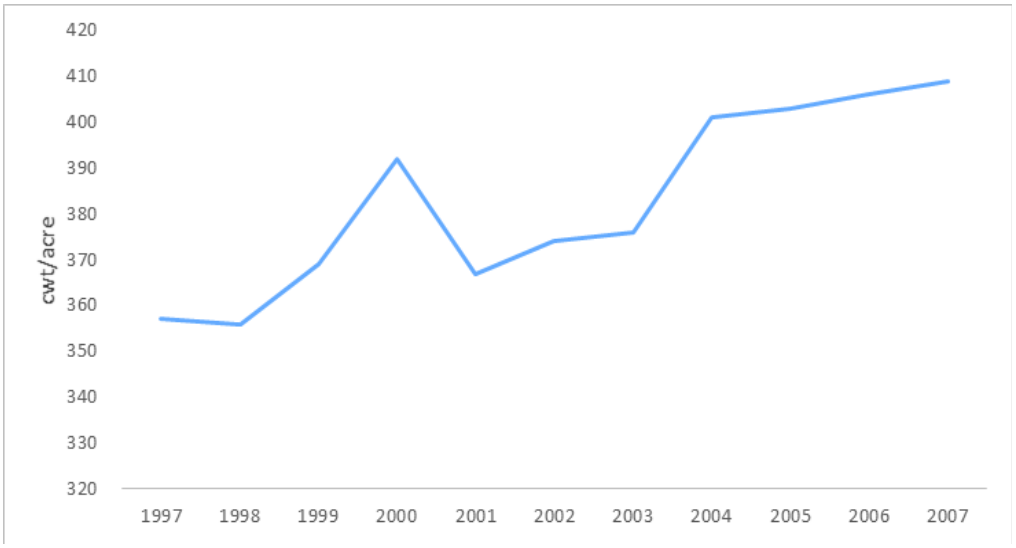


Source: prepared with data from USDA 2017.

A slight downward trend in stocks can be observed. In addition to this, total demand in the United States grew, average exports exceeded imports, and the area planted decreased (1997: 1,383,500 acres -> 2007: 1,149,100 acres). This scenario suggests that domestic potato prices in the United States should have risen, but Figure 1.6 shows that precisely the opposite occurred.

A plausible (albeit partial) explanation of this behavior could be the adoption of new technology, which is a determent of supply. Technology can help raise productivity per unit of cultivated area and thus be a determining factor in regulating the price. Figure 1.7 shows the long-term trend toward higher potato productivity in the autumn. Autumn was selected as it is the time of the year when the vast majority of the potato crop is harvested in the United States. One of the main variables that accounts for this upward trend is the adoption of technology.

Figure 1.7. Trend in U.S. potato productivity.

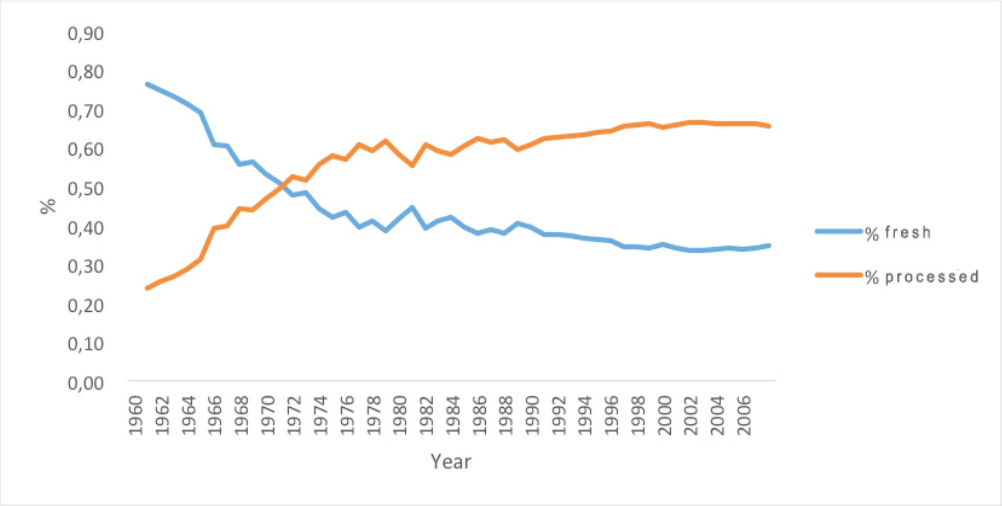


Source: prepared with data from USDA 2017.

Another determining factor in the evolution of prices, which is related to consumer demand, is the change in tastes and preferences. In 1970, consumers began to prefer processed potatoes, a trend that continued until 2006 (Figure 1.8). This was due to changing consumer lifestyles that had a direct impact on consumption habits. Whereas in 1960 fresh potatoes accounted for 76% of consumption, by 2007 the figure had fallen to just 35%.

Around 60% of potatoes are converted into frozen products (extending their shelf life), chips and dehydrated potato or potato flour, while 6% are reused as seed. The average U.S. citizen consumes more than 54 kilograms of potatoes every year, far above the world average; however, consumption of fresh potatoes has declined, falling to 16 kilograms in 2006.

Figure 1.8. Trend in the percentage of fresh and processed potatoes consumed.

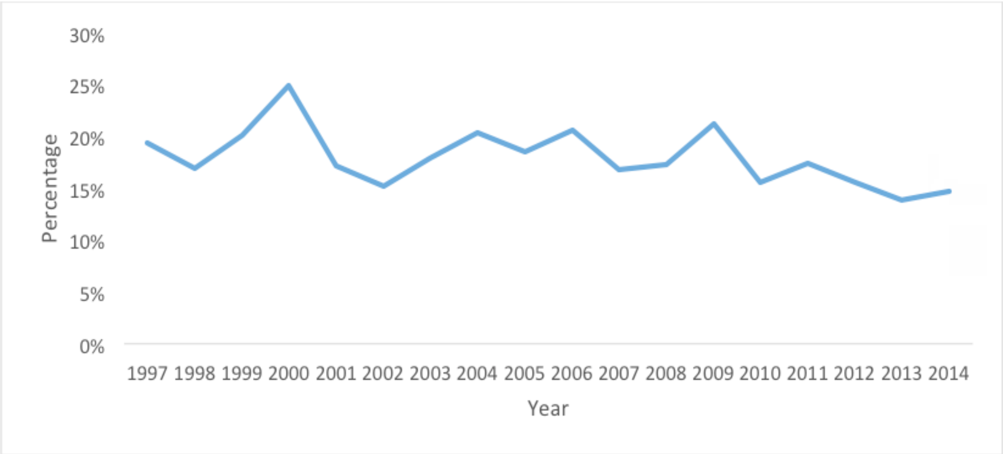


Source: prepared with data from USDA 2017.

With respect to the price formation process and each economic agent's share of the final price, in the United States farmers received 15% of the total price paid by consumers through 2016, while the other actors in the chain involved in the price formation process accounted for 85%.

The next figure shows the trend in the price paid to farmers as a percentage of the price paid to retailers. The trend is downward, i.e., the price paid to farmers is relatively lower in relation to the final price (Figure 1.9).

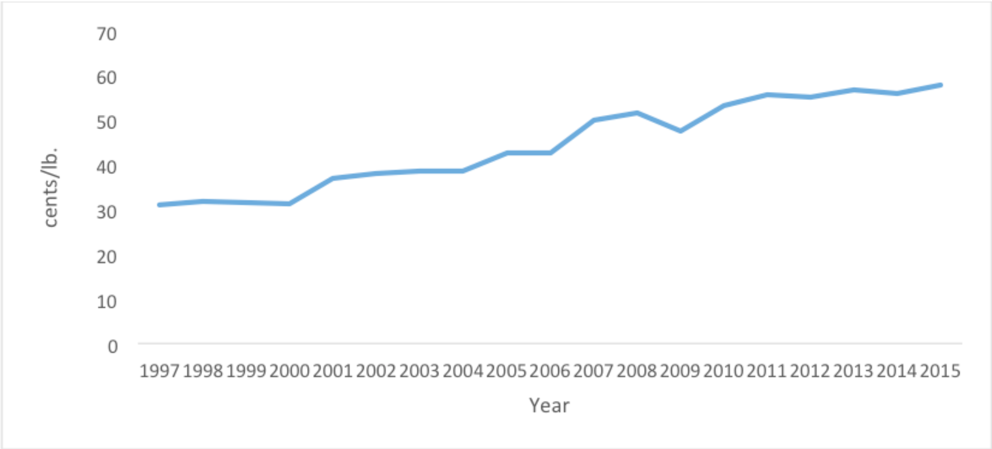
Figure 1.9. Trend in the price paid to producers as a percentage of the retail price.



Source: prepared with data from USDA 2017.

Although both prices have risen, the proportional increase in prices means that the difference between the price paid to farmers and the retail price has risen constantly, as can be observed in Figure 1.10. It should be noted that this price formation process includes a series of additional aspects, such as production costs (inputs, labor), the evolution of income and the increase in the population, which have not been mentioned previously.

Figure 1.10. Trend in the difference between the price paid to farmers and the retail price.



Source: prepared with data from USDA 2017.

Annex 1. Pricing in a monopoly

The change in the monopolist's profits corresponds to the change in revenue minus the changes in production costs:

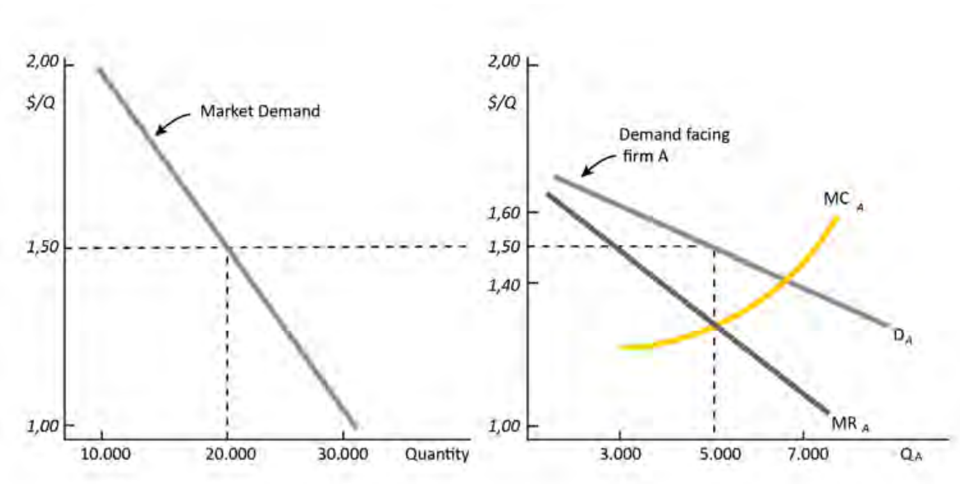
$$\frac{\Delta \pi}{\Delta Q} = \frac{\Delta R}{\Delta Q} - \frac{\Delta C}{\Delta Q}$$

Where:

π= profit, **R=** revenue, **C=** cost, **Q=** quantity

When the profit is maximized, the derivative of the profit curve is equal to zero (Figure 1.11). As can be observed in the following figures, the monopoly reaches this point when the marginal cost is equal to the marginal revenue. This would be the point where the monopolist decides how much to produce. As the demand curve is further to the right than the marginal revenue of the monopoly, the firm can set a higher price, because it knows that consumers are going to purchase the product (Figure 1.12).

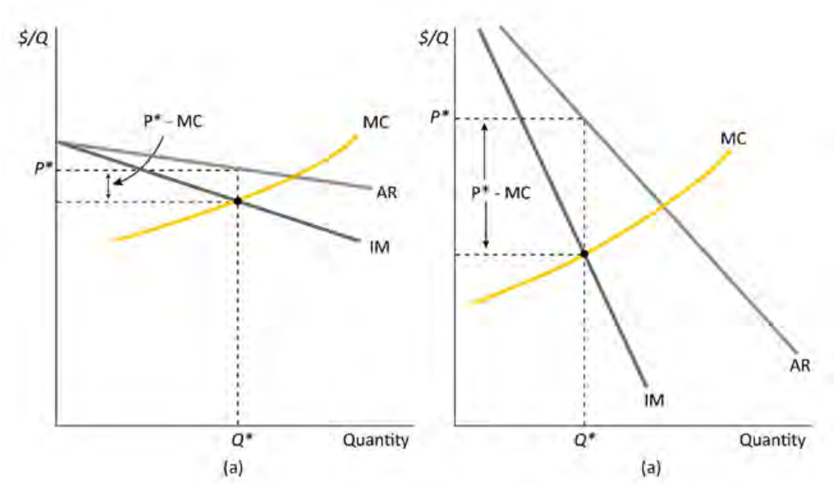
Figure 1.11. Pricing in a monopoly



Source: taken from Pindyck and Rubinfeld 2009.

The monopolist can therefore set as its sale price the price that the consumer is prepared to pay. This can be observed on the demand curve, which is always going to be above the marginal revenue curve (right side of the graphic). However, the monopolist's power to set the price depends on the elasticity of demand. If a very inelastic good is involved, monopoly power is high (b), but if the demand curve is very elastic, monopoly power is less (a), as the distance between the demand curve (average revenue) and the marginal revenue curve is smaller (see Figure 1.12).

Figure 1.12. Effect of the elasticity of the demand curve on monopoly power.



Source: taken from Pindyck and Rubinfeld 2009.

Example: pricing in a monopoly market and under perfect competition

Monsanto patented the production of the Roundup Ready herbicide, making it the only authorized producer worldwide. However, the patent expired in 2014, opening up the market. Assuming that the demand curve for Monsanto is given by $P=850\ 000-Q^2-0.45Q$, the monopoly cost curve is $C=6Q^2+2Q+100$. Where Q is given in tons and P in dollars.

Find the price per ton and the quantity offered until 2014, assuming that there have not been changes in the demand curve.

Profit maximization requires the condition *MgR=MgC* and to obtain the revenue of this firm: P*Q

As a result: $R=[850{,}000 -Q^2-0.45Q]*Q$

Marginal revenue is given by: $MgR=850{,}000-3Q^2-0.9Q$

And the marginal cost: $MgC=12Q+2$

Therefore, to maximize profits: $8500-3Q^2-0.9Q=12Q+2$

Solve Q: $0=3Q^2+12.9Q-84998$

$Q=530.14$ (tons)

The monopoly is: $P=850{,}000-(530.14)^2-0.45(530.14)$

P=USD 568,713.02 / ton of Roundup Ready

Assuming the same demand curve, what would be the price and quantity offered if, from 2014 onward, a large number of firms entered the market with a product with the same chemical formula?

Assuming perfect competition, the condition that maximizes the profits of each firm is given by $P=MgC$

Therefore: $850{,}000 -Q^2-0.45=12Q+2$

$Q=915.74$ (tons)

P=USD 110,078.17 / ton of Roundup Ready

When the situation changes from a monopoly to perfect competition, prices would be expected to fall and the quantity offered to increase.

CHAPTER 2

Sources of price variation

Introduction

Time series express the evolution of different types of variables over a period of years. They are used to analyze data of many kinds, such as demographic (birth and mortality rates), physical (temperature, quantity of water fallen) and economic (prices, price index, inflation) statistics. Time series provide important information in the form of basic short- and medium-term statistical indicators.

Indicators of price components (trend-cycle, seasonality and volatility) are useful for clarifying the causes of price fluctuations. Calculating the seasonal index makes it possible to identify the patterns of growing seasons, which can help farmers to make better decisions with respect to the products they purchase, sell and store. For example, statistical values of soybean prices reach their highest levels in December/January of each year, and then begin to fall as the next harvest approaches.

It is possible to identify price series throughout a production chain (farm gate, wholesale and retail purchase and sale prices). With different prices in each link of the chain, it is important to standardize their periodicity for any kind of analysis. This means that in a time series all observations are equally spaced, making it possible to observe price series by hours, days, months, years or any other measurement of time. It can be intuited that periodicity is very important in the analysis of agricultural data, as there are products in this sector with marked seasonal supply and demand, which affects prices. Hence the need to take maximum advantage of time series data with high periodicity; for example, switching from weekly to monthly time series can result in the loss of information that would make it easier to understand price behavior.

Sources of price variation are analyzed in order to project or forecast prices, in the belief that history repeats itself and price behavior observed in the past tends to be repeated in the future. This chapter contains a description of the four basic components of price that exist in a time series, namely:

1. Trend
2. Cycle
3. Seasonality
4. Volatility

The use of models that explain price behavior in relation to other variables is very common within the agriculture sector, mainly for producing forecasts. This topic will not be addressed in this chapter, however. The principal objective of this chapter is to help the reader understand the concept of each of the four components, and how they can be decomposed and analyzed, in addition to their main practical applications. This will be done by studying and applying methodologies such as those of mobile averages and seasonal indices, among others. Case studies will be used to illustrate the procedures for calculating these indicators, in which agricultural prices form the basis of the analysis.

2.1 Initial considerations prior to the identification of sources of price variations

Before carrying out a price analysis, the data has to be cleansed and the information contained in the time series evaluated. This step is of the utmost importance, as the series may contain errors such as:

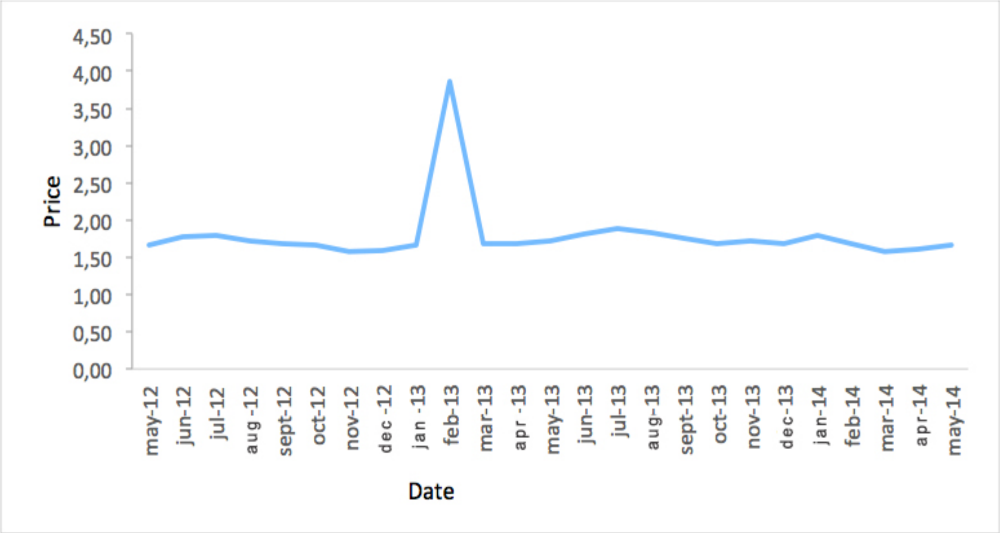
1. Typing errors: the person responsible for inputting or transferring the prices to the final database may have inverted a number or copied values that did not belong to the time series in question.
2. Calculation errors: analyses are often carried out based on time series of prices converted to dollars or another specific unit. Conversions of this kind usually involve simple calculations but mistakes may be made.

In addition to these two kinds of errors, it is important to detect whether a time series includes outliers or extreme data. Outliers may owe their existence either to errors like those mentioned above, or to a true but extreme datum produced by extraordinary events such as floods, hurricanes or strikes. Even if the datum reflects the true situation, it is important to evaluate whether it should be considered in the analysis, because its mere inclusion can significantly alter the results.

The method for identifying and managing outliers is as follows. The first step is to verify that all the data in the series is expressed in the same unit. In the case of prices, it is necessary to confirm that the entire series is in the same unit of currency and that the periodicity of data distribution is uniform.

The creation of a graph is the first technique used to identify and show data that lies outside the statistical norm. Figure 2.1 shows the behavior of the monthly average price of cattle at auction (USD/kg) in Costa Rica, in which an example of an atypical datum is identified (Feb 13) that can be considered an outlier.

Figure 2.1. Price of cattle at auction (USD/kg) in Costa Rica.



Source: prepared with data from CORFOGA 2017.

Note: the February 2013 price (outlier) has been used as an example and does not correspond to real data.

In this case, the price in February 2013 was 3.87 USD/kg, which is clearly not consistent with the typical behavior of the data. The following descriptive data (Table 2.1) was obtained for the time series in the above graph (Figure 2.1).

Table 2.1. Descriptive indicators of cattle at auction (USD/kg) in Costa Rica.

Average	1,58 US$/Kg
Standard deviation	0,44 US$/Kg
Coefficient of variation	0,28

To illustrate the effect that an outlier can have on the results of an analysis, the average price in Table 2.1 is 1.58 USD/kg. The standard deviation that expresses the dispersion of the data around the average has also been calculated. The lower the figure, the more uniform the data, which means that most of the observations are close to the average. The higher the standard deviation, the greater the dispersion of the observations around the average, which means that bigger differences between the data can be observed. On the other hand, the coefficient of variation is calculated by dividing the standard deviation by the average ratio, which, as well as the standard deviation, provides information about the dispersion of the data. The bigger the coefficient of variation, the more important the standard deviation from the average, and vice versa. In the specific case of the example, the standard deviation is 0.43 and the coefficient of variation is of 0.27[2].

Now consider the same time series, but this time without the outlier, which was replaced with the average of the values immediately before and after it. This procedure gives the following descriptive indicators (Table 2.2).

Table 2.2. Comparison of descriptive indicators for cattle at auction (USD/kg) in Costa Rica

Category	Without outlier	With outlier
Average	1,53	1,58
Standard deviation	0,24	0,44
Coefficient of variation	0,16	0,28

As can be seen in Table 2.2, simply replacing the outlier with the average of the adjacent prices reduces the average, the standard deviation and the coefficient of variation. The standard deviation decreases by around 45%. This example shows how a single datum can have a big effect on the descriptive indicators of a time series, so the way in which an outlier is handled is no small matter. The following points are useful for dealing with an outlier.

1. If possible, verify whether the atypical cases identified are due to an error of procedure, such as a mistake made when inputting the data or a coding error.
2. Identify whether the atypical observation occurs as a consequence of an extraordinary event. In this case, the outlier may be a datum that was calculated correctly but does not represent the normal conditions of the market.
3. Lastly, if there is no plausible explanation for an outlier, the question of how to handle it will have to be addressed.

---

[2]*For any type inference in which the standard deviation is to be used, the behavior of the data distribution must be considered.*

There are various techniques for identifying outliers, including the tests developed by Chauvenet, Grubb and Dixon. However, many of these techniques assume that the data behaves in the same way as a normal distribution curve and call for more complex statistical tests. A basic technique will be presented in this chapter that is not intended to replace other tests but is a useful means of familiarizing the reader with the subject of outlier identification. The following example shows how the interquartile method can be used to identify outliers.

Identification of outliers using the interquartile method

Continuing with the series of meat prices in Costa Rica, the following data was compiled on the price of cattle at auction (USD/kg):

1,67	1,77	1,78	1,71	1,69	1,66	1,58	1,60
1,67	3,87	1,69	1,69	1,72	1,81	1,88	1,83
1,75	1,68	1,72	1,69	1,79	1,68	1,58	1,61

The first step in identifying outliers is to rearrange the data in ascending order as follows:

1,58	1,58	1,60	1,61	1,66	1,67	1,67	1,68
1,68	1,69	1,69	1,69	1,69	1,71	1,72	1,72
1,75	1,77	1,78	1,79	1,81	1,83	1,88	3,87

Once that has been done, quartile 1 and quartile 3 of the data set are calculated:

Quartile 1	1,67
Quartile 3	1,78
Interquartile Range	0,11

For the calculation in Excel: =quartile (data matrix, quartile). In this case, the word “quartile” is replaced with 1 if you want to obtain quartile 1, and with 3 if you want to obtain quartile 3.

Then, to obtain the minimum and maximum border values that will be used to determine whether a datum is an outlier, the procedure is as follows:

1. Subtract 1.5 times the interquartile range from quartile 1, which gives the lowest value.

2. Then add 1.5 times the interquartile range to quartile 3, which gives the highest value.

3. The rule is that any datum outside this range is considered an outlier and its formation needs to be analyzed.

In this example, the values are obtained as follows:

1. Lowest value: 1,67-1,5*0,11 = 1,51

2. Highest value: 1,78+1,5*0,11=1,93

3. Any value below 1.51 and over 1.93 should be analyzed as an atypical datum. Thus, in this time series the datum of 3.87 is clearly an outlier and its origin needs to be analyzed.

Once the outliers have been identified, the question of what to do with them arises. It is recommended that, as in the previous example, efforts be made to determine whether the outlier is responsible for significant changes in the average, the standard deviation and other indicators. If it is, it becomes necessary to verify whether the atypical datum is the result of an error. If it is not, but is due to atypical market behavior (an unusual event), it may only be eliminated if it is deemed to be generating statistical indicators that do not reflect the true nature of the series. A commonly used technique involves replacing the outlier with an average of nearby data, provided their behavior is typical.

On the other hand, databases are often incomplete and data may be missing. In this case, many empirical practices can be used, provided the time series is clearly understood. If it is not, it could result in data being added that is not consistent with the typical behavior of the series.

For example, if there are prices with marked seasonality, replacing a missing datum with the general average of the price series may not be a good technique to use, since it would be more logical to replace it with a price that makes sense in light of the seasonal behavior of the series. In this case, replacing the datum with the average data for the same month could come closer to approximating the real datum. In estimating missing data with existing data, many variables should be included, such as the trend in the data, seasonality and the relative importance of past prices in explaining current prices.

2.2 Principal sources of variations in a time series

Studies of time series have identified four basic characteristics (trend, cycle, seasonality and volatility), also called patterns, movements or variations.

A **trend** is an upward or downward movement that is maintained over a lengthy period. Usually, it is regarded as being induced by macro forces such as changes in the size of the population, in demographic characteristics or in income, health, education or technology. Long-term trends follow various patterns (Hernández-Rodriguez 2008). On the other hand, the **cycle** component is made up of undulating fluctuations that can last from two to ten years, or even longer, measured from maximum to maximum or minimum to minimum. The periodicities of cycles vary, so that a single series may have cycles of three or four years. However, in practice cycles are not always easy to identify, so they are usually analyzed together with the trend. As a result, it is common for reference to be made to the "trend-cycle movement" of a series.

The third characteristic is the **seasonal** component. This refers to the fluctuations in an agricultural price within a calendar year. A seasonal index can usually be calculated to illustrate the seasonality of a series graphically.

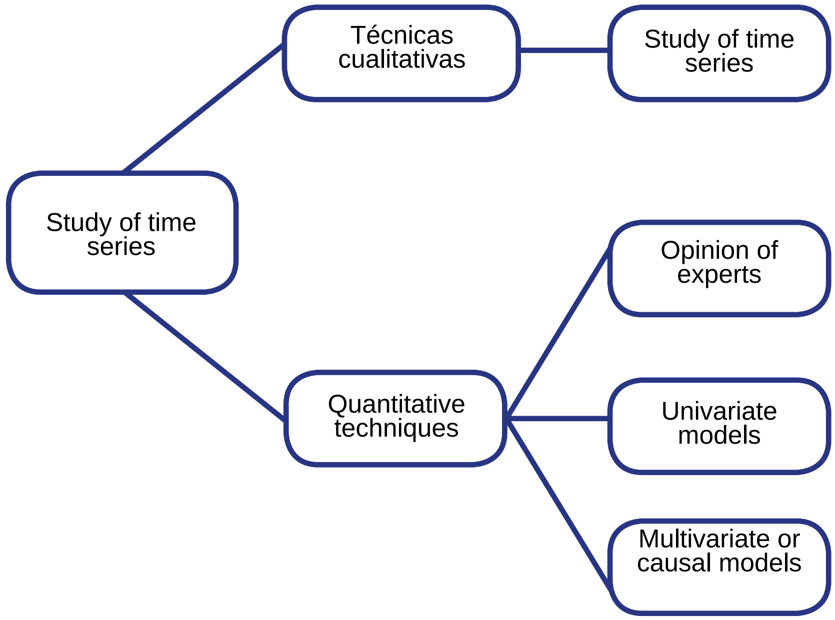
Lastly, there is the **volatility** component. This consists of variations without any regular or identifiable pattern, as it corresponds to the part of the time series that behaves randomly. The trend does not show a regular pattern of behavior since prices rise, remain constant or fall in an unpredictable way. This factor can be said to be what remains of the time series after the behavior of the trend-cycle and seasonality has been isolated.

It should be noted that there are both simple and very sophisticated methodologies for quantifying these basic concepts. Qualitative and quantitative techniques are two overarching types of series analysis. This manual will focus on quantitative techniques only; it will not deal with qualitative techniques such as the consulting of experts.

Two models are used for quantitative analysis:

1. Multivariate or causal models
2. Univariate models

Figure 2.2. Techniques for the study of time series



The underlying principle of multivariate models is that an economic relationship exists between different variables and the price, which can be expressed by means of mathematical relations. In this case, the price is used as a dependent variable, which is explained or caused by other variables.

Consider the following multivariate model of the price of milk:

$$P_t^{milk} = f(O_t P_{t-1}^{Inputs}, P_t^{Substitutes}, P_t^{Complementary})$$

In this case, it is considered that the current price of milk can be determined by variables such as the quantity supplied in the same period, the price of inputs during the previous period, and the price of substitute and complementary products.

On the other hand, univariate models use historical data for the same variable to identify patterns that help provide a better understanding, in order to be able to extrapolate the variable's behavior in the future. Consider the following example:

$$P_t = \emptyset P_{t-1} + \theta P_{t-3} + \mu_t$$

In this case, the current price P_t can be partially explained by the price in the previous period (P_{t-1}) and the three previous periods (P_{t-3}). Usually, previous prices close to the current price have a greater relative importance in explaining the current price than much older prices.

In the previous example, it is observed that P_{t-3} also plays an important role in explaining the current price, but why can the price in three previous periods explain a current price? In this case, the price in three previous periods was used for illustrative purposes only; the value could be 2, 3, 4, 5, or any other. This lag may be attributed to various variables, including the production cycle or the weather. So if the production cycle is three months long, and we have monthly data on prices, the current price is very probably going to be influenced by the price three months ago. In order to determine the number of lags that are going to be used in the model, it is necessary to analyze the nature of the product.

The analyses and examples presented below are univariate models (a single variable is considered). However, the analysis techniques used in univariate models are usually combined with the techniques used in multivariate models (many variables are considered), as changes in prices do not necessarily depend on a single variable. For example, if prices fall at a specific moment in time, it is because there is an excess supply due to a series of variables or factors such as the weather, the effect of the prices of substitute/ complementary products, or the behavior of input prices. In other words, changes in prices do not usually depend on a single variable, but the effect of that variable can be isolated in order to understand its impact on the behavior of prices using univariate methods.

2.2.1 Multiplicative and additive method

Multiplicative and additive processes can be used to decompose the sources of variation of price series. The price of a good is comprised of its trend, cycle, seasonality and volatility. In a multiplicative process, the price is a multiplication of the four components, while in an additive process, the price is the sum of them:

Under the multiplicative method, price formation is given by: $Y=T*C*S*V$

Under the additive method, price formation is given by: $Y = T+C+S+V$

Where:

Y= response variable (Price)

T= trend

C= cycle

S= seasonality

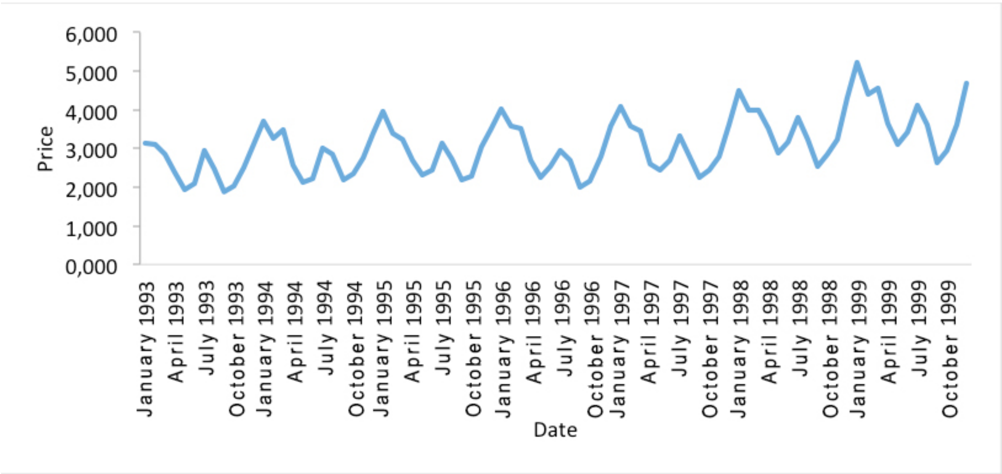
V= volatility

Recognizing each of these components enhances the potential of historical price analysis for projecting or forecasting prices in the short and medium terms. An example is presented below in which two methods are used to calculate each component of a time series.

2.2.1.1 Multiplicative method

To analyze price behavior, it is advisable to disaggregate each component of the price. The monthly prices of product X were used to illustrate the multiplicative method (see Figure 2.3). It is important to remember that the fact that there are no outliers or missing information must be verified. It was also confirmed that all the data was in the same currency unit. Plotting the data helps to confirm that there are no missing values or atypical values (outliers).

Figure 2.3. Price behavior (USD/kg) of product X



Once the price behavior has been plotted, each component is isolated. The first step is to calculate the moving average (MA), which contains information about both the trend (T) and the cycle (C). In this case, the calculation of the moving average is for 12 months (MA 12), since the data is monthly and, therefore, 12 values are observed. However, if the data covered four-month periods, the MA would be based on 3 values and, if it were daily, 365 values.

The following procedure is used to estimate the MA: the first MA 12 is located in June, as this month represents half of the year. This value is 2.538 (USD/kg), as shown in Table 2.3. For the next MA 12, the value of January 1993 is discarded and the value for January 1994 added, giving an average of 2.585 (USD/kg). The procedure is repeated t-12 times.

The next step is to calculate the centered moving average (CMA), which also contains information from the trend and cycle of a time series, which means that the CMA is an approximation of the behavior of the trend-cycle, i.e., CMA =T*C. Once the CMA has been estimated (which corresponds to the average of two consecutive MA), it is possible to separate the trend from the cycle. In order to do this, we are going to begin by calculating the trend.

Table 2.3. Calculation of the moving average and centered moving average

Date	P (USD/kg)	MA 12	CMA (12*2) = T*C
January 1993	3.141		
February 1993	3.100		
March 1993	2.838		
April 1993	2.381		
May 1993	1.924		
June 1993	2.107	2.538	
July 1993	2.959	2.585	2.562
August 1993	2.487	2.599	2.592
September 1993	1.880	2.653	2.626
October 1993	2.020	2.667	2.660
November 1993	2.502	2.685	2.676
December 1993	3.119	2.695	2.690
January 1994	3.703	2.699	2.697
February 1994	3.273	2.729	2.714
March 1994	3.475	2.754	2.742
April 1994	2.552	2.781	2.768

The procedure for calculating the **trend (T)** in Excel is as follows:

1. Step 1: price graph (Y = price and X = time)
2. Step 2: once the table has been created, double-click on the price line, then right click to display the Excel options and select "Add Trendline." The box that should be displayed is the one shown below.
3. Step 3: select the "exponential equation" check box.

4. Step 4: select the “display equation on chart” check box.

What this procedure does is estimate a line of best fit by means of ordinary least squares (OLS), establishing the relation between the price (axis Y) and the time (axis X).

5. Step 5: extract the formula that explains the relation between X and Y, which in this case is: Y=2,4701e^{0,0045x}

6. Step 6: now estimate the trend as follows: the trend in the first cell corresponds to the initial price (3.141), but from the second row onward, the calculation is equal to “=Exp(Ln(P)+0,0045*n”

For example, the calculation for February is =Exp(Ln(3.141)+0.0045*2.

It is important to clarify that the first price remains constant throughout the calculation, while “n” varies in each of the corresponding months. Table 2.4 shows the calculation of the trend of some of the months in the series.

To calculate the **cycle (C)**, once the trend has been established, considering that the CMA = T*C, the trend can be separated from the cycle by means of the division $(T*C)/T=C$. In this way, the cycle and the trend are isolated and then analyzed as individual components. The estimate of the cycle can also be observed in Table 2.4.

Table 2.4. Estimate of the trend and cycle of a time series

n	Date	Month	P (USD/ kg)	T*C	T	C
1	January 1993	January	3,141		3,141	
2	February 1993	February	3,100		3,169	
3	March 1993	March	2,838		3,184	
4	April 1993	April	2,381		3,198	
5	May 1993	May	1,924		3,212	
6	June 1993	June	2,107		3,227	
7	July 1993	July	2,959	0,790	3,242	0,790
8	August 1993	August	2,487	0,796	3,256	0,796
9	September 1993	September	1,880	0,803	3,271	0,803
10	October 1993	October	2,020	0,809	3,286	0,809
11	November 1993	November	2,502	0,811	3,300	0,811
12	December 1993	December	3,119	0,811	3,315	0,811
13	January 1994	January	3,703	0,810	3,330	0,810
14	February 1994	February	3,273	0,811	3,345	0,811
15	March 1994	March	3,475	0,816	3,360	0,816
16	April 1994	April	2,552	0,820	3,375	0,820
17	May 1994	May	2,139	0,823	3,391	0,823
18	June 1994	June	2,233	0,826	3,406	0,826
19	July 1994	July	3,003	0,829	3,421	0,829
20	August 1994	August	2,851	0,830	3,437	0,830
21	September 1994	September	2,182	0,825	3,452	0,825

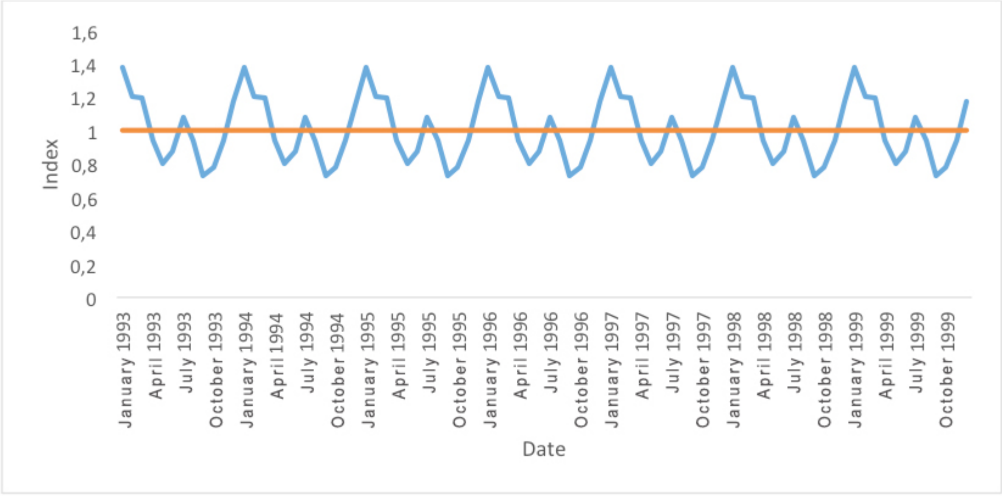
The third component of the price is **seasonality (S)**, which tends to be analyzed first as a seasonal index. Y corresponds to the monthly averages of the price divided by the centered moving average (P/CMA), which is equivalent to the price divided by the trend-cycle.

The procedure for estimating this datum in Excel is as follows:

1. Insert a column with the series by month only (without the year)
2. Use the function =average.if.group(price range, month range, initial month)
3. Calculate the above datum for each subsequent month.

Once the monthly averages have been obtained from the seasonal index, it is possible to observe whether the behavior of the data for each month is above or below the average. It is useful to plot this data in order to be able to observe the monthly behavior more clearly (Figure 2.4).

Figure 2.4. Seasonal index



As can be observed in Figure 2.4, the prices are highest in the first and last months of the year and, as a result, the seasonal index is greater than 1. In every month for which the seasonal index is less than 1, the prices are below the average. For example, the seasonal index for February is 1.19, which means that the price in February is 19% above the average of the entire series; in contrast, the price in June only represents 87% of the average price of the entire series (i.e., the price in June is 13% below the average price of the series). This is done to standardize the index, so that the annual average of the index is equal to 1.

Once these values have been obtained, the geometric mean is calculated in order to isolate the seasonality (S) completely, defined as:

$$GM=\sqrt[n]{\prod_{i=1}^{n} x_i}=\sqrt[n]{x_1,x_2 \ldots x_n}.$$

It can be obtained in Excel through =geomean(range), where the range is all the seasonal indices calculated previously. The seasonality can be estimated by calculating the geometric mean. Each seasonal index calculated previously is divided by the geometric mean “x”. These calculations can be observed in Table 2.5.

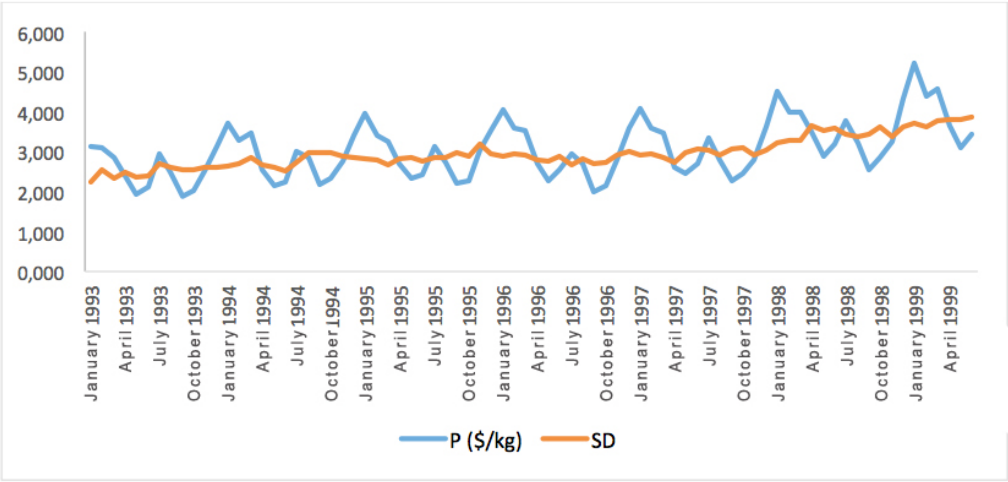
Table 2.5. Calculation of the seasonal index and seasonality (multiplicative method)

Month	P/CMA	S
January	1.379	1.403
February	**1.199**	1.220
March	1.192	1.212
April	0.942	0.958
May	0.803	0.817
June	**0.870**	0.885
July	1.080	1.098
August	0.938	0.954
September	0.724	0.737
October	0.776	0.789
November	0.941	0.957
December	1.175	1.194
Average	**1.002**	
Geometric mean	**0.983**	

(V*S)/ Geometric mean

Finally, the last component of a price is volatility (V). The seasonally adjusted series (SAS) is estimated by means of SAS=P/S. This procedure eliminates seasonality from the time series. It can be observed in Figure 2.5 below, in which the seasonally adjusted series (red) is contrasted with the original price series (blue).

Figure 2.5. Seasonally adjusted series and original price series.

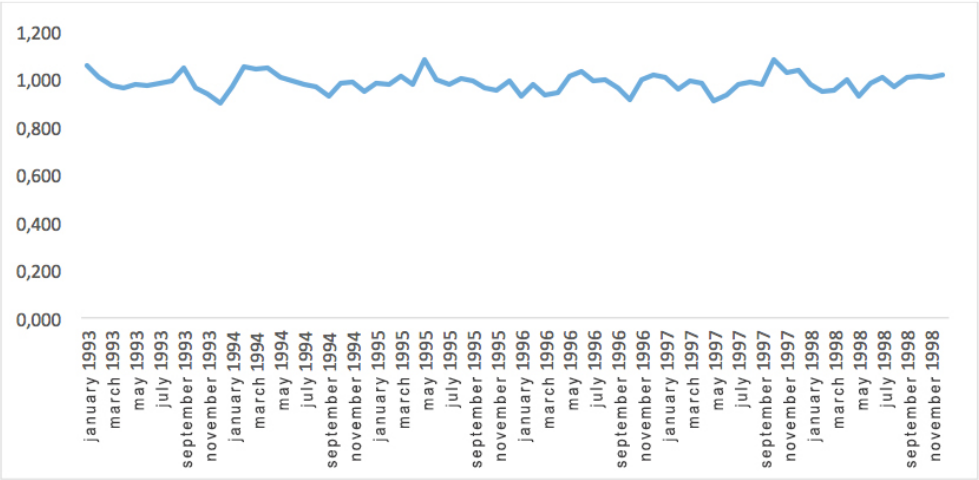


As in the multiplicative method, it is assumed that the multiplication of each of the price components must be the same as the price, volatility can be estimated by means of the following formula:

$$V = \frac{P/(T*C)}{S}$$

The behavior of volatility can be observed in Figure 2.6.

Figure 2.6. Volatility



The data for each of the abovementioned calculations can be seen in Table 2.6; the multiplication of T*C*S*V = P corresponds to each of the steps explained previously.

Table 2.6. Calculations using the multiplicative method

Date	Month	P (USD/kg)	T	C	S	V
January 1993	January	3,141	3,141		1,403	
February 1993	February	3,100	3,169		1,220	
March 1993	March	2,838	3,184		1,212	
April 1993	April	2,381	3,198		0,958	
May 1993	May	1,924	3,212		0,817	
June 1993	June	2,107	3,227		0,885	
July 1993	July	2,959	3,242	0,790	1,098	1,052

Date	Month	P (USD/kg)	T	C	S	V
August 1993	August	2,487	3,256	0,796	0,954	1,005
September 1993	September	1,880	3,271	0,803	0,737	0,972
October 1993	October	2,020	3,286	0,809	0,789	0,962
November 1993	November	2,502	3,300	0,811	0,957	0,977
December 1993	December	3,119	3,315	0,811	1,194	0,971
January 1994	January	3,703	3,330	0,810	1,403	0,979
February 1994	February	3,273	3,345	0,811	1,220	0,989
March 1994	March	3,475	3,360	0,816	1,212	1,046
April 1994	April	2,552	3,375	0,820	0,958	0,963
May 1994	May	2,139	3,391	0,823	0,817	0,938
June 1994	June	2,233	3,406	0,826	0,885	0,897
July 1994	July	3,003	3,421	0,829	1,098	0,964
August 1994	August	2,851	3,437	0,830	0,954	1,048
September 1994	September	2,182	3,452	0,825	0,737	1,040
October 1994	October	2,345	3,468	0,820	0,789	1,045
November 1994	November	2,746	3,484	0,821	0,957	1,004
December 1994	December	3,404	3,499	0,821	1,194	0,991
January 1995	January	3,959	3,515	0,822	1,403	0,977
February 1995	February	3,400	3,531	0,818	1,220	0,965
March 1995	March	3,239	3,547	0,813	1,212	0,927
April 1995	April	2,704	3,563	0,809	0,958	0,980
May 1995	May	2,329	3,579	0,808	0,817	0,986
June 1995	June	2,430	3,595	0,809	0,885	0,944
July 1995	July	3,130	3,611	0,807	1,098	0,978
August 1995	August	2,720	3,627	0,807	0,954	0,974
September 1995	September	2,195	3,644	0,808	0,737	1,012
October 1995	October	2,277	3,660	0,807	0,789	0,977
November 1995	November	3,043	3,677	0,803	0,957	1,077
December 1995	December	3,512	3,693	0,800	1,194	0,996
January 1996	January	4,036	3,710	0,795	1,403	0,975
February 1996	February	3,587	3,727	0,789	1,220	1,000
March 1996	March	3,514	3,744	0,783	1,212	0,989
April 1996	April	2,683	3,760	0,776	0,958	0,960
May 1996	May	2,257	3,777	0,768	0,817	0,952
June 1996	June	2,541	3,794	0,763	0,885	0,991

Date	Month	P (USD/kg)	T	C	S	V
July 1996	July	2,944	3,812	0,761	1,098	0,925
August 1996	August	2,698	3,829	0,758	0,954	0,974
September 1996	September	1,991	3,846	0,754	0,737	0,932
October 1996	October	2,149	3,863	0,749	0,789	0,941
November 1996	November	2,799	3,881	0,747	0,957	1,009
December 1996	December	3,583	3,898	0,747	1,194	1,029
January 1997	January	4,078	3,916	0,750	1,403	0,990
February 1997	February	3,594	3,934	0,752	1,220	0,996
March 1997	March	3,454	3,951	0,752	1,212	0,959
April 1997	April	2,609	3,969	0,755	0,958	0,909
May 1997	May	2,442	3,987	0,754	0,817	0,994
June 1997	June	2,708	4,005	0,751	0,885	1,017
July 1997	July	3,336	4,023	0,753	1,098	1,003
August 1997	August	2,786	4,041	0,758	0,954	0,953
September 1997	September	2,265	4,059	0,764	0,737	0,991
October 1997	October	2,446	4,078	0,775	0,789	0,981
November 1997	November	2,792	4,096	0,785	0,957	0,907
December 1997	December	3,623	4,115	0,791	1,194	0,932
January 1998	January	4,504	4,133	0,796	1,403	0,975
February 1998	February	3,996	4,152	0,802	1,220	0,984
March 1998	March	3,978	4,171	0,805	1,212	0,977
April 1998	April	3,502	4,189	0,808	0,958	1,079
May 1998	May	2,871	4,208	0,813	0,817	1,027
June 1998	June	3,178	4,227	0,821	0,885	1,035
July 1998	July	3,786	4,246	0,831	1,098	0,977
August 1998	August	3,223	4,265	0,838	0,954	0,945
September 1998	September	2,536	4,285	0,844	0,737	0,952
October 1998	October	2,858	4,304	0,847	0,789	0,993
November 1998	November	3,242	4,323	0,847	0,957	0,925
December 1998	December	4,311	4,343	0,848	1,194	0,981
January 1999	January	5,215	4,362	0,849	1,403	1,003
February 1999	February	4,395	4,382	0,852	1,220	0,965
March 1999	March	4,567	4,402	0,853	1,212	1,003
April 1999	April	3,636	4,422	0,851	0,958	1,009
May 1999	May	3,102	4,442	0,851	0,817	1,004

2.2.1.2. Additive method

In addition to the multiplicative method explained above, the four components of the time series presented in Figure 2.3 were analyzed using the additive method. The first step involved estimating a moving average for 12 data points, as was done in the case of the multiplicative method. The second step was to obtain the centered moving average, which represents the trend and cycle component, also in the same way as in the multiplicative method.

The third step was to subtract the value of the centered moving average (CMA) from the original price. This is done to obtain the volatility (V) and seasonality (S) components. The datum corresponding to V+S can be observed in Table 2.7.

In the fourth step, the volatility and seasonality component for the entire series was averaged for each month. Taking the CV+CS component of January 1993, the CV+CE component of January 1994 was added, and so on and so forth with each component from January up to the year 1999. This sum was divided by six, since the period 1994-1999 includes six years. This division gave the average for January for the V+S component of the entire series. The procedure was repeated for each subsequent month. The fifth step in the procedure consisted of obtaining the average for the V+S component of every month. The next (sixth) step involved obtaining the seasonality (S) by subtracting the general average from the V+S component.

Table 2.7 Calculation of the seasonal index and the seasonal factor, using the additive method

Fourth step: Average of the V+S component for the month of January for the years 1993-1999

Month	V+S	S
January	1,188	1,166
February	0,629	0,607
March	0,611	0,588
April	-0,159	-0,181
May	-0,595	-0,617
June	-0,380	-0,402
July	0,233	0,211
August	-0,167	-0,190
September	-0,810	-0,832
October	-0,657	-0,679
November	-0,173	-0,195
December	0,548	0,526
General Average	**0,022**	
Sum		0

Sixth step: 1,188-0,022

Fifth step: Average of the CV+CS component

The seventh step involved obtaining the volatility by subtracting the seasonality from the V+S component, thus leaving the volatility component isolated from the series.

Finally, the seasonally adjusted series (SAS) was obtained by subtracting the seasonal factor from the original datum of the series. This result appears in the SAS column. The results of each of the abovementioned calculations can be observed in Table 2.8. It can be seen how the sum of (T+C)+S+V = P.

Table 2.8 Calculations of the additive method

Step 7: (V+S) - S = V

Step 8: (P-S)

Date	Month	P (USD/kg)	MA (12)	T+C	V+S	S	V	SAS
January 1993	January	3,141				1,166		
February 1993	February	3,100				0,607		
March 1993	March	2,838				0,588		
April 1993	April	2,381				-0,181		
May 1993	May	1,924				-0,617		
June 1993	June	2,107				-0,402		
July 1993	July	2,959	2,538			0,211		
August 1993	August	2,487	2,585	2,562	-0,075	-0,190	0,115	2,676
September 1993	September	1,880	2,599	2,592	-0,712	-0,832	0,120	2,712
October 1993	October	2,020	2,653	2,626	-0,606	-0,679	0,073	2,699
November 1993	November	2,502	2,667	2,660	-0,158	-0,195	0,037	2,697
December 1993	December	3,119	2,685	2,676	0,443	0,526	-0,083	2,593
January 1994	January	3,703	2,695	2,690	1,013	1,166	-0,152	2,537
February 1994	February	3,273	2,699	2,697	0,576	0,607	-0,031	2,666
March 1994	March	3,475	2,729	2,714	0,761	0,588	0,173	2,887
April 1994	April	2,552	2,754	2,742	-0,189	-0,181	-0,008	2,734
May 1994	May	2,139	2,781	2,768	-0,629	-0,617	-0,012	2,756
June 1994	June	2,233	2,802	2,792	-0,559	-0,402	-0,156	2,635
July 1994	July	3,003	2,826	2,814	0,189	0,211	-0,022	2,792
August 1994	August	2,851	2,847	2,836	0,015	-0,190	0,205	3,041
September 1994	September	2,182	2,857	2,852	-0,670	-0,832	0,163	3,015
October 1994	October	2,345	2,838	2,848	-0,502	-0,679	0,177	3,024
November 1994	November	2,746	2,850	2,844	-0,098	-0,195	0,097	2,941
December 1994	December	3,404	2,866	2,858	0,545	0,526	0,019	2,878
January 1995	January	3,959	2,883	2,874	1,085	1,166	-0,081	2,793
February 1995	February	3,400	2,893	2,888	0,512	0,607	-0,095	2,793
March 1995	March	3,239	2,882	2,888	0,351	0,588	-0,237	2,650
April 1995	April	2,704	2,883	2,883	-0,179	-0,181	0,003	2,886
May 1995	May	2,329	2,878	2,881	-0,552	-0,617	0,065	2,946
June 1995	June	2,430	2,902	2,890	-0,460	-0,402	-0,058	2,832
July 1995	July	3,130	2,912	2,907	0,223	0,211	0,013	2,920
August 1995	August	2,720	2,918	2,915	-0,194	-0,190	-0,005	2,910
September 1995	September	2,195	2,933	2,926	-0,731	-0,832	0,102	3,027

Date	Month	P (USD/kg)	MA (12)	T+C	V+S	S	V	SAS
October 1995	October	2,277	2,956	2,945	-0,668	-0,679	0,012	2,956
November 1995	November	3,043	2,955	2,955	0,087	-0,195	0,282	3,238
December 1995	December	3,512	2,949	2,952	0,560	0,526	0,034	2,986
January 1996	January	4,036	2,958	2,953	1,082	1,166	-0,084	2,870
February 1996	February	3,587	2,942	2,950	0,636	0,607	0,029	2,979
March 1996	March	3,514	2,941	2,942	0,573	0,588	-0,016	2,926
April 1996	April	2,683	2,924	2,932	-0,249	-0,181	-0,067	2,865
May 1996	May	2,257	2,913	2,918	-0,661	-0,617	-0,043	2,875
June 1996	June	2,541	2,893	2,903	-0,362	-0,402	0,040	2,943
July 1996	July	2,944	2,899	2,896	0,049	0,211	-0,162	2,734
August 1996	August	2,698	2,902	2,900	-0,202	-0,190	-0,012	2,888
September 1996	September	1,991	2,903	2,902	-0,911	-0,832	-0,079	2,824
October 1996	October	2,149	2,898	2,900	-0,751	-0,679	-0,072	2,829
November 1996	November	2,799	2,892	2,895	-0,096	-0,195	0,100	2,994
December 1996	December	3,583	2,907	2,899	0,683	0,526	0,158	3,057
January 1997	January	4,078	2,921	2,914	1,164	1,166	-0,002	2,912
February 1997	February	3,594	2,954	2,937	0,657	0,607	0,050	2,987
March 1997	March	3,454	2,961	2,957	0,497	0,588	-0,091	2,866
April 1997	April	2,609	2,984	2,972	-0,363	-0,181	-0,182	2,791
May 1997	May	2,442	3,008	2,996	-0,554	-0,617	0,064	3,060
June 1997	June	2,708	3,008	3,008	-0,300	-0,402	0,103	3,111
July 1997	July	3,336	3,011	3,010	0,327	0,211	0,116	3,126
August 1997	August	2,786	3,047	3,029	-0,243	-0,190	-0,053	2,976
September 1997	September	2,265	3,080	3,063	-0,798	-0,832	0,034	3,098
October 1997	October	2,446	3,124	3,102	-0,656	-0,679	0,023	3,125
November 1997	November	2,792	3,198	3,161	-0,369	-0,195	-0,174	2,987
December 1997	December	3,623	3,234	3,216	0,407	0,526	-0,119	3,097
January 1998	January	4,504	3,273	3,254	1,250	1,166	0,085	3,338
February 1998	February	3,996	3,311	3,292	0,704	0,607	0,097	3,389
March 1998	March	3,978	3,347	3,329	0,649	0,588	0,060	3,389
April 1998	April	3,502	3,370	3,358	0,143	-0,181	0,324	3,683
May 1998	May	2,871	3,404	3,387	-0,516	-0,617	0,102	3,489
June 1998	June	3,178	3,441	3,423	-0,244	-0,402	0,158	3,581
July 1998	July	3,786	3,499	3,470	0,316	0,211	0,106	3,576
August 1998	August	3,223	3,558	3,528	-0,305	-0,190	-0,116	3,413
September 1998	September	2,536	3,591	3,575	-1,039	-0,832	-0,206	3,368

Date	Month	P (USD/kg)	MA (12)	T+C	V+S	S	V	SAS
October 1998	October	2,858	3,640	3,616	-0,758	-0,679	-0,079	3,537
November 1998	November	3,242	3,651	3,646	-0,404	-0,195	-0,209	3,437
December 1998	December	4,311	3,671	3,661	0,650	0,526	0,124	3,785
January 1999	January	5,215	3,691	3,681	1,534	1,166	0,368	4,049
February 1999	February	4,395	3,718	3,705	0,690	0,607	0,083	3,788
March 1999	March	4,567	3,749	3,734	0,833	0,588	0,245	3,978
April 1999	April	3,636	3,758	3,754	-0,117	-0,181	0,064	3,818
May 1999	May	3,102	3,765	3,761	-0,659	-0,617	-0,042	3,720
June 1999	June	3,425	3,796	3,780	-0,355	-0,402	0,047	3,828
July 1999	July	4,106	3,828	3,812	0,294	0,211	0,083	3,895

Additional Exercises

Exercise 1: Sources of price variation in the case of peaches in Mexico.

Agricultural production is largely determined by the geographical location of producer countries, the climatic conditions and crop requirements. Seasonality is a particularly important characteristic of agricultural production, since, while consumption may remain relatively constant throughout the year, production usually takes place within just a few months and such variations can lead to significant changes in price behavior.

The behavior of peach prices in the Mexican market has been used as an example. The prices selected for the case study were those recorded between 2007 and 2015 for peaches from Chihuahua destined for the Central de Abasto, or wholesale market, in Iztapalapa (Figure 2.7). As peaches are produced only in the months of July, August, September and October, Chihuahua only supplies fruit to this specific market during certain months of the year. Figure 2.8 shows the Mexican regions where peaches are grown, as well as the months in which the fruit is imported. Data was also included for the same product in the Peruvian market, where peaches are available throughout the year. Using the multiplicative method, and based on monthly peach prices in the market of Lima, Peru, the following components were estimated for the period 2007-2017:

a. The moving average
b. The centered moving average
c. The trend-cycle
d. The seasonal index (monthly)
e. Price volatilitys

Figure 2.7. Price of peaches (pesos/kg)

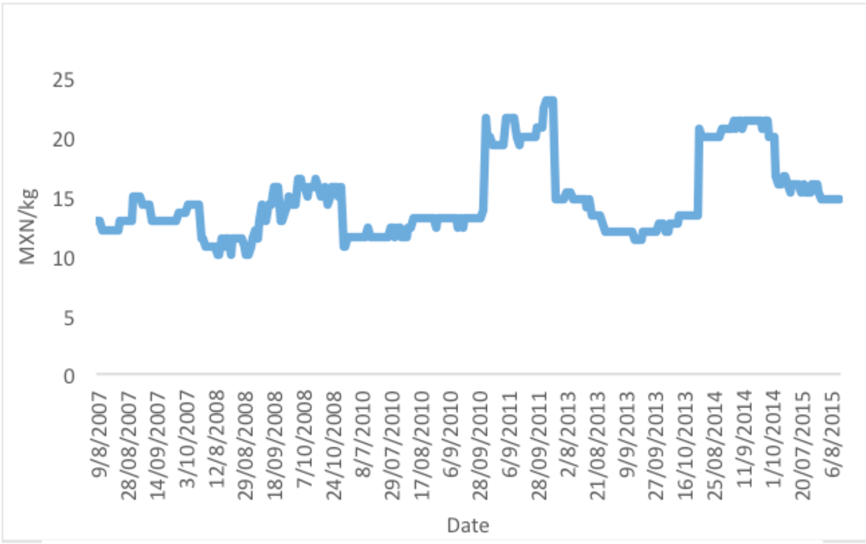
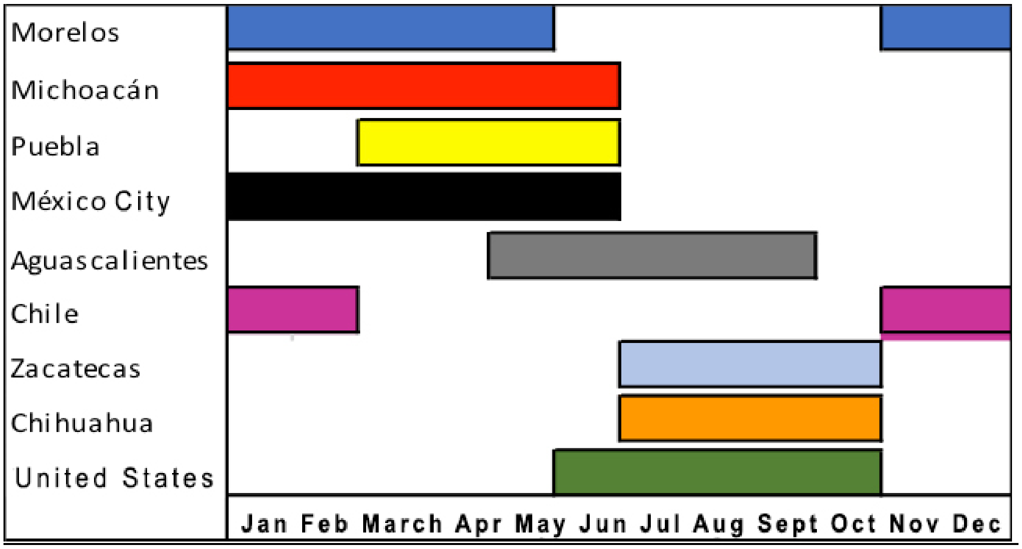


Figure 2.8. Seasonality of peach growing, Mexican market



Source: prepared based on SISAP 2017.

Exercise 2: Sources of price variation in the case of soybeans in Argentina

Barriers to trade are an important cause of price volatility, as they are designed to isolate domestic markets from international price fluctuations. Producers and consumers are isolated from the international market and the adjustment between supply and demand occurs more slowly, affecting the behavior of prices. Barriers of this kind also influence international prices, especially if a country has an important share of the world market of a product and, therefore, a major impact on the process of international price formation.

One of the objectives of liberalization policies and the WTO trade negotiations was to build an integrated world market big enough to absorb, with limited price variations, any supply or demand shocks (FAO 2011).

As noted in Chapter 1, the percentage of total consumer income spent on food decreases as income rises. For example, FAO found that spending on food accounted for 70% of personal income in Tanzania and 45% in Pakistan, compared with 10% in the United States. This proportion is directly related to product shortages that drive up prices. Prices of basic grains are usually determined by the international market, but between January 2007 and June 2008 they increased by between 37.5% (sugar) and 224% (rice). However, in real terms prices have remained similar to those of 1960, and lower than those recorded in times of crisis. Prices in international food markets continue to show an upward trend and are more volatile (with a high random component).

The monthly prices of maize, soybeans and wheat include the relationship between the exchange rate and international commodity prices. The biggest producers and consumers of soybean oil are the United States, Argentina, China, Brazil and the European Union. Changes in their production therefore have a strong impact on international soybean prices. The behavior of this product in the Argentine market was analyzed, using the multiplicative method and focusing on soybean prices during the period 1997-2017, to estimate the following:

a. The moving average
b. The centered moving average
c. The trend-cycle
d. The seasonal index (monthly)
e. Price volatility

Conclusions

Source: prepared based on Ministerio de Agricultura de Argentina 2017.

Among the various price analysis techniques that exist, univariate studies make it possible to identify the typical patterns of a time series with regard to short-term fluctuations (seasonality) and long-term fluctuations and behavior (trend-cycle). Learning how to interpret the behavior of the main components of a time series is of the utmost importance for decision making, e.g., for deciding when to plant, sell and purchase products. A better understanding of a variable's behavior also provides information that is essential for generating forecasting models.

In analyzing time series, the verification of certain aspects in particular, such as the fact that periodicity is the same throughout the series and prices are expressed in a single unit of measure, is of key importance to ensure that the correct conclusions are drawn. Furthermore, the aspects in question should be regarded as initial steps before estimating any calculation.

Another equally important point is the identification of outliers and missing data. Failure to include these aspects may alter the results of an analysis and lead to erroneous conclusions about the behavior of a price series. Complex methodologies exist for identifying outliers, but the interquartile range method is a useful basic tool for doing so. On the other hand, missing data should only be added if sufficient and accurate information is available about the behavior of the time series, so that the prices added are not at variance with the trend, cycle and seasonality.

It is important to remember that a price series can be decomposed, using either the additive or multiplicative method, in order to observe each of its components separately. Time series with high volatility are more difficult to understand than those with low volatility, because volatility is closely related to randomness in the behavior of data.

As mentioned earlier, the results of this type of analysis are extremely important for decision making, as they provide tools for decomposing price behavior into its four basic components, which are what determine it. To this end, it is of the utmost importance not only to disseminate the price analysis but also to transfer it to producers in an understandable form. In doing so, novel, innovative ways of transmitting price and market information that capture producers' attention should be sought, using tools that contain elements with which farmers are familiar.

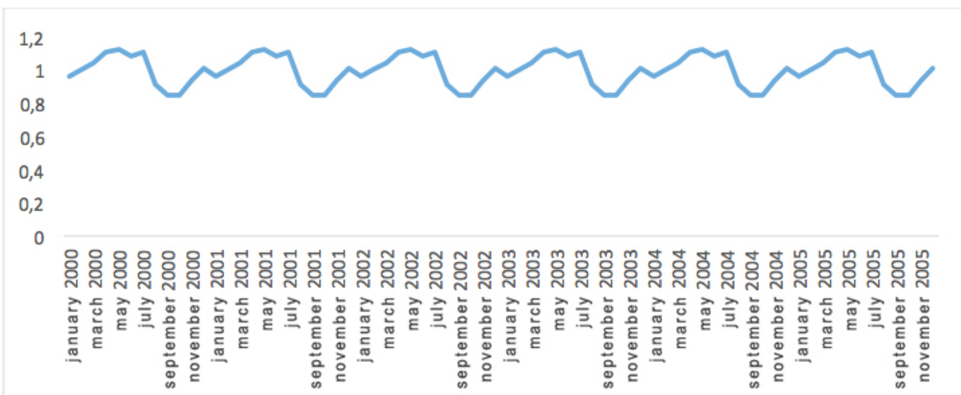
Practical example: Sources of price variation, a case study of potatoes

As mentioned in Chapter 1, the potato market is very broad and price variations over time affect both consumers and producers, which, in turn, influences the behavior of the market. Based on the behavior of potato prices described in Chapter 1 of this manual, each of the components analyzed in this chapter have been estimated. Monthly potato prices between 2000 and 2005 were used to obtain each of the price variation components described above.

The seasonal index was estimated and, as can be seen in Figure 2.9, U.S. potato prices during the months of August, September and October each year were below the average for the period, while they were above the average during the months of March, April, May and June.

In addition to seasonality, the moving average was calculated (following the procedure

Figure 2.9. Seasonality of U.S. potato production (2000-2005)

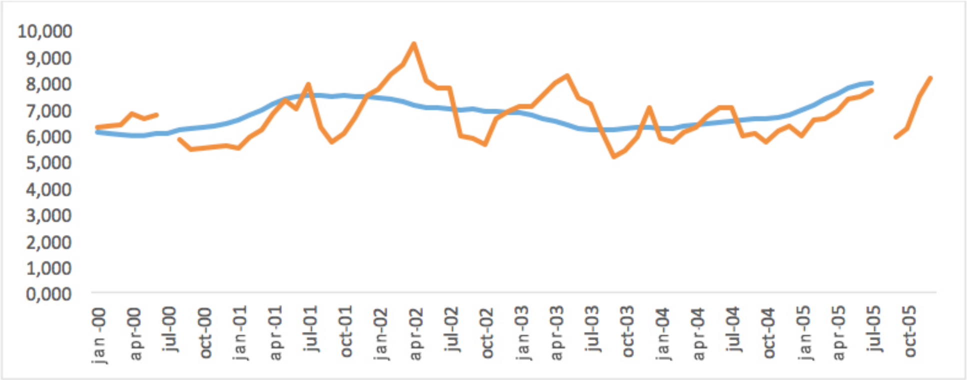


Source: prepared based on USDA 2017.

described in the examples included in this chapter). The next figure (Figure 2.10) shows the behavior of prices throughout the period, as well as the corresponding moving average. Thus, it is possible to see the long-term trend in price behavior. Roughly speaking, from May 2001 to May 2003 there was a downward trend in prices, while from January 2000 to May 2001 and May 2003 to May 2005, there was an upward trend.

The question of how to predict the behavior of such increases or falls in the prices of an agricultural product is addressed in chapters 3 and 4 of this capacity building manual, which describe and suggest some methodologies for forecasting price behavior over both the short and long run.

Figure 2.10. Behavior of U.S. potato prices and the trend (2000-2005)



Source: prepared based on USDA 2017.

Communication of the results

Correct interpretation of the components of a time series is vital to enable all the actors in the market to make timely decisions, especially government officials directly involved in the design and implementation of agricultural policies. Therefore, the representation of these components in a form that is clear and easy to understand can be a key communication tool for helping producers to understand the behavior of the components in a market.

Costa Rica's National Production Board has an Agrifood Information System that generates periodic reports to disseminate the prices of some agricultural products. The table included below is one way of representing the seasonality of tomato prices in Costa Rica. The negative symbols (-) indicate that the price is below the average, and the positive ones (+) that it is above the average. A colored scale was also generated, in which green indicates the year's lowest prices (September), and red, the highest (December).

Month	Price variation
January	2,33%
February	0,83%
March	-10,62%
April	-11,25%
May	-11,33%
June	-14,64%
July	1,49%
August	9,37%
September	-21,05%
October	0,30%
November	15,38%
December	39,18%

¢ Low ¢ High

The complete report is available in SIA/CNP 2016.

CHAPTER 3

Technical analysis of prices

Introduction

The observed price of an agricultural product results from the interaction of the supply and demand forces, whereby the former push prices up and the latter, down. In a market environment with many suppliers and consumers, players with balanced power and equal access to information, prices could be fixed quite efficiently. This means that they would result exclusively from the supply-demand interaction. In such a scenario, prices would purely and immediately reflect the known market information (Martinez-Barbeito, 2014).

Markets should ideally behave as described above. However, most of the times prices are not necessarily formed on the basis of an efficient process, and they are impacted by factors such as marker power, asymmetric access to information, barriers to market penetration, among others.

From this perspective, market behavior may be somehow predictable since it becomes possible to identify certain patterns in terms of trends, cycles or seasonality – as discussed in Chapter 2 of this Manual – that serve as a diagnosis of when to buy or sell a given farm or agricultural product. It is worth noting that the more efficient the market conditions, the less predictable the price and, hence, the harder it will be to anticipate market behavior. According to Malkiel (1973), efficient markets respond quickly to new information, but this cannot be predicted. Conversely, less efficient markets assume that all of the information available cannot be fully assimilated by the prices in the short term, so some players (who do have access to all of the information) reap greater benefits than the average market players.

In this context, even when price behavior patterns are identifiable, prices might be hard to read without a solid technical analysis, especially due to their random component (volatility). According to Arias et al. (2003), price analyses take into account some essential factors, namely: political decisions, economic theory, available indicators, as well as the current status of the world market and the expectations of the players of the agricultural supply chain, among others. At this point technical analyses are no longer subjective, since the price itself contains the necessary information to produce forecasts and make timely decisions.

Experience has shown that the agricultural sector is exposed to a high level of risk vis-à-vis other industries due to the fact that production is subject to sensitive conditions such as floods, droughts, hurricanes, pests, etc. (Sumpsi, 2011). Therefore, performing a technical analysis becomes even more important to identify behavior patterns and provide the necessary tools to draw the best possible conclusions with the available information.

This chapter is aimed at describing the meaning of technical price analysis through description and explanation of some basic technical analysis methods. These methods will be illustrated to facilitate understanding and show their adoption for decision making purposes.

3.1 Basic Notions to Approach the Technical Analysis of Prices

Before addressing the issue of methodologies and calculations, it is necessary to understand certain basic notions related to market behavior and the so-called price series. The first theoretical (but essential) concept to understand market behavior is the differentiation between efficient markets vs. perfect markets.

The concept of efficient market is closely related to information access. Gene Fama referred to this concept for the first time in 1970, arguing that those markets whose prices constantly assimilate all available information should be called "information efficient markets". Therefore, in an efficient market, information is available and is processed on a timely basis so that prices quickly react to it. These markets do not allow for above-average long-term results (Fama & Blume, 1966) because, considering that prices quickly reflect new information and that future information is unpredictable, then prices become unpredictable themselves. If we assume that big changes are infrequent, then the closest we can get to future prices are those of today.

In sum, information is essential to price formation. Indeed, it is the key factor that most of the times balances supply with demand. Let us consider the following example of how the use of technology for information sharing contributes to price stabilization.

Example based on an Article by Robert Jensen in 2007

Kerala is a state in India with a large fishing industry that plays a significant role in its economy. The adoption of mobile phones by wholesalers and fishermen of this state resulted in a dramatic reduction in price dispersion, product waste, and near-perfect adherence to the law of one price – which states that the price of the same good should not differ between any two markets by more than the transportation cost between them.

To shed some more light on this example, let us assume that a product (apples) is highly valued by consumers in market ‘’X’’, so much so that they would pay a high unit price. Therefore, it becomes apparent that the profit margin of agent “A” who sells its products in such market is high. If there was another market “Y”, for instance, where apples are not as highly appreciated by consumers, it could be assumed that the profit margin of agent “B” who sells in such market “Y” is not as high. However, there has been no mention of the potential active communication between agents “A” and “B”, in which case agent “B” could opt to introduce a certain quantity of apples into the market where agent “A” operates, thus bringing about three effects:

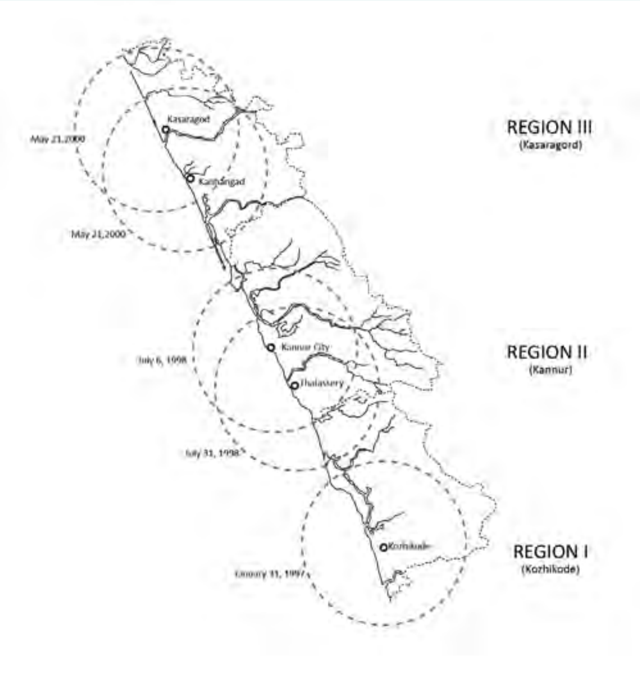
1. The prices in market “X” would fall, since the amount of apples available would increase, thus increasing supply. Here we assume that it is not only agent “B” who would introduce apples into this market, since other agents would probably follow suit after becoming aware of the greater profit margin available in such a market.

2. The prices of market “Y” would rise since fewer apples would be available here, thus reducing supply.

3. At some point the prices in both markets would be similar.

Furthermore, there were three regions identified in Kerala as shown below (Figure 3.1):

Figure 3.1. Mobile phone coverage in the districts of Kasaragod, Kannur and Kozhikode.

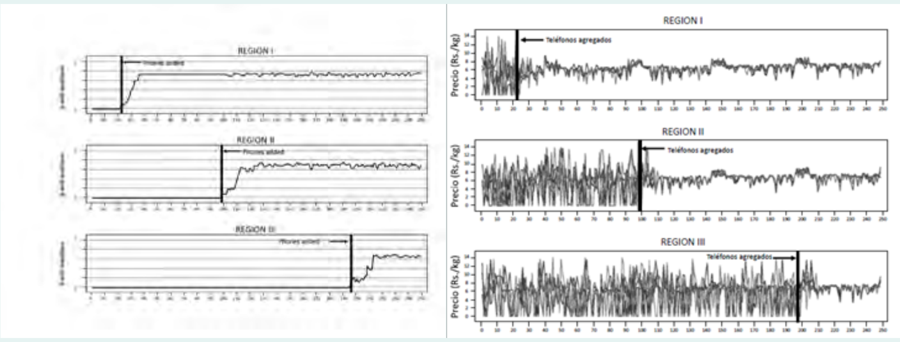


Source: Jensen 2007.

Each region represents a fishing area. It is worth noting that this activity is quite random, so the fishermen from region I could have gone fishing and have had an unproductive day. On such a day, the prices of region I would have been high because supply was low. On the same day, the fishermen from region II could have had a productive day and come back to the market with many products, thus reducing the prices in this region. Therefore, on the same day, prices could have been high in region I, and low in region II.

Due to this problem, mobile phones were adopted in each area so that fishermen could communicate when offshore and exchanging their products. Therefore, if one of them did very well on any given day, he would transfer a certain amount of fish to those with lower catches to ensure that they would go back to their relevant markets with the amount to satisfy the expected demand. This is how prices were stabilized in all regions. Figure 3.2 shows how price dispersion is directly linked to the adoption of mobile phones in each region.

Figure 3.2. Adoption of mobile phones by fishermen and prices per region.



Source: Jensen 2007.

After understanding how information impacts market prices, it is worth clarifying the concept of efficient and perfect markets, and their differences. In sum, a perfect market is based on the following assumptions:

- No Market Power. There are no customers large enough as to determine market prices, and there are no suppliers large enough so as to manipulate selling prices. For instance, if the suppliers are farmers, there cannot be one single farmer who controls a high percentage of the entire supply since, if this were the case, he would exert a certain power in terms of price fixing[3]. In theory, each producer should sell a small portion of the total market supply so that their decisions do not impact the price. It is therefore considered that producers are price takers.

[3] *See Chapter 1. Market Structures.*

• Homogeneous Products. This means that the features of available products are very similar. In this case, one product is perfectly replaceable by another, so nobody is able to charge higher prices without losing clients. This assumption is very important since it guarantees a single price in the market, which is determined by supply and demand.

• Free Entrance and Exit. This means there are no prohibitive costs or legal barriers hindering the introduction or exit of a new company into/from the market..

• Market Transparency. It means that all buyers and sellers are fully aware of the general market conditions since they have enough information about the quality of the products and their prices.

As mentioned before, efficient markets quickly adapt to new information; however, in practice, prices may take some time to reflect any event. Moreover, current prices may be determined by the same price registered sometime in the past. This behavior can be explained with autoregressive models, in which today's price consists of three components:

1. One constant (C).

2. One or more lags of the same price, i.e. the past prices of the same good can explain the behavior of a current price (P_{t-1}). This is the main reason why these models are called autoregressive.

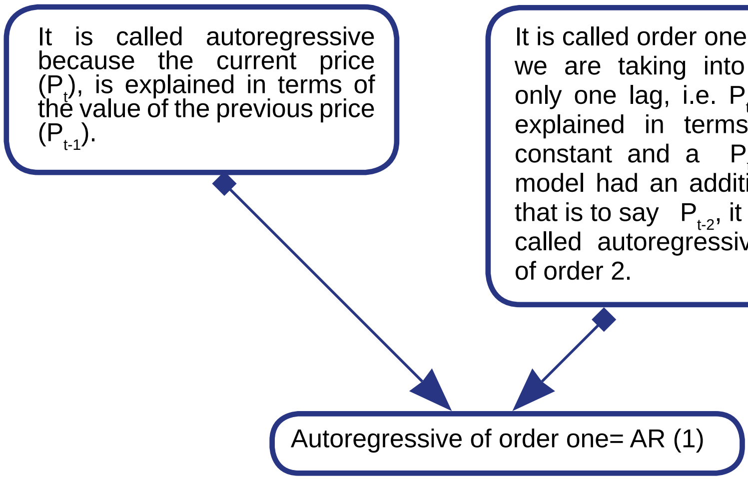
3. One random component, i.e. the portion of the prices that cannot be explained in terms of the other two components (a_t).

Let us consider the following equation illustrating an autoregressive model of order 1, also referred to as AR (1).

$$P_t = C + \varphi_1 P_{t-1} + a_t$$

Where C and φ_1 are constant values and a_t takes random values[4]. Equation 1 is then considered an autoregressive model of order one, referred to as AR (1) for the following reasons.

[4] *In addition to taking random values, a_t will be a sequence of uncorrelated and evenly distributed random variables with mean 0 (zero) and constant variance (σ_a^2). In addition, it is assumed that a_t is independent from Z_(t-1). For further information on this topic, please see the book (Hernández-Rodriguez, 2008).*



Let us consider the following model AR (2), where the price expected for today is based on the prices observed for the same goods in the two previous periods.

$$P_t=5,3-0,6P_{t-1}+0,32P_{t-2}+\alpha_t$$

It is worth noting that this analysis has been made with monthly data, i.e. if it is June, then price P_{t-1} represents the one from the previous month (i.e., the prices observed at the end of May), and P_{t-2} is the price corresponding to the end of April.

Therefore, if the price in May was USD 30 and in April, USD 28, today's price should be calculated as follows:

$$P_t=5,3-0,6*30+0,32*28+\alpha_t$$

$$P_t=32,26 +\alpha_t$$

Based on the above model, the price in June would amount to USD 32.26. Errors may randomly adopt a positive or negative value. Therefore, it cannot be asserted that the price in June will be exactly 32.26 USD because there is an additional unknown value to be added to this calculation which results from unpredictable, random events. For instance, if the price in June is finally 38 USD because of weather conditions affecting the crops, then the value of α_t would be 5.74 USD[5].

Forecasts can also be produced through weighted moving averages where the forecasted price is the outcome of a weighted average calculated "n" period ago. In general, the most relevant weighing is that of the last price since frequently the best benchmark to forecast a price is the last observed value for the same price. Let us consider the following example of a weighted moving average calculation:

Weighted Moving Average

There follows an example of price forecasting of a product for the next month with moving averages as, for example, the price of peaches for January next year. The following rationale was used to determine the most suitable type of moving average:

Table 3.1 Calculating the Weighted Moving Average

Weighing		Prices in USD							
WMA3	WMA4	Month	Observed Price	Forecasted Price WMA(3)	E	E^2	Forecasted Price WMA(4)	E	E^2
25%	10%	January	3,14						
30%	20%	February	3,10						
45%	30%	March	2,84						
	40%	April	2,38	2,99	-0,61	0,37			
		May	1,92	2,70	-0,77	0,60	2,74	-0,81	0,66
		June	2,11	2,29	-0,18	0,03	2,36	-0,25	0,06
		July	2,96	2,12	0,84	0,70	2,18	0,78	0,61
		August	2,49	2,44	0,04	0,00	2,44	0,05	0,00
		September	1,88	2,53	-0,65	0,43	2,50	-0,62	0,38
		October	2,02	2,33	-0,31	0,10	2,30	-0,28	0,08
		November	2,50	2,09	0,41	0,17	2,16	0,34	0,11
		December	3,12	2,20	0,92	0,84	2,23	0,89	0,79
		January Forecast		**2,66**			**2,59**		

[5] $P_t=32{,}26+\alpha_t$ -> $38=32{,}26+\alpha_t$ -> $\alpha_t=5{,}74$us$. *The forecasted value for June is 32.26 but, in this case, the actual price was higher due to weather conditions, resulting in a 5.74 USD difference between the forecasted and the actual price. Such difference is the so-called random component of the model due to which the accurate value of the price cannot be calculated.*

In this case, the price forecast for April is the weighted average of January, February and March according to the WMA (3), which has been calculated as follows:

$$P_{april} = 0{,}25*P_{january} + 0{,}3*P_{february} + 0{,}45*P_{march}$$

$$P_{april} = 0{,}25*3{,}14 + 0{,}3*3{,}1 + 0{,}45*2{,}84$$

$$P_{april} = 2{,}99$$

The calculation is always made by considering the three months prior, and multiplying each of them by their relative weight, and so on and so forth. Hence, the forecasted price for January next year is the weighted average of the prices corresponding to October, November and December.

The WMA (4) is calculated in the same way, but four months are weighted for price estimation, thus begging the question of which one is the most useful. The indicators shown in Table 3.2 below were obtained to answer this question:

Table 3.2. Comparison of Indicators

Indicators	WMA (3)	WMA (4)
Addition of error values	-0,33	0,09
Average of error values	-0,04	0,01
Mean error	0,36	0,34

Column E in Table 3.1 shows the Error, which is calculated by deducting the forecasted price from the observed price, thus showing the big difference between the former and the latter. If the error (E) is a negative value, it shows that the value forecasted by the WMA is lower than the actual one, thus implying that the WMA is underestimating actual values. Then, error values are added up resulting in a negative value, thus confirming that the addition of negative error values is higher than that of positive values. The foregoing is reconfirmed by the fact that the average of error values shows that the WMA(3) estimated an average price that was 0.04 times lower than the actual price. Finally, due to the fact that the average of error values is impacted by negative and positive values, the mean error is calculated by elevating the relevant amount (column E) to the second power. The WMA chosen will be the one with the lowest error values, since this means it is the one that gets closer to forecasted values. In this case, WMA(4) was chosen because the sum and average of error values, as well as the mean error, are lower than those of WMA(3).

As discussed above, any WMA or regressive model, as well as any other price analysis model, entails the analysis of a series of past price values. Over time, the prices of agricultural products –and all other prices in an economic system– are affected by a phenomenon known as inflation, thus resulting in a steady increase with the passing of the years. According to the Bank of Mexico (2017), inflation is the steady and widespread increase in the prices of goods and services of an economy over time. Price increases for a single good or service, or the increase of all prices just once, are not considered inflation.

It is certainly difficult to keep track of each and every product and its price behavior, so one may wonder how inflation is measured; it is done by measuring certain indexes in relation to a basic basket of goods and services typically consumed by households. An index is then developed based on the relative significance of these products accounting for the prices of all goods and services in an economy. Such index is known as the Consumer Price Index (CPI) and it is considered a reliable approach to measuring inflation, since it takes into account the generalized price increase in an economy. What follows is an exercise to calculate the CPI in a simplified economy.

Calculating the CPI

The CPI is calculated based on a basket of goods and services; for illustration purpsoses only, in this case, we only considered three items in order to understand how the CPI is obtained. See Table 3.3.

Table 3.3 General Components of the CPI

Item	2015	2016	2017	Expenses (in %)
Food	100	120	140	50
Transportation	50	65	80	30
Clothing	80	100	130	20

With regard to food, a price increase can be observed in the three-year period analyzed, from 100 currency units in 2015 to 120 in 2016, and 140 in 2017. The last column (Expenses %) shows the percentage of total expenses incurred by an individual in such an economy in relation to each relevant item, i.e. in this case 50% of the money spent by an individual in that economy accounts for food expenses.

Now let us calculate the corresponding CPI. Firstly, we must choose a base year to obtain a price indicator for each item. In this case we chose 2015 for the sake of simplification.

$$PI_F^{2015} = \frac{P_{15}^F}{P_{15}^F} = \frac{100}{100} = 1$$

If the same operation is repeated for the other two items, we will obtain the following results: $PI_T^{2015}=1$ y el $PI_C^{2015}=1$. The subscripts T and C account for Transportation and Clothing, respectively.

Following the same pattern, we can calculate the CIP for 2015 with the following formulae:

$$CPI_{2015}=PI_A^{2015}*50+PI_T^{2015}*30+PI_C^{2015}*20$$

In this case (2015) all CPI equal 1, thus:

$$CPI_{2015}=1*50+1*30+1*20=100$$

The foregoing shows that to calculate the CPI it is necessary to have a base year, the CPI of which will always be 100.

Now let's calculate the CPI for 2016:

$$PI_F^{2016}= \frac{P_{16}^F}{P_{15}^F} = \frac{120}{100} = 1,2$$

$$PI_T^{2016}= \frac{P_{16}^T}{P_{15}^T} = \frac{65}{50} = 1,3$$

$$PI_C^{2016}= \frac{P_{16}^C}{P_{15}^C} = \frac{100}{80} = 1,25$$

Therefore, the CPI for 2016 is obtained as follows:

$$CPI_{2016}=1,2*50+1,3*30+1,25*20=124$$

The above calculation shows that the prices for 2016 are, on average, 24% higher than those of 2015, thus quantifying the inflation rate. The same procedure will be applied to calculate the CPI for 2017.

When prices are analyzed without considering the effect of inflation, they are referred to as actual (or constant) prices. This analysis allows us to determine if prices have actually increased or not since their upward trend may be attributed exclusively to inflation. Market prices (i.e. non deflated prices) are also referred to as current prices. Actual prices are calculated by dividing current prices by the relevant CPI.

3.2 Tools for Technical Analysis of Prices

Time has proven that economy and markets are driven by trends, since there is a relationship between current prices and those of previous periods. Therefore, price trends could be a useful tool to determine their behavior or, at least, anticipate their future increase or decrease. Analyzing price behavior contributes to decision making by reducing the degree of uncertainty. By way of illustration, a price rising trend may last for several periods, so anticipating for how long such a trend will last may impact on the decision of whether to enter a given market or not.

As mentioned in Chapter 2, the first recommendation for decision making is to plot time series in graphics to understand their behavior, analyze them and identify influential factors. Observing the price behavior graphically shows at a glance whether recent periods experienced falling or rising trends. However, graphical analyses are not enough to make the right decisions. Therefore, this chapter seeks to provide market players with a series of non-exhaustive tools to begin analyzing prices for decision-making purposes.

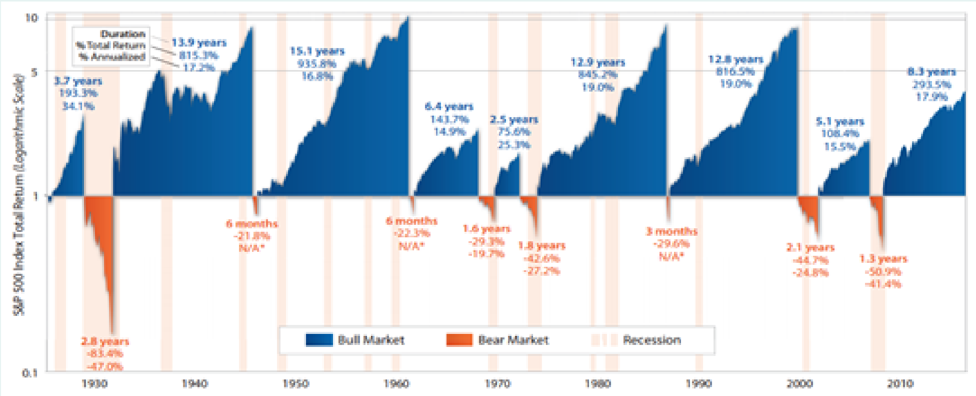
Stock markets are commonly regarded as bearish or bullish according to their price trends. Bear markets are characterized by falling prices and a pessimistic attitude towards market behavior, whereby shareholders sell their shares because they are depreciated with the passing of time. Conversely, bull markets show rising prices and an optimistic approach towards the market itself. The following example shows how the price trend of shares of stock can be used to determine market behavior.

Bear and Bull Markets in the United States

The Standard & Poor's 500 Index, aka S&P 500, is one of the main indicators used in the US to understand market behavior, since it analyzes the behavior of the top 500 US companies. Therefore, global rising and falling market trends in the US economy have been determined based on such S&P 500 Index. Rising stock prices represent a bull market, whereas falling prices correspond to a bear market (See Figure 3.3).

This type of information shows the general status of a country's economy. For instance, in 1930 there was a 2.8-year period with a falling trend in share prices, which corresponds to the economic crisis of 1929.

Figure 3.3. Bear and Bull Market Periods in USA according to S&P500



Source: First Trust Advisors 2017.

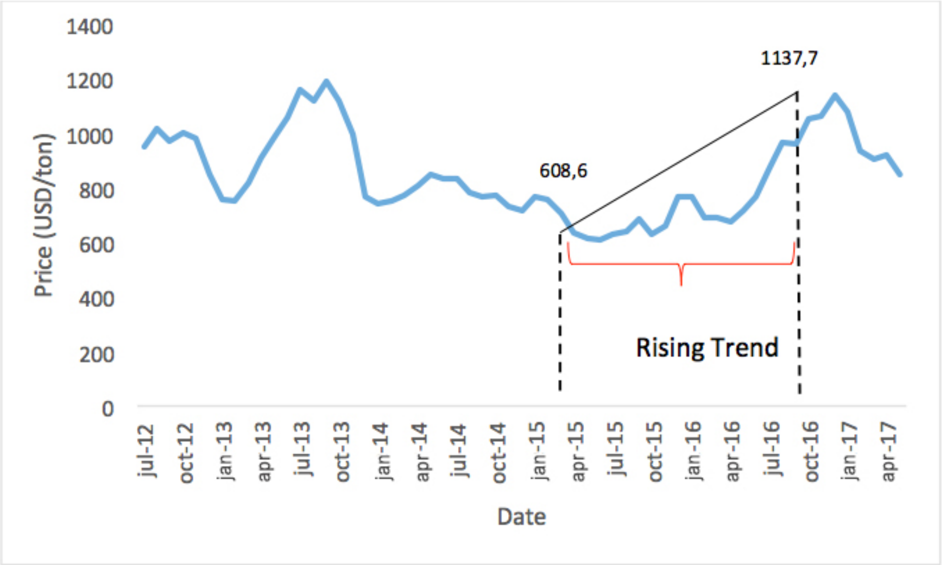
Now, considering this type of visual charts, the key to anticipating price behavior is identifying how long the rising and falling trends will last because, as previously analyzed, markets adopt a cyclical behavior.

The analysis of the rising or falling trends for agricultural product prices does not need to involve the entire sector, as was the case of the 500 top companies considered in the previous example. Even though the prices of agricultural products are somehow related, as discussed in Chapter 1, each product can be analyzed in isolation to understand price behavior at a glance.

Regarding the graphical analysis, we can first simply outline price trends by time periods. This is achieved by identifying maximum and minimum prices in a given time series, and representing rising trends with an upward line and falling trends with a downward line. (Arias, Lizarazo, Rodriguez, & Segura, 2003).

The following graph shows the prices of oranges over the period between July 2012 and April 2017 (Figure 3.4). This period saw a rising trend from May 2016 – when prices reached 608.64 USD/ton – to November 2016 – when prices amounted to 1137.7 USD/ton. A rising trend is shown here. However, this does not mean that the prices for each consecutive month were higher than those of the previous one, but that there is a rising trend on average.

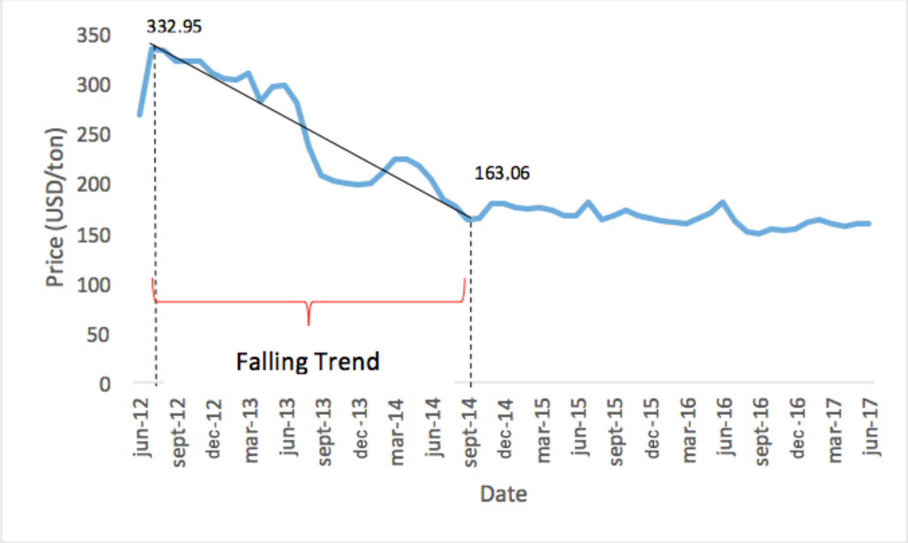
Figure 3.4. Orange Prices (USD/metric ton)



Source: Based on Indexmundi 2017.

For maize prices, the trend (Figure 3.5) is just the opposite. The period analyzed shows a downward trend, with July 2012 showing the highest price for the entire period (332.95 USD/ton). This price experienced a downward trend until it reached 163.06 USD/ton in September 2014. The above, however, does not mean that the price for each month was lower vis-à-vis the previous one.

Figure 3.5 Maize Prices (USD/metric ton)



Source: Based on Indexmundi 2017.

Regarding the decisions that could be made based on this first analysis, it would make sense to enter bull markets and exit bear markets. However, a key aspect of trend analysis is understanding when rising trends may change and vice versa, since this could be key to identifying the best moment to start or end a business.

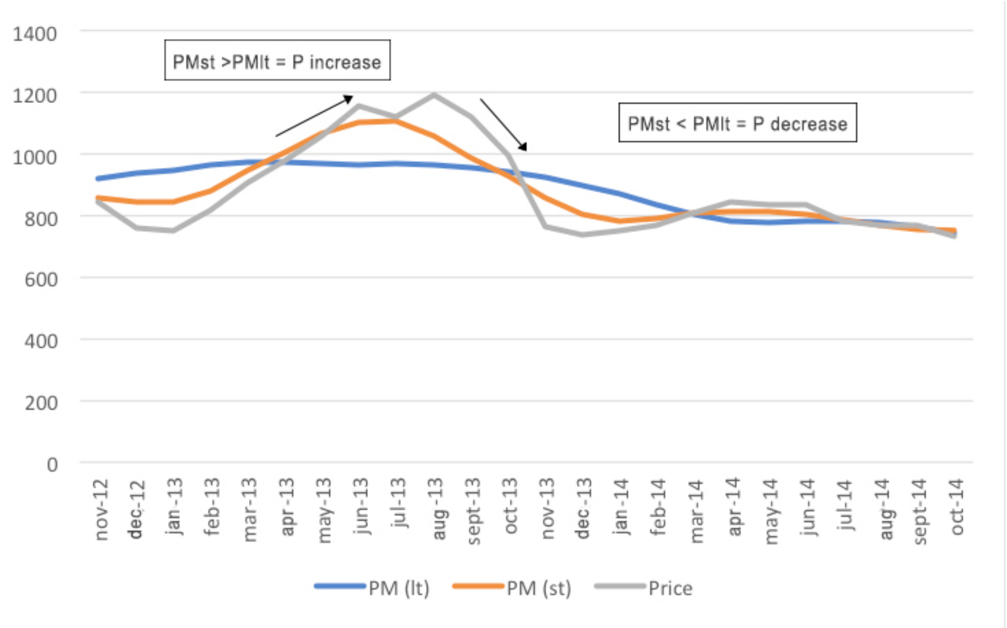
The following decision-making rule may be applied to anticipate rising or falling price trends based solely on graphic representations:

- If the trend line is an upward line, it is expected to remain as such while the subsequent minimum prices are still above the trend line.
- If, however, the trend is represented by a downward line, it is expected to remain as such while the maximum prices are still below the line.

A useful tool to analyze price behavior without relying only on data observance is the use of moving averages since, as explained in Chapter 2, they contain information on the prices for previous periods, which largely account for current price behavior. Trend behavior can be analyzed in a given time series by comparing current prices with moving averages (MA). If the MA is higher than current prices, a rising trend can be expected, whereas the opposite may occur if the MA is below current prices.

Notwithstanding the foregoing, the time period considered to determine the MA is of the essence for correct price forecasting. Given that MAs are normally calculated over longer periods of time (i.e. one year = 12 months), shorter term analyses are required to anticipate market behavior. Figure 3.6 below shows an example of a long term MA (12 months) and a short term MA (6 months) in relation to the prices of oranges discussed above. As explained in Chapter 2, the MA (lt) is used for annual averages, whereas the MA (st) is used for six-month periods. It is worth noting that the period analyzed will depend on the production cycle of each relevant product and must not necessarily be 12 and 6 months.

Figure 3.6. Long Term (12 months) and Short Term (6 months) Moving Average

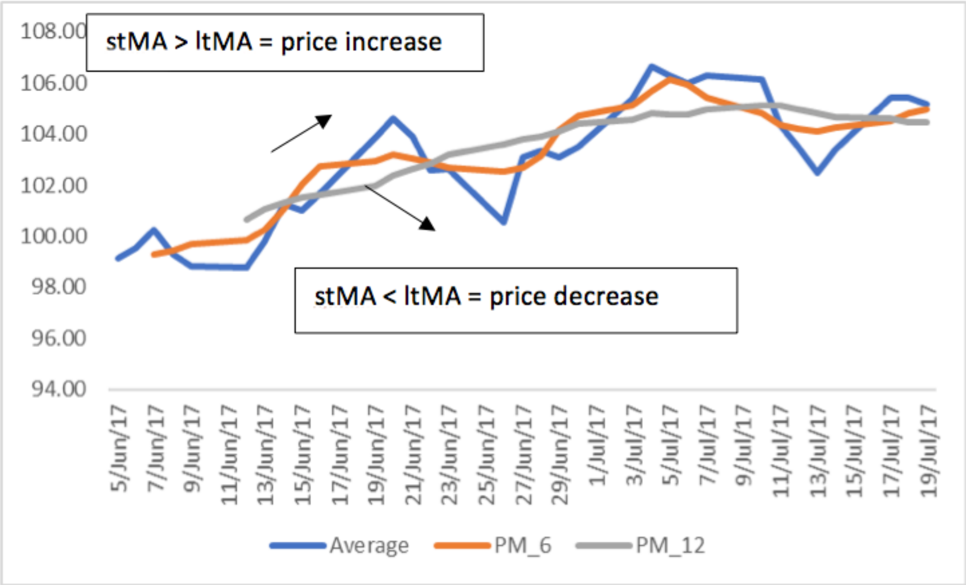


Source: Based on Indexmundi 2017.

If daily prices are available, indicators can provide data in an even shorter term, allowing farmers to make more informed decisions regarding prices. For instance, they may identify which market offers better prices and, hence, in which one it is more convenient to sell their products. However, to calculate the MA of shorter terms, such as weeks or days, greater data availability is required and prices need to be recorded on a daily basis.

Figure 3.7 shows daily coffee prices as recorded by the International Coffee Organization (ICO). The 12-day moving average (ltMA) and 6-day moving average (stMA) were estimated. When the stMA is higher than the ltMA (June 9-11 and 15), it means that prices are about to rise, as shown in the dates refered to.

Figure 3.7. Daily Coffee Prices and their Short and Long Term Moving Averages.



Source: Based on ICO 2017.

Below are some additional tools that may contribute to decision making.

3.2.1 Price Oscillator (OSC)

This tool is particularly useful when there is no clear price trend, since it analyzes the duration of trend changes, providing additional information to supplement the graphic analyses shown above. This tool contributes to forecasting rising and falling trends by identifying excessive supply or demand (See Table 3.4).

The simple OSC compares short and long term MAs and measures price changing rates, therefore: $OSC=MA_{st}-MA_{lt}$

Let us consider the following example: the daily prices of Robusta coffee, pursuant to the ICO, for both the US and European markets have been identified and weighted. They are shown in the Price column (USD ct/lb). The short term (6 days) and long term (12 days) moving averages have been calculated based on the above data, and they are shown in columns MA(6) and MA(12) of Table 3.4 below.

Table 3.4. Illustration of Price Oscillator Calculation

Day	Price (USD ct/lb)	MA (6)	MA(12)	OSC
8/Jun/17	98.80	99.83	100.67	-0.85
9/Jun/17	99.79	100.23	101.07	-0.84
12/Jun/17	101.26	101.07	101.32	-0.25
13/Jun/17	101.00	102.04	101.52	0.51
14/Jun/17	101.70	102.72	101.63	1.09
15/Jun/17	103.86	102.94	101.98	0.96
16/Jun/17	104.60	103.22	102.36	0.85
19/Jun/17	103.92	103.03	102.64	0.39

Source: Based on ICO, 2017 data.

If the OSC results in a positive number, the stMA is higher than the ltMA, hence the price is expected to increase because the demand is greater than the market capacity to satisfy it. Conversely, if the stMA is lower than the ltMA, the price is expected to decrease because the product supply is higher than the market demand.

3.2.2 Relative Strength Index (RSI)

The RSI is generally used in stock markets. It is a price oscillator measuring the price fluctuation rate and variations as follows:

$$RSI = 100 - \frac{100}{1+RS}$$

$$RS = \frac{MA\Delta +}{MA\Delta -}$$

MA Δ+ is the moving average of all positive price variations (i.e. profit average), whereas MAΔ - stands for the moving average of all negative price changes.

Regarding the time period to be analyzed, it should ideally be 14 days in the stock market; however, for the agricultural sector it is worth considering the number of time periods in one year, as well as the number of palnting seasons, which varies according to each product.

Below is an example to calculate the RSI of the international prices for Colombian coffee.

Calculating the RSI of Coffee Prices

The Price column (Colombia) of Table 3.5 shows the price of Colombian coffee on a monthly basis from January 2011 to June 2015. The first step to calculate the RSI is to estimate price changes, i.e.: p_t-p_{t-1}, so as to identify whether the price went up or down and determine if it was a positive (+) or negative variation (-).

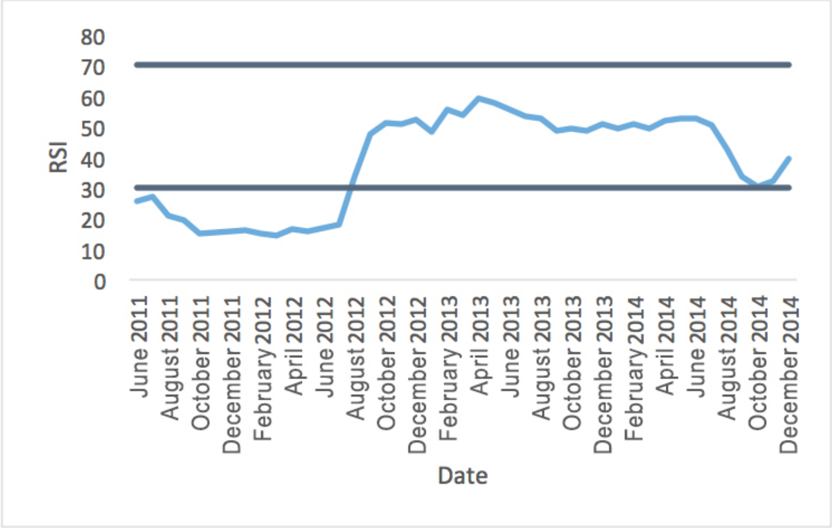
Each period without a positive variation (for instance, May 2011) is given a zero value. Likewise, a zero value is also given to those periods without negative variations.

Next the moving average is calculated based on the number of periods identified pursuant to the frequency of the data available. Two planting seasons have been considered here, i.e. 24 prices a year, since they are given on a monthly basis. Therefore, the MA was calculated on a 24-month basis, for instance MA + (24) takes the values from January 2011 to December 2012, and so forth. The RS and RSI are calculated as shown above (See Table 3.4)

To simplify the interpretation of the RSI, a chart was created (Figure 3.8) to illustrate the upper and lower price ranges and show their rising or falling indicators. The standard adopted is that when the RSI is higher than 70 or lower than 30, there are clear indicators of price variation. In some cases, ranges of 80-20 are adopted for a more conservative approach towards decision- making, since there is a broader range of price oscillation considered "normal". An RSI higher than 80 or lower than 20 indicates price variations that should be taken into account to make decisions.

In this specific case, from June 2011 to August 2012, the RSI was below 30, showing a falling price trend that could change onto a rising trend. Conversely, prices were never above 70, which means that there is no strong reason to believe that coffee prices will go down, at least during the analyzed period (Figure 3.8).

Figure 3.8. Relative Strength Index –Daily Coffee Prices



Source: Based on ICO 2017.

Prices have been recorded on an annual basis (i.e. 12 periods); however, considering that there are two growing campaigns per year, the total amount of periods to be considered is 24.

Table 3.5. Calculating the RSI for Daily Coffee Prices

$$RS = \frac{MA+(24)}{MA-(24)}$$

$$RSI = 100 - \frac{100}{1+RS}$$

Date	Prices (in Colombian Pesos)	Price Variation	+ Variation	- Variation	MA + (24)	MA - (24)	RS	RSI
January 2011	279.88							
February 2011	296.44	16.56	16.56	0.00				
March 2011	300.68	4.24	4.24	0.00				
April 2011	312.95	12.27	12.27	0.00				
May 2011	302.17	-10.78	0.00	-10.78				
June 2011	287.95	-14.22	0.00	-14.22				
July 2011	285.21	-2.74	0.00	-2.74				
August 2011	286.97	1.76	1.76	0.00				
September 2011	287.54	0.57	0.57	0.00				
October 2011	257.66	-29.88	0.00	-29.88				
November 2011	256.99	-0.67	0.00	-0.67				
December 2011	251.60	-5.39	0.00	-5.39	2.63	7.65	0.34	25.60
January 2012	255.91	4.31	4.31	0.00	2.72	7.34	0.37	27.07
February 2012	244.14	-11.77	0.00	-11.77	2.03	7.65	0.27	21.00
March 2012	222.84	-21.30	0.00	-21.30	1.86	7.65	0.24	19.52
⋮								⋮
June 2015	152.02	1.83	1.83	0.00	3.01	4.61	0.65	39.52

Source: Based on ICO, 2017 data.

Table 3.5 illustrates each of the necessary steps to calculate the RSI, which shows when to expect significant price increases or decreases. As long as the RSI ranges from 70 to 30, the market behavior can be expected to maintain its normal average. If RSI>70, a rising trend cannot be sustained so prices are expected to go down instead of up. However, in the case of RSI<30, prices are not expected to continue to fall; after reaching this threshold they are expected to rise.

3.2.3 Tracking Signal (TS)

The tracking signal is an indicator to determine if a moving average is good enough to be relied on for price forecasting. The lower the tracking signal value, the more accurate the price forecasting will be for the relevant period.

The TS is calculated by deducting the moving average from the price of a given period and dividing the result by the mean absolute deviation (MAD), which includes the absolute value of forecast errors averaged over the entirety of the forecast time periods. The following equation is used:

$$TS = \frac{|P-MA|}{MAD}$$

Where:

MA= moving average

P= price

MAD= $\frac{\sum|MA-P|}{n}$

n= number of periods

The following example shows the forecasted moving average (6 days, randomly) of daily Robusta coffee prices at the international market. The estimated error appearing in Table 3.5 is the difference between the price for the relevant period and the MA (6). The smallerthis difference is, the more accurately MA(6) will forecast price behavior during the relevant period. Table 3.6 shows the breakdown of each item.

The absolute error is then estimated since it is necessary as an input to calculate the MAD, which consists of the addition of errors and the number of time periods elapsed since the first forecasted day (n).

Table 3.6 Calculating the MAD and Tracking Signal for Daily Coffee Prices

Moving Average (6 days) — Error: Price - MA(6) — n = Number of Periods

Date	P (ct/lb)	MA	P-MA	|MA-P|	∑MA-P	MAD	n	TS
5/Jun/17	124.55	122.85	1.70	1.70	1.70	1.70	1	1.000
6/Jun/17	122.29	122.78	-0.49	0.49	2.19	1.09	2	0.445
7/Jun/17	122.11	123.01	-0.90	0.90	3.08	1.03	3	0.874
8/Jun/17	122.26	122.80	-0.53	0.53	3.62	0.90	4	0.591
9/Jun/17	122.82	122.96	-0.14	0.14	3.75	0.75	5	0.180
12/Jun/17	124.02	123.29	0.73	0.73	4.49	0.75	6	0.981
13/Jun/17	123.27	123.43	-0.16	0.16	4.65	0.66	7	0.246
14/Jun/17	123.25	123.47	-0.22	0.22	4.87	0.61	8	0.364
15/Jun/17	**124.10**	**123.02**	**1.08**	**1.08**	**5.95**	**0.66**	**9**	**1.635**

A good tracking signal must be as close as possible to zero since it means that the difference between the forecast –MA (6) here– and the actual price for this period is as low as possible.

3.2.4 Mean Absolute Percentage Error (MAPE)

The MAD used to estimate the TS is an error indicator calculated with the same units as those of the data used for the forecast, so it might not be comparable with MAD values corresponding to other products or different time periods. The MAPE can be used if a comparable (percentage) indicator is required. Let us consider the following equation where MAPE consists of the addition of the relative variation between the MA and the price (times 1/n):

$$MAPE=\frac{1}{n}*\sum\frac{|MA-P|}{MA}$$

For instance, the forecast for June 15 (as per Table 3.7) is the 9th price for this month, hence n=9 and MAPE= 0.5%. Therefore, for this specific date, the forecast deviated from the actual price by 0.5%.

Table 3.7 Calculating the MAPE

Date	n	$\sum \frac{\lvert MA-P \rvert}{MA}$	MAPE
5/Jun/17	1	0.014	1,36%
6/Jun/17	2	0.004	0,88%
7/Jun/17	3	0.007	0,83%
8/Jun/17	4	0.004	0,73%
9/Jun/17	5	0.001	0,61%
12/Jun/17	6	0.006	0,61%
13/Jun/17	7	0.001	0,54%
14/Jun/17	8	0.002	0,49%
15/Jun/17	**9**	**0.009**	**0,54%**

Therefore the MAPE for June 15, 2017 is calculated as follows:

$$MAPE = \frac{1}{9} * 0.048$$

$$MAPE = 0,54\%$$

The foregoing shows that actual prices for that date deviated by 0.54% from the prices forecasted through the MA(6).

3.2.5 Exponential smoothing

Exponential smoothing is a forecasting tool that combines its own forecasts with values observed pursuant to the following formula:

$$P_{t+1} = \theta P_t^{observed} + (1-\theta)\, P_t^{forecasted}$$

The operation above shows the price for the following period, i.e. the forecast (P_{t+1}), which will result from the weighted average of the price observed for the current period ($\theta P_t^{observed}$) and the forecasted price for the current period ($P_t^{forecasted}$).

The smoothing parameter is represented by θ and its values range from 0 to 1. Therefore, the higher it is, the greater the relevance of the observed price will be vis-à-vis the forecasted price, and vice versa. Let us review the following price series to illustrate how to implement exponential smoothing.

Table 3.8 shows the wholesale prices of strawberries per kilogram in the Peruvian market. It shows the observed prices and the prices estimated by exponential smoothing with different smoothing parameters.

Table 3.8. Illustration of an Exponential Smoothing Calculation

	August		
Month	**Observed Price**	**Smoothing (θ =0,3)**	**Smoothing (θ =0,8)**
January 2009	3,63	3,82	3,82
February 2009	3,84	3,76	3,67
March 2009	3,962	3,78	3,81
April 2009	3,94	3,84	3,93
May 2009	4,026	3,87	3,94
June 2009	3,763	3,92	4,01
July 2009	3,836	3,87	3,81
August 2009	3,882	3,86	3,83
September 2009	4	3,87	3,87
October 2009	3,66	3,91	3,97
November 2009	3,442	3,83	3,72
December 2009	3,72	3,72	3,50
January 2010	3,895	3,72	3,68
Forecast for February 2010		**3,77**	**3,85**

The column "Smoothing (θ=0.3)" is calculated with the equation (2). Let us estimate the price for February 2009:

$$P_{t+1} = \theta P_t^{observed} + (1-\theta)\, P_t^{forecasted}$$

$$P_{Feb,2009} = (0,3)*3,63_{January,2009}^{observed} + (1-0,3)*3,82_{January,2009}^{forecasted}$$

$$P_{Feb,2009} = 3,76$$

Now let us imagine that it is late January 2010 and we wish to estimate the average for February, i.e. next month. In this case, we should calculate the actual price observed in January 2010 and the forecast for such month[6].

There follows the operation used to calculate the forecast for February 2010 with exponential smoothing.

Smoothing with θ=0.3

$$P_{t+1} = \theta P_t^{observed} + (1-\theta)\, P_t^{forecasted}$$

$$P_{Feb,2010} = (0,3)*3,63_{January,2010}^{observed} + (1-0,3)*3,72_{January,2010}^{forecasted}$$

$$P_{Feb,2010} = 3,77$$

Smoothing with θ=0.8

$$P_{Feb,2010} = (0,8)*3,9_{January,2010}^{observed} + (1-0,8)*3,72_{January,2010}^{forecasted}$$

$$P_{Feb,2010} = 3,85$$

There is no rule of thumb to calculate θ; however, the same indicators used for moving averages can be used, i.e. the addition of error values, the average of error values, and the mean error. Experience tends to be the best indicator to choose the most appropriate value parameters.

It is worth considering that the lower the smoothing parameter, the fewer fluctuations there will be on a series created with this methodology. Conversely, the higher the smoothing parameter, the more similar the prices will be to observed values, thus resulting in bigger fluctuations and greater distances between the minimum and the maximum values. The following chart shows the observed series where θ=0.3 and θ=0.8.

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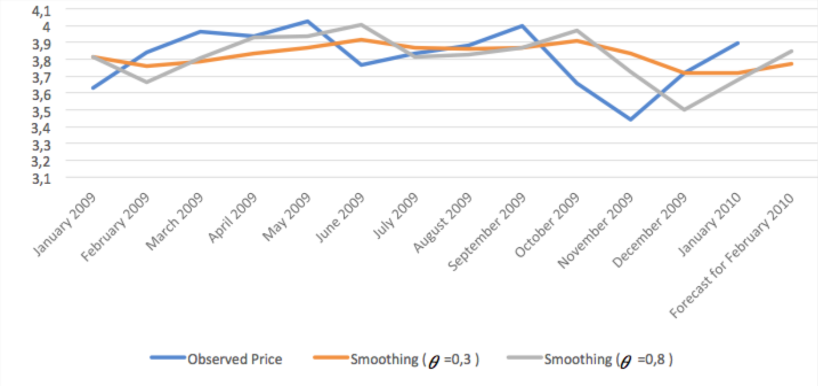
[6] *Please note that the price for January 2010 was forecasted in December 2009.*

Figure 3.9. Comparison of Smoothing Parameters



The figure above clearly shows that the series with a high smoothing parameter experiences sharper fluctuations than the one with a low parameter.

Conclusions

It may be argued that plotting time series in graphics is a mandatory first step before making any judgment regarding price behavior, since graphics provide information that can be intuitively understood in terms of trends, cycles and seasonality of any given time series.

Examining graphic data, analyzing the current scenario and considering experts' opinions should be sufficient for a basic price analysis. However, if our goal is to have a deeper understanding of price and price component behavior, a technical analysis is required. It is worth noting that basic and technical price analyses do not exclude one another, but are actually complementary.

A technical analysis of prices involves studying their past behavior to identify patterns and develop forecasts on trends, seasonality and cycles. These analyses are based on the assumption that prices accurately represent all relevant and available market information about agricultural products, and that they are not determined by chance, i.e. that they are not completely random and that some patterns and features can be identified. As a result, and through the application of certain tools, it is possible to forecast prices and better understand their behavior.

The different tools available for price analysis include the relative strength index, tracking signal, price oscillator, exponential smoothing, weighted moving averages and autoregressive models. The purpose of this is Chapter was to provide the reader with the basic notions on more complex forecasting models, such as ARIMA[7].

Finally, it is worth noting that no model is 100% reliable, so all-technical analysis tools used to forecast prices have a margin of error. This is due to the random component of all prices that consider the observed price close or far from the forecasted value. The foregoing is very important when it comes to the farming and agricultural sector since it is quite a sensitive industry, not only due to market factors but also to external events such as weather conditions (hurricanes, droughts), fees, food safety barriers, pests, harvesting cycles, among others.

[7] *The acronym ARIMA stands for Autoregressive Integrated Moving Average Model.*

Practical Example. Case Study – Technical Analysis of Potato Prices

One of the first topics discussed in this chapter was efficient markets. Considering the significance of data availability in price formation processes, we have analyzed the behavior of potato prices in the US since it is one of the main crops at world level, especially in the US market. Therefore, a large part of the population, regardless of their social class, is impacted by the behavior of potato prices, particularly the lower classes that spend more in food on proportion to their income level.

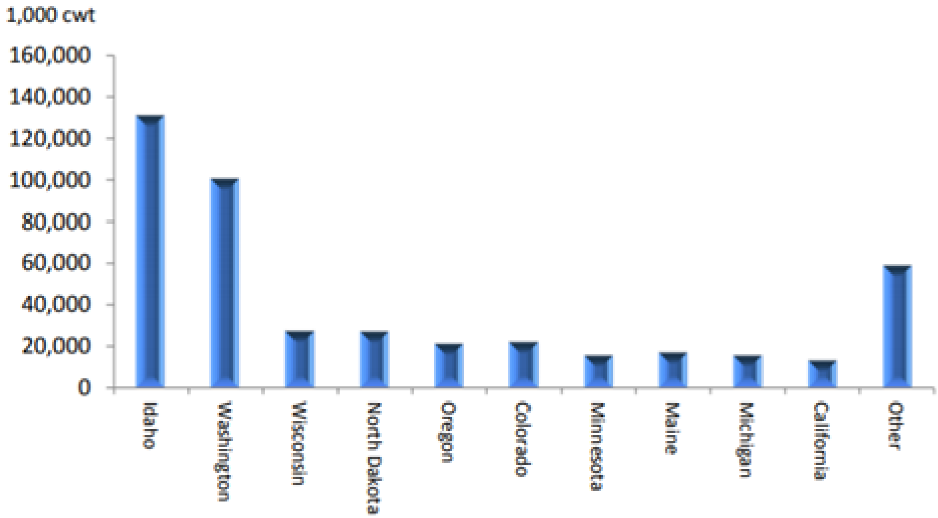
Food banks represent a valid alternative for food redistribution in order to mitigate poverty and safeguard food safety. Some benchmark international research centers argue that food scarcity is more attributable to food distribution than production. Food banks opted to use competitive markets with many buyers and sellers; however, one of the problems posed by this system is that there are some regions with an excess of supply, whereas other regions suffer from a shortage of the same product.

The US federal government ensures the existence of a food bank in each state to introduce agricultural products in different states throughout the country. However, supply and demand are not yet balanced by product distribution. For instance, Idaho is one of the main potato producers in the US (Figure 3.10), and its food bank director refused to receive any more potatoes because warehouses were still full from previous shipments. This is a classical supply issue resulting from centralized management, since before 2005 new donations would be sent to the food bank ranking first on the waiting list (Mullainathan, 2016). To make up for the food surplus in certain places and the shortage in others, a virtual bidding system was adopted for each food bank to submit their tenders. Therefore, those requiring more potatoes, for instance, would attach a higher value to such a product (higher virtual bid). The value, therefore, behaves as an indicator of the needs of each region.

This system proved quite profitable in many regards, but for now let us focus on potatoes. Thanks to this system, the food banks with a surplus (oversupply) managed to sell their surplus. The Idaho bank, for instance, sold the excess of potatoes and bought other products. These transactions resulted in a redistribution of 6 million kilograms of products on a yearly basis. Donations also increased since products were more efficiently allocated and no longer rejected (Mullainathan, 2016).

The reference to potato supply in the food bank of Idaho was not random since potato production in Idaho, together with Washington, accounts for more than half of the annual production of this crop in the US, as shown in Figure 3.10.

Figure 3.10. Potato Production per State in USA (1000 cwt)



Source: USDA 2016.

Within the USDA, there is one specific division devoted to managing the data on prices, production and farms, thus ensuring access to information by both producers and consumers. In addition, there is online information on where to buy each relevant product, so the data relating to points of sale is also made available (AgMRC, 2014).

For a better understanding of this manual, the following exercise includes an analysis of potato prices at the farmers' level with the tools presented. The first step was to make a forecast based on a six-month moving average MA (6) as shown in Figure 3.11.

Figure 3.11. Potato Prices vis-à-vis MA (6)

Source: Based on USDA 2017.

Next, the MAD, Tracking Signal and MAPE (Table 3.9) were calculated to analyze the behavior of potato prices as described throughout this manual. By way of illustration, Table 3.9 shows that the forecast for February and March 2002 was slightly below the actual price for these months, thus the Tracking Signal was negative, showing that there was an almost 5% difference between the observed and forecasted prices.

The months with the largest gap between forecasted and actual prices show a higher MAPE, such as October 2001 (MAPE = 5.19%), April 2002 (MAPE = 5,00%), October 2002 (MAPE = 5.61%) and November 2002 (MAPE = 5.47%).

Table 3.9. Calculating the Tools for Technical Analysis of Potato Prices in USA

Date	No.	Price	Forecast	Absolute Error	Cumulative Error	MAD	TS	MAPE
Jan-00		6,30						
Feb-00		6,35						
Mar-00	1	6,40	6,53	0,13	0,13	0,13	-1,00	2,04%
Apr-00	2	6,80	6,58	0,22	0,35	0,17	0,48	2,67%
May-00	3	6,60	6,49	0,11	0,46	0,15	1,25	2,33%
Jun-00	4	6,75	6,33	0,42	0,87	0,22	2,78	3,39%
Jul-00	5	6,60	6,12	0,48	1,36	0,27	4,02	4,30%
Aug-00	6	5,80	5,94	0,14	1,50	0,25	3,80	3,98%
Sep-00	7	5,45	5,75	0,30	1,80	0,26	2,53	4,15%
Oct-00	8	5,50	5,57	0,07	1,87	0,23	2,50	3,79%
Nov-00	9	5,55	5,58	0,03	1,90	0,21	2,61	3,43%
Dec-00	10	5,60	5,71	0,11	2,01	0,20	2,20	3,28%
Jan-01	11	5,50	5,93	0,43	2,43	0,22	0,08	3,63%
Feb-01	12	5,90	6,22	0,32	2,75	0,23	-1,31	3,75%
Mar-01	13	6,20	6,45	0,25	3,00	0,23	-2,38	3,76%
Apr-01	14	6,80	6,85	0,05	3,05	0,22	-2,75	3,55%
May-01	15	7,30	6,92	0,38	3,43	0,23	-0,95	3,68%
Jun-01	16	7,00	6,83	0,17	3,60	0,23	-0,22	3,60%
Jul-01	17	7,90	6,71	1,19	4,79	0,28	4,05	4,43%
Aug-01	18	6,30	6,60	0,30	5,09	0,28	2,98	4,44%
Sep-01	19	5,70	6,68	0,98	6,08	0,32	-0,44	4,98%
Oct-01	**20**	**6,05**	**6,66**	**0,61**	**6,68**	**0,33**	**-2,24**	**5,19%**
Nov-01	21	6,65	6,99	0,34	7,03	0,33	-3,26	5,18%
Dec-01	22	7,50	7,48	0,02	7,04	0,32	-3,36	4,95%
Jan-02	23	7,75	8,05	0,30	7,34	0,32	-4,31	4,90%
Feb-02	24	8,30	8,28	0,02	7,36	0,31	-4,43	4,70%
Mar-02	25	8,65	8,33	0,32	7,68	0,31	-3,39	4,67%
Apr-02	**26**	**9,45**	**8,34**	**1,11**	**8,78**	**0,34**	**0,20**	**5,00%**
May-02	27	8,05	7,95	0,10	8,88	0,33	0,51	4,86%
Jun-02	28	7,80	7,48	0,32	9,20	0,33	1,47	4,84%
Jul-02	29	7,80	6,85	0,95	10,15	0,35	4,10	5,15%
Aug-02	30	5,95	6,61	0,66	10,81	0,36	2,15	5,31%
Sep-02	31	5,85	6,46	0,61	11,42	0,37	0,45	5,44%

Date	No.	Price	Forecast	Absolute Error	Cumulative Error	MAD	TS	MAPE
Oct-02	**32**	**5,65**	**6,34**	**0,69**	**12,11**	**0,38**	**-1,39**	**5,61%**
Nov-02	**33**	**6,60**	**6,53**	**0,07**	**12,18**	**0,37**	**-1,24**	**5,47%**

Source: Based on data from USDA 2017.

Additionally, the forecast and actual prices for February 2002 were exponentially smoothed with two random smoothing parameters for the purposes of comparison. The higher the smoothing parameter, the closer the forecasted price gets to the actual one, since the latter acquires a higher relative value or, in other words, the former gets a lower relative value.

Table 3.10. Example of Exponential Smoothing

/	Prices in USD		
Month	**Observed Price**	**Smoothing (θ=0,5)**	**Smoothing (θ= 0,9)**
Jan-01	5.5	6.66	6.66
Feb-01	5.9	6.08	5.62
Mar-01	6.2	5.99	5.87
Apr-01	6.8	6.09	6.17
May-01	7.3	6.45	6.74
Jun-01	7	6.87	7.24
Jul-01	7.9	6.94	7.02
Aug-01	6.3	7.42	7.81
Sep-01	5.7	6.86	6.45
Oct-01	6.05	6.28	5.78
Nov-01	6.65	6.16	6.02
Dec-01	7.5	6.41	6.59
Jan-02	7.75	6.95	7.41
Forecast for February 2002		**7.35**	**7.72**
Actual Price for February 2002	**7.75**		

Source: Based on data from USDA 2017.

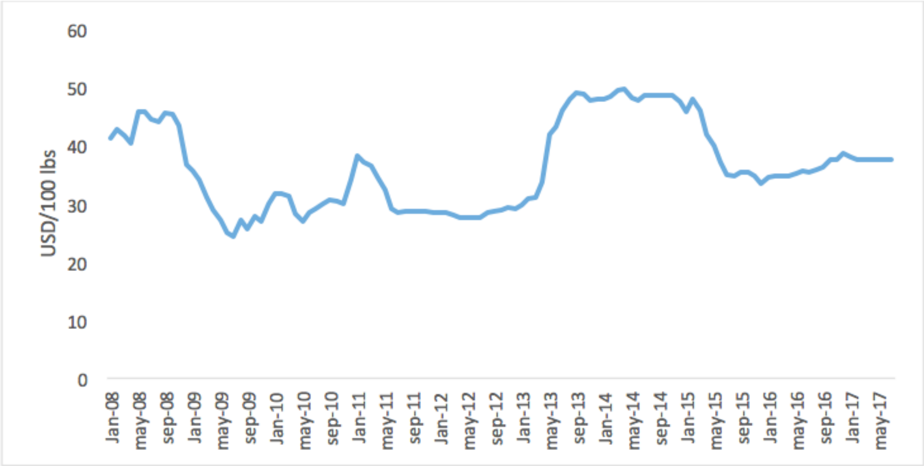
Additional Practice

Exercise 1. Technical Analysis of Rice Prices in Bolivia

Below is an example of monthly wholesale prices of rice in La Paz, Bolivia expressed in USD/100 lbs. (weight unit equivalent to 46 kgs.)

The data for the period from January 2008 to the present is shown in Figure 3.12.

Figure 3.12. Rice Prices in La Paz, Bolivia (USD/100 lbs)



Source: Based on GIEWS 2017.

Please make the following calculations based on the historical prices of rice in Bolivia:

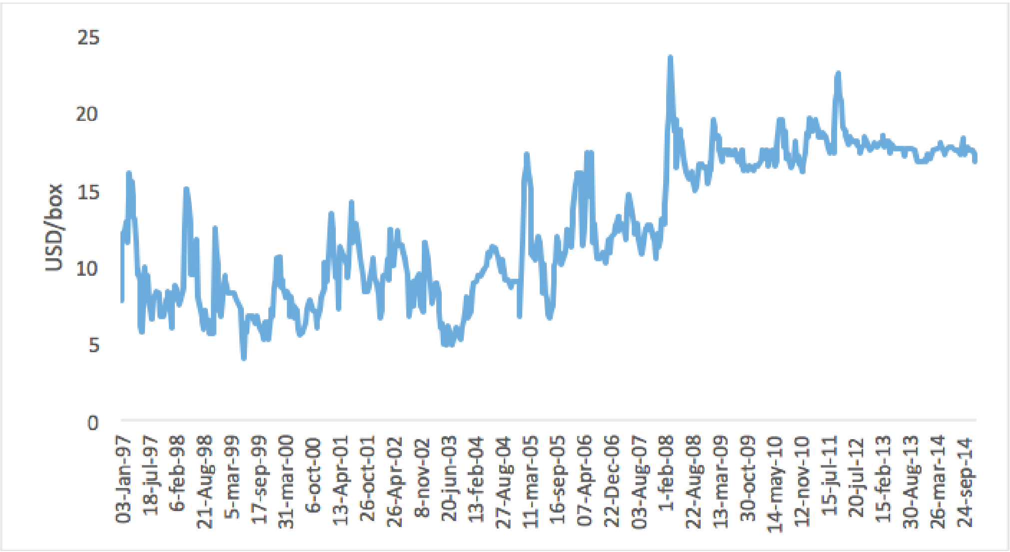
1. Calculate the relative strength index for the given time period.
2. Plot the results in a chart and determine when prices can be expected to rise or fall, regardless of normal fluctuations.
3. Prepare a forecast for March 2017 with exponential smoothing, where $\theta = 0.6$.

Exercise 2. Technical Analysis of Banana Prices in Central America

We gathered the international prices for Central America bananas, which are expressed in USD/box, each of which weighs 18.14 kg.

1. Please use the interquartile method to identify outliers in the banana price series.
2. Calculate the RSI and determine when prices could have been expected to rise or fall according to this indicator.

Figure 3.13. Banana Prices in Central America (USD/box)



Source: Based on GIEWS 2017.

CHAPTER 4

How do agricultural markets connect?

Introduction

Western markets reached a turning point when the price of basic grains rose sharply and governments refused to promote free trade. However, the drawbacks of a closed economy became more apparent with the passage of time and as a result; governments gradually lifted their trade barriers, as shown in the following illustrative example.

Trade openness in Great Britain: Corn Laws

The modern history of free trade dates back to 1846 when the UK public policies began promoting trade with other countries. These policies were aimed at protecting British and Irish grain producers from the introduction of other grains at lower costs.

At that time, the Corn Laws imposed tariffs on imported grains, thus increasing their price. Due to the enforcement of these laws, the prices of both national and international basic grains skyrocketed to such an extent that consumers could not afford them anymore. This was worsened by poor harvest campaigns, and the national grain supply was insufficient to satisfy the demand. Therefore, the price of basic grains became prohibitive and resulted in a famine, the famous Great Irish Famine.

As a consequence, the British Parliament allowed grain imports for the first time as a result of prioritizing the general economic interests of the population and in order to mitigate the famine in Ireland and offer more affordable prices. With an insufficient amount of grains, the solution was to open trade to increase supply and, therefore, reduce prices.

The above example is known as the first step in history towards free trade. Also, the first free trade agreement was signed between the United Kingdom and France in 1869 (the Cobden–Chevalier Treaty), which paved the way for the many subsequent multilateral treaties that nowadays represent the main instruments for trade promotion.

International trade has undergone many changes in modern history, but as a result of these international conflicts, different joint efforts were made for the promotion of peace and trade. According to economist John Mill (1848), fostering international trade can greatly contribute to ensuring world peace, since safety is promoted within a context of constant exchange of ideas. However, the assumption that trade may contribute to and promote the resolution of international conflicts stemmed from a historical process, triggered mostly by the World Wars in an attempt to restore world peace.

The modern international trade system was the result of the aftermath of World War II. In 1945, a proposal was made for a World Trade Organization with lower tariffs, no more quotas, preferences or subsidies, among other trade barriers. And it was in 1947 when the General Agreement on Tariffs and Trade (GATT) to reduce tariffs was finally negotiated and signed by 23 countries (VanGrasstek, 2013).

The economic recovery period that followed the Wold War II was experienced very differently by the countries involved, since recovery took longer for some countries than for others. However, international trade increased between 1950 and 1960, reaching unprecedented levels, even higher than before 1940. In addition, containers were invented in 1956, thus simplifying the shipment of goods and boosting trade (Feenstra &Taylor, 2008).

Even though the proposal for an international trade system was not successful at first, all of the progress made in this field contributed to turning the world trade system into a multilateral trade system at the Uruguay Round (1986-1994) with the creation of the World Trade Organization (WTO), i.e. the current international trade regulating body. Nowadays, Free Trade Agreements (FTAs) are governed by the WTO regulations or bilateral agreements between the countries involved. This normally depends on the features of the relevant goods; however, agricultural products tend to be among the groups of products with greater exclusions.

Pursuant to Article XXIV, Paragraph 8 of the GATT, the duties with respect to basic trade between the parties to free trade agreements and customs unions should be eliminated; however, “sensitive” products are normally excluded from these provisions. There are some 11,000 products excluded, which account for 7 per cent of all tariff lines. These are generally agricultural products or food, and are excluded on a temporary or permanent basis (Van Grasstek, 2013).

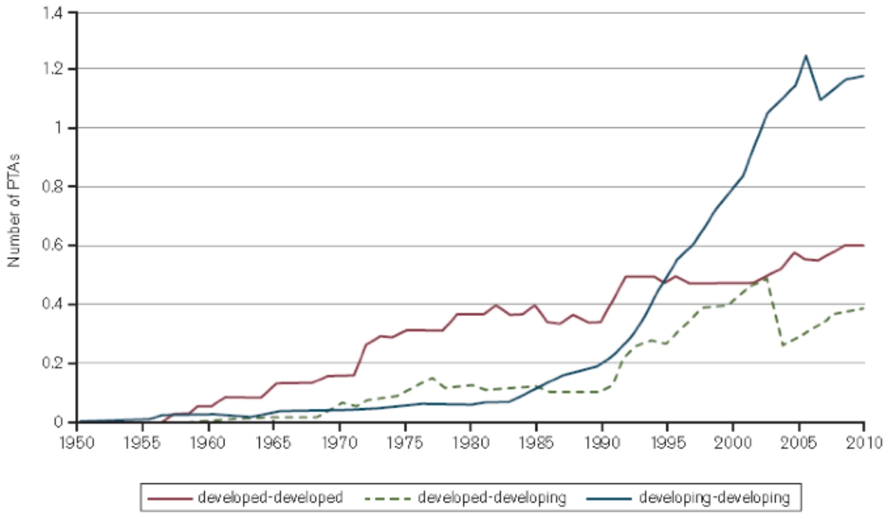
As has been explained, the agricultural sector has distinctive features that have always been considered controversial. This is due to the fact that trade is intended to reduce consumer prices but, at the same time, pressure is exerted for farmers to offer their products at lower prices.

4.1 Preferential Agreements and Market Integration

Preferential trade agreements are classified by the WTO according to the following criteria:

1. Level of Development. The level of development has been key to determine the number of trade agreements; however, since 1970 the number of trade agreements signed with developing countries has increased. Figure 4.1 shows that agreements show an overall increase, particularly those executed between developing countries.

Figure 4.1. Evolution of Trade Agreements between Developed Countries and Developing Countries



Source: From VanGrasstek 2013.

2. Geographical Coverage. The regional approach started losing ground only 10 years ago, which means that the predominant agreements are no longer those between adjacent regions. Agreements are diversifying, and by 2010 the number of intra-regional and cross-regional PTAs remained the same.

3. Types of PTAs. Bilateral, plurilateral or regional preferential trade agreements.

4. Degree of Market Integration

International trade expansion resulted in greater market integration, since the scope of the newest trade agreements goes beyond the reduction of tariffs to also cover intellectual property, technical trade issues and even conflict resolution (VanGrasstek, 2013). This means that due to the increase in trade between countries and markets, prices (and the relevant fluctuations) of a given market impact on the prices of the countries that trade with such market, especially in a free trade environment. Therefore, fluctuating prices in a country X that trades with country Y will affect the prices of Y. However, analyzing this behavior is based on certain conditions that will be addressed further in this chapter.

In addition, the price formation process in agricultural value chains is becoming increasingly significant since profit margins are being assessed, especially in terms of the percentage earned by each link in the chain, farmers generally being those who earn the less. Therefore, the question of how much of the retail price[8] is passed on to farmers, and vice versa, becomes imperative.

As already discussed, the stances adopted in relation to free trade and its potential benefits for both consumers and farmers have always been controversial, since many possible conclusions can be drawn. International trade has occasionally promoted competition and reduced consumer prices, but this resulted in a further reduction of the prices received by farmers. Price adjustments throughout the value chain resulting from external market shocks are one of the main features of efficient markets, since they depend not only on trade itself, but also on the agricultural policies of the respective countries or regions. Effects can vary and will depend, in turn, on the features of each market.

The two types of price transmission, either from international to domestic markets or throughout the value chain, depend on market integration processes. These issues will be the main focus of this chapter.

4.2 Link between International and Domestic Prices

World agricultural markets are becoming increasingly interconnected and as a result, climate or political changes in one country may affect the food price behavior of other countries. To understand better the relationship between agricultural prices, it is necessary to identify the variables due to which the effect of an event in a given market is transferrable onto another.

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[8] **Retailers** *buy large quantities of products from manufacturers or importers, either directly or through a wholesaler, but they sell units or small quantities to the general public.*

The process through which price changes in a market –or any link in the chain– cause an impact in another market –or link– is known as **price transmission**, which is the baseline to understanding the connection among agricultural markets. As discussed in Chapter 2 of this Manual, we assume that international and national market prices reflect market features, thus showing each country's protection level against business partners, its dependence on imports, and the size of its economy, among others.

To better understand the term "price transmission", it is first worth considering the two main types of transmission, namely **vertical** and **horizontal**, which are explained below:

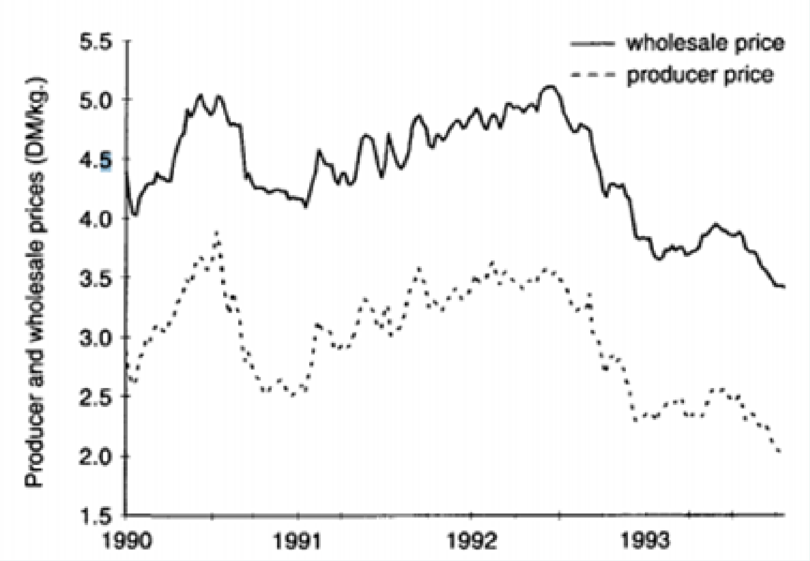
4.2.1 Vertical Price Transmission

According to (Von-Cramon Taubadel & Meyer, 2004), vertical price transmission is mainly focused on the relationship between farm-> wholesaler -> retailer, i.e. the links of the agricultural supply chain and their relationship at different levels. This type of transmission deals with how prices change at the wholesale level when there are changes at the farm level, or the price changes suffered by retailers when wholesaler prices are modified, and vice versa. Vertical transmission means that, if for any reason farmers start offering a cheaper product to wholesalers, the latter will also reduce their prices for retailers who may, in turn, decrease prices for end consumers. Below is an illustration of vertical price transmission.

Vertical Price Transmission

Von-Cramon (1997) examined the relationship between the prices offered by pork producers and wholesalers in Northern Germany noting that they behave similarly and react in the same way to market shocks, as shown in Figure 4.2.

Figure 4.2. Prices of Pork Producers and Wholesalers in Germany



Source: Von-Cramon 1998.

The above chart shows that when the prices of producers increase, wholesalers' prices follow suit and vice versa, i.e. when prices go down, they do so for both producers and wholesalers. It is worth noting that reactions in both cases are similar for both sharp price increases or decreases, and for subtle, longer-term price variations. This type of behavior is important to conclude (by simply observing the graphic analysis) that price series are closely related.

4.2.2 Horizontal Price Transmission

As opposed to vertical transmission, horizontal transmission takes into account the way in which the price of a product reacts in different places, i.e. how price variation in one region affects prices in another region, so as to identify whether they are integrated, also known as market cointegration. The concept of market cointegration will be analyzed in depth later on, but for the time being, it can be defined as price co-movement, or the transmission of price movement from one market to another, even if they are geographically apart (Goletti, Ahmed & Farid, 1995).

> Transaction costs are those that cover both trade and arbitration-associated costs. In addition to shipment and freight, transaction costs entail risk insurance, data gathering, negotiation costs, as well as the cost of remaining in a regional market (Serra, Gil & Goodwin, 2006).

The degree of transmission of market shocks from one market to another is a key indicator for determining their level of integration. It also provides significant information on market structure, infrastructure and how public policies impact market efficiency. All horizontal price transmission analyses are based on the **law of one price**, which states that the price of a product will vary from one place to another only in terms of transaction costs[9] (Hallam & Conforti, 2003). Let us consider the following example to better illustrate horizontal price transmission.

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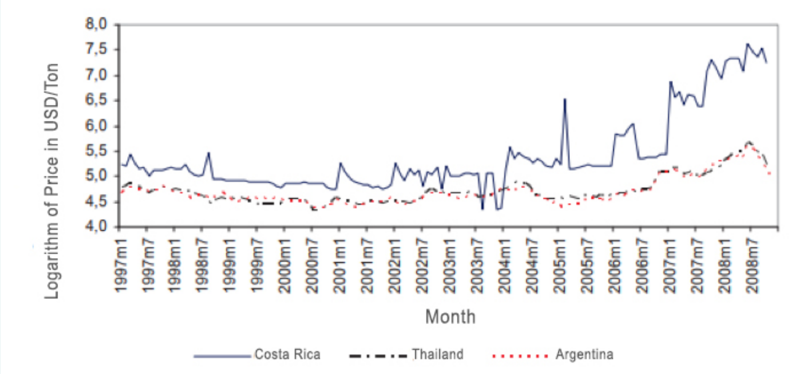
[9] For further information on transaction costs, please see (Williamson, 1979). Available at: http://www.jstor.org/stable/725118?seq=1#page_scan_tab_contents

Horizontal Price Transmission

Costa Rica is a net corn exporter, which leads to the assumption that international corn prices will affect domestic prices.

Figure 4.3. Wholesale Corn Prices in Costa Rica and International Corn Prices



Source: Dutoit, Hernández & Urrutia 2010.

The above figure shows a difference between the price considered as international and that of Costa Rica, which can be attributed to the costs incurred to import the product into Costa Rica. It also shows how Costa Rican prices behave more or less similar to international corn prices. In this case, and considering that Costa Rica imports a significant percentage of the corn consumed by this country, it becomes apparent that the variation of international prices is to some extente translated into domestic prices.

As shown in Figure 4.3, price variations in Costa Rica do not exactly imitate international price movements, thus showing that price transmission is not always symmetrical. On the other hand, when the changes in one market are immediately and equally reflected in another market, the transmission is said to be symmetrical.

4.3 Graphical Analysis of Price Transmission

As already explained, graphical analyses are a good first step to assess time periods. In this case such an analysis constitutes a first approach that helps to determine the extent of market integration, if any, among the different links in a value chain and between domestic and international markets. This is how market integration and the mutual impact of its behavior is analyzed. If two markets are integrated, it means that their prices move in the same direction and react similarly to market shocks and, thus, international prices could be used to forecast the behavior of domestic ones.

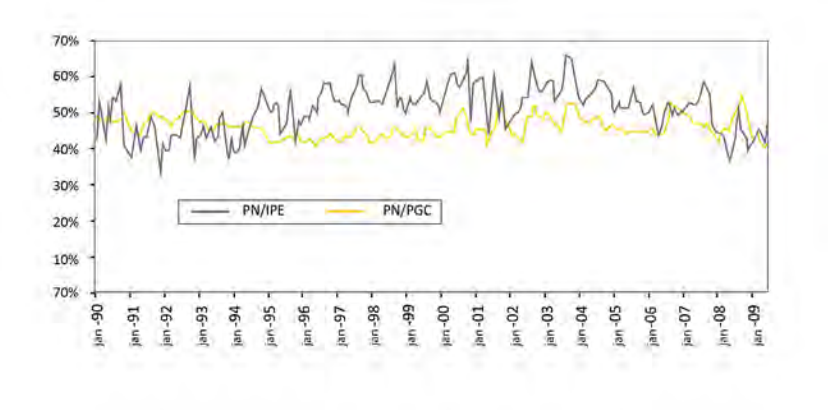
Using international prices to analyze domestic prices might be a good or a bad choice, depending on their level of integration. Below is an illustration of price variation in the links of the beef production chain in Uruguay.

Graphical Analysis: Beef Production in Uruguay (Alfaro & Olivera, 2009)

Uruguay has produced and exported beef since 1860; however, local prices have been impacted by different events throughout history. For instance, beef can only be exported with the appropiate cooling equipment. Such equipment has been manufactured by international oligopolies for a long time. On the other hand, beef exports were supported by public policies only until 1992, when the Uruguayan market opened up. Considering the above scenario, the following example analyzes the price formation of cattle for slaughter.

For this purpose, our price transmission analysis emphasizes the relationship between export and producer prices since the international market receives 70 per cent of the slaughtered cattle. Therefore, considering that Uruguay normally adopts international prices, it might be assumed that if the beef market is efficient, international prices should be transmitted to producers.

Figure 4.4 Evolution of the Relationship between Producer and Wholesale Prices.



Source: Alfaro & Olivera 2009.

In Figure 4.4, PN represents the price of standing heifers, i.e. the price at the producer level. The PGC (over-the-hook price, as per its Spanish acronym) accounts for the price paid by final consumers, whereas the IPE (average export income, as per its Spanish acronym) represents export prices. Therefore, PN/IPE represents the percentage collected by producers from the export price, whereas PN/PGC accounts for the percentage received by producers from the price charged to final consumers.

Regarding price formation throughout the value chain, the producer price (i.e. the price of standing heifers) in relation to the over-the-hook price was 40%-50%; whereas the producer price in relation to the average export income was 40%-60%, thus showing that there are other factors that affect price change and cannot be exclusively attributed to the international market.

Graphical analyses and market cointegration tests contribute to better understanding price changes in a given market. If, for instance, there is no connection between international and domestic or local prices, domestic prices should be analyzed based on local supply and demand without trying to understand local behavior in terms of international prices. However, if there is any type of connection, such analyses help identify how fast domestic prices react to international price changes.

With respect to two domestic prices, this analysis shows whether market "A" impacts market "B", or vice versa, and whether both influence each other's prices. Understanding this relationship helps to translate trends into local prices.

Difference between Causality and Correlation

It is worth noting the difference between causality and correlation, since the latter means that two time periods are related to one another, without meaning that the movements in one period are the cause of those in the other.

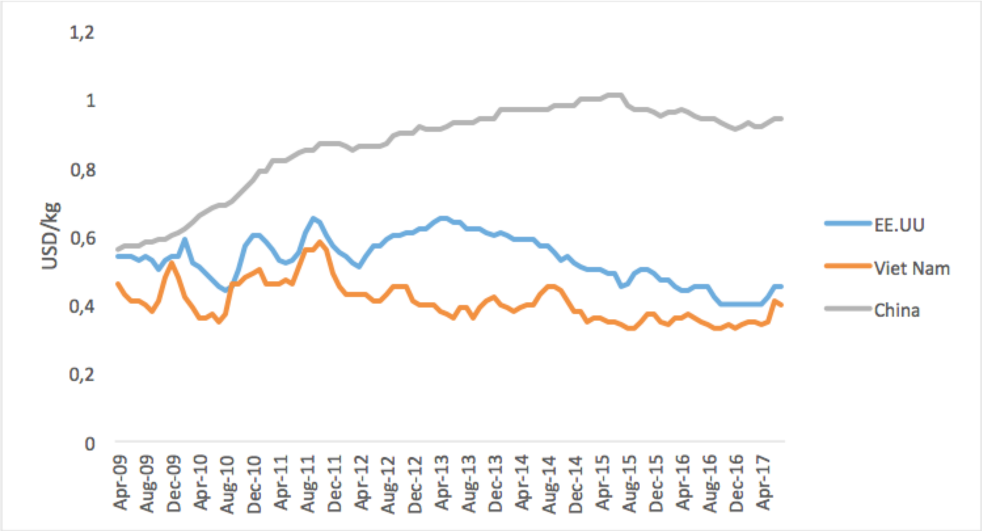
Finally, it is worth mentioning that price transmission also helps identify the patterns of many markets and commodities that can be, in turn, used to understand other trends that were not the subject matter of the original study. This is due to the fact that, as mentioned in Chapter 1, the relationships between (complementary and substitute) products impact consumption patterns and, hence, prices (Food Security Portal, 2012).

When analyzing the behavior of two or more time periods, there are at least three types of price transmission between markets. We have illustrated these transmission types with a graphical analysis of the price of rice in different markets. Figure 4.5 shows the behavior of rice prices in three places: Vietnam (orange), United States (blue) and China (grey). Rice prices in Vietnam and the USA are international since both countries are global benchmarks for this product. The graph shows the following:

1. When markets are integrated, prices move similarly through the different time periods. Figure 4.5 shows that the behavior of rice prices for both Vietnam and USA are quite similar. Therefore, even if we have not yet proved that both markets are cointegrated, visually we can deduce that they are.
2. When markets are moderately integrated, prices adopt a similar but not identical behavior through the different time periods. Figure 4.6 shows rice prices in Vietnam and Colombia. As in the case of the USA and Vietnam, prices seem to behave similarly but not throughout all of the different time periods.

3. When markets are not integrated, price behaviors in the different time periods show no similarity whatsoever. This means that when an external shock causes price changes in a country or region X, they do not affect the prices in country Y. A preliminary graphical analysis of Figure 4.5 shows that the prices in China are not in line with those in the USA or Vietnam. The domestic market in China also plays an important role in the international domain, especially in terms of consumption, but its domestic prices do not seem to be integrated with those of international markets.

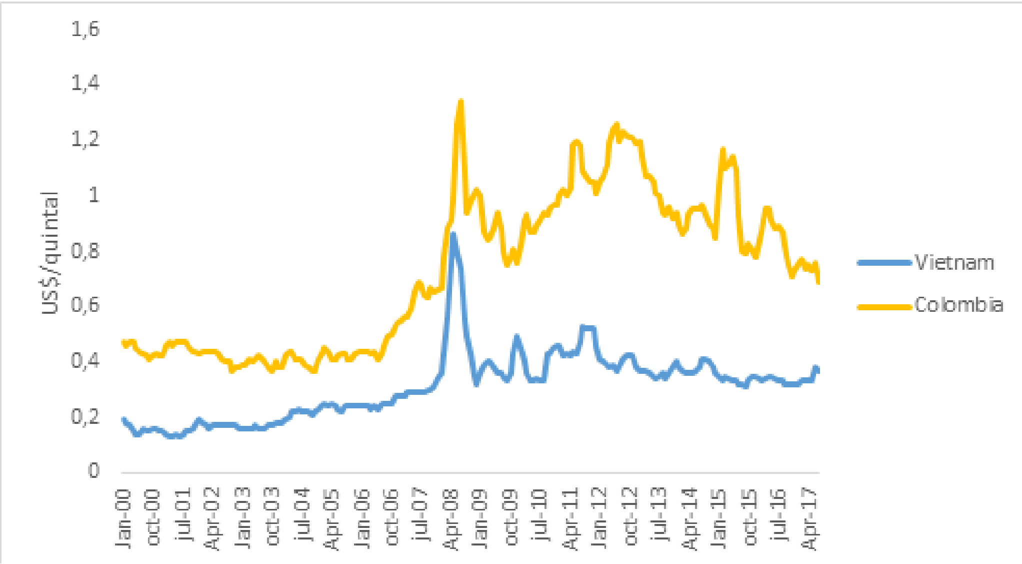
Figure 4.5. Evolution of Rice Prices in China, Vietnam and USA



Source: Based on Giews 2017.

Even though there is a clear connection between the prices for Vietnam, USA and Colombia, their relationship is not fully apparent. Further tests are required to determine whether these markets are truly integrated.

Figure 4.6. Evolution of Rice Prices in Vietnam and Colombia.

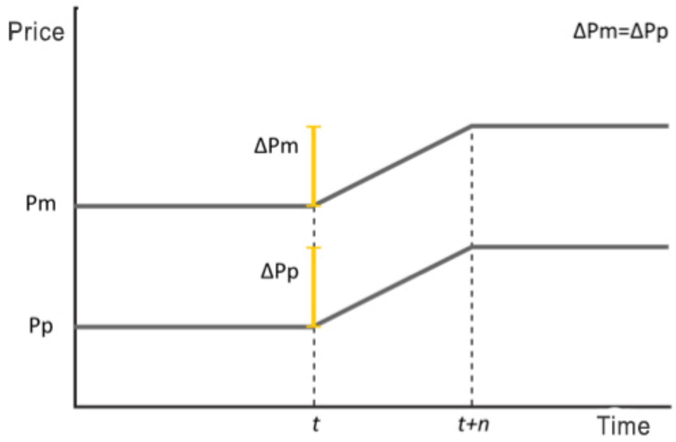


Source: Based on Giews 2017.

There are two more parameters to be considered to supplement the graphical analysis, namely:

1. Scale. In relation to vertical price transmission, it means that changes in producers' prices must be transmitted in the same scale as those of wholesalers' prices, as illustrated in Figure 4.7.

Figure 4.7. Scale



P_p stands for producers' prices, i.e. the amount received by producers on farms, whereas P_m is the price charged by wholesalers. Figure 4.7 shows that, assuming that price transmission is symmetrical, producers' prices change in the same scale as those of wholesalers.

2. Speed. It means that when prices in a market change, this change must be reflected in the prices in the other market.

Now let us assume that P_p falls, thus also reducing P_m. Symmetrical price transmission is based on the assumption that as soon as a change is introduced at any point along the chain, it will be transmitted onto the following one.

Figure 4.8. Speed

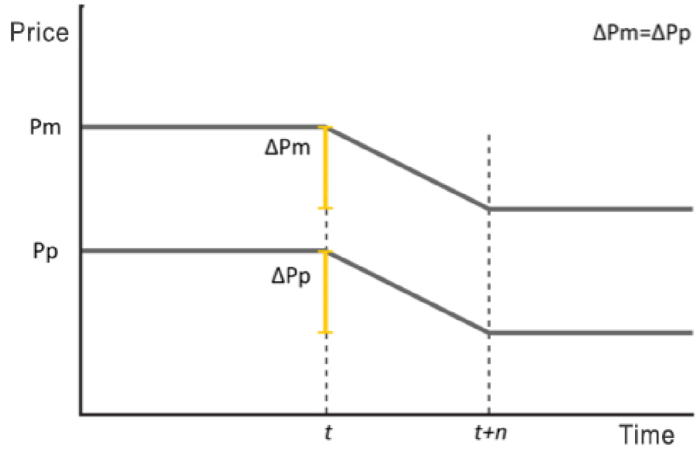


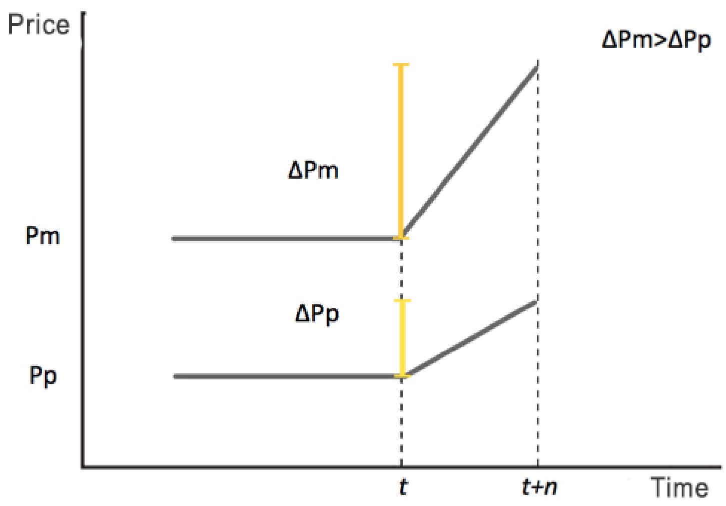
Figure 4.8 shows that the change introduced in P_p took an n amount of time to be completed, which was the same time that P_m needed to reflect this change to its full extent. It also shows that as soon as P_p falls down, then P_m immediately reacts by falling as well. Moreover, the rate at which both prices fall is the same.

It becomes apparent that symmetry is difficult to achieve, making assymetrical price transmission the most common scenario. According to Peltzman (2000) asymmetrical transmission is far more commonplace in almost every market, including the agrifood sector. Asymmetrical price transmission can be observed in many products (KInnucan & Forker, 1987), such as pork meat and beef (Hahn, 1990) and fresh vegetables (Ward, 1982), among others.

According to Von-Cramon Taubadel & Meyer (2004), asymmetry in price transmission can be classified based on three parameters.

1. The first one is the kind of transmission that does not occur at the same scale or rate, as shown in Figures 4.9, 4.10 and 4.11.

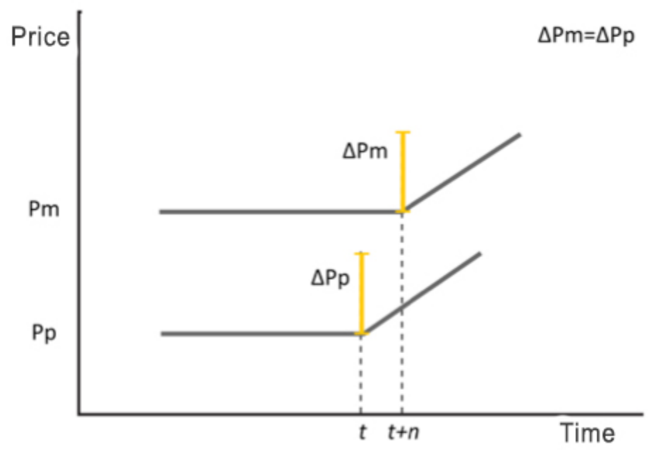
Figure 4.9. Asymmetrical Price Transmission due to Scale



Assuming that P_m reacts to changes undergone by P_p, Figure 4.9 shows that the change in P_p is more subtle than that in P_m. It can then be argued that price transmission is asymmetrical since P_m reacts to the changes in P_p , but at a greater scale.

On the other hand, in this case the price transmission rate is asymmetrical. Even though both prices experienced the same level of change, a time lag can be observed. Please see Figure 4.10 as a way of illustration.

Figure 4.10. Asymmetrical Price Transmission due to Speed



In this case the scale is the same, but the reaction of P_m to the change sustained by P_p is delayed. An asymmetrical price transmission is observed in terms of speed of reaction rather than scale, since P_m did not react immediately to the change.

Finally, Figure 4.11 shows asymmetrical price transmission due to different scales and reaction speeds.

Figure 4.11 Asymmetrical Price Transmission due to Scale and Speed

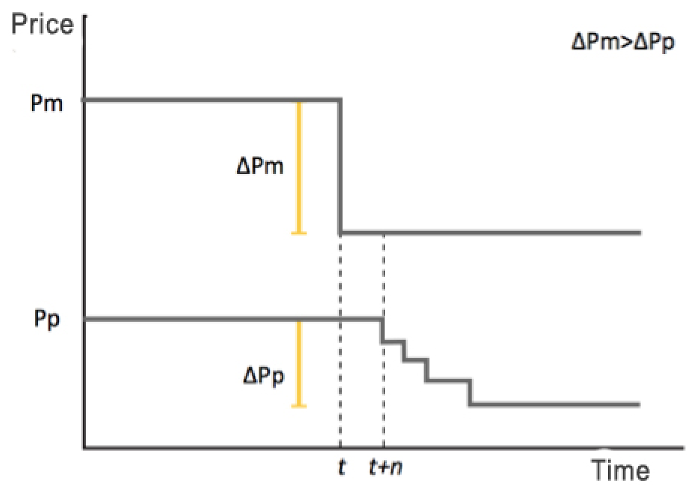


Figure 4.11 illustrates that wholesale prices fell over a certain timespan (t); however the producer prices reacted much later to this decrease, specifically in t+n. This example shows asymmetry in terms of the reaction speed, but also regarding the scale of price changes, since the total change in P_p is lower than that of P_m.

2. Asymmetry in price transmission can be positive or negative (Von-Cramon Taubadel & Meyer, 2004), the former occuring when P_m reacts more completely and rapidly to P_p rises. Figure 4.12 shows a typical example of positive asymmetry.

Figure 4.12 Positive Asymmetry

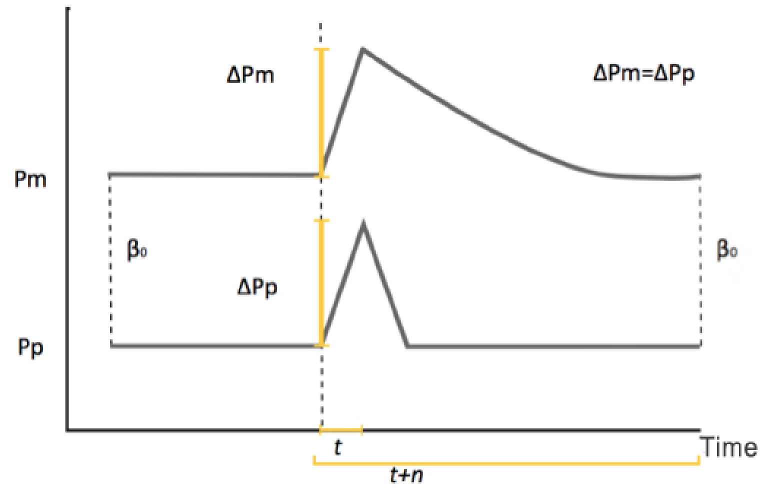


Figure 4.12 shows that P_m reacts immediately and on the same scale to increases in P_p; however, when P_p decreases, it takes longer for P_m to recover the pace kept with P_p before the shock. This is called positive asymmetry.

If, on the other hand, P_m takes longer to react to positive changes in P_p instead of negative ones, the phenomenon is called negative asymmetry.

Figure 4.13. Negative Asymmetry

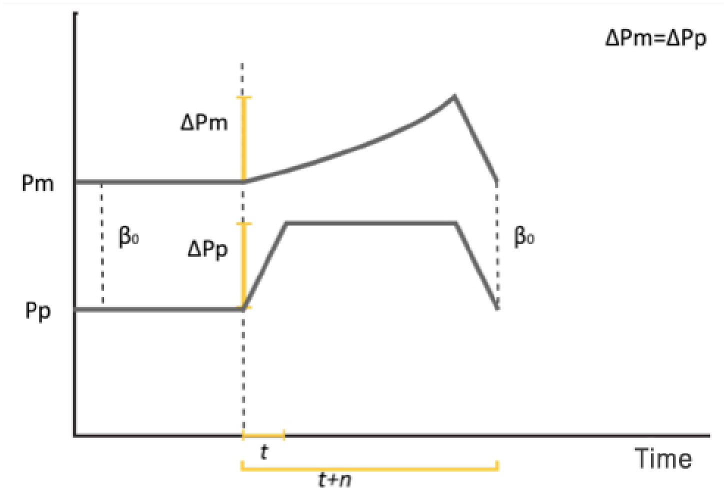


Figure 4.13 shows that P_p reaches its maximum value over a time period t, whereas P_m needs longer (t+n) to do the same. However, when P_p goes down, P_m reacts quickly by falling in the same scale and at the same speed required by P_p. This is the typical behavior of a negative asymmetrical relationship.

3. The third and final parameter is based on whether price asymmetry is horizontal or vertical, which has already been discussed.

After describing the different types of asymmetries, it is also important to understand their origin. Asymmetries stem mainly from the context of **non-competitive markets** structures.

In the agricultural sector, it is common to find a different number of players at each link of the supply chain; for instance, there may be a large number of farmers but not enough wholesalers and even fewer retailers. The current literature offers many case studies about asymmetrical price transmission, most of which attribute it to the non-competitive nature of the market and, hence, the use (and abuse) of the market power exercised by intermediaries[10].

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[10] *For further information see KInnucan & Forker (1987), Miller & Hayenga (2001), McCorriston & S (2002).*

Therefore, it becomes apparent that the market power is a variable that contributes to asymmetrical price transmission. For instance, a monopoly can cause positive asymmetry because the market will react quickly when the cost of supplies goes up, and prices will drop very slowly when the cost of inputs falls

Even though markets are normally oligopolistic and competition is fierce, no seller will be willing to raise prices at the risk of losing his market share. If, however, prices are reduced for any reason – for example, a technological development – then all competitors would do this immediately. The above scenario of negative asymmetrical price transmission has been well described by Bailey & Brorsen (1989) and Ward (1982). If, on the other hand, there is an oligopoly, but market players opt for price collusion instead of entering into fierce competition, then none of them would reduce prices below the agreed value since this could result in retaliation by the other companies. The latter scenario is an illustration of positive asymmetry.

This shows that before identifying market features and structures to hypothesize on price transmission, it is important to understand the relationship between market players to better understand price variations. Finally, it is also worth noting that, in general, the more market players there are, the lower the degree of price asymmetry, and vice-versa (Von-Cramon Taubadel & Meyer, 2004).

Asymmetrical price transmission can also be attributed to **repricing costs**, i.e. the costs incurred by companies when the prices of their supplies or final products change. For example, a supermarket will only reprice its goods if the benefit is higher than the cost incurred to do so. Therefore, retail prices are less sensitive because a change in producer prices may not be reflected in the price charged to final consumers.

Research studies have shown concrete figures to illustrate this situation. For instance, Levy, Bergen, Dutta, & Venable (1997) compared food repricing in the five largest US supermarkets. Four of them operated in States not subject to repricing rules, whereas one was regulated by certain repricing laws. The outcomes showed that the four unregulated supermarkets changed the prices of 15.6% of their products on a weekly basis, whereas the regulated one did so only in 6.3% of the products. These behaviors are attributed to the fact that repricing proved to be more beneficial than detrimental, so unregulated supermarkets could change their prices freely, leading to more flexible prices for them.

Other factors that affect repricing costs – and, therefore, price asymmetry – are perishability and stock management[11], as well as transportation costs. However, the latter may be more attributable to horizontal transmission. According to Goodwin & Piggot (2001),

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[11] *For further information on perishability, please see Balke, Brown, & Yücel (1998) or Miller & Hayenga (2001).*

transportation infrastructure and handling procedures are often intended to generate one-way trade for historical reasons. For instance, the entire trade infrastructure of Ukraine is designed to import grains from Russia due to their vicinity; however, this infrastructure is not suitable for exporting goods to the rest of the world. Likewise, natural conditions may cause asymmetry in terms of the speed and scale at which prices are transmitted. By way of illustration, shipping goods to an upstream location, i.e. against gravity, may take longer and be more expensive than the other way around (Meyer & Von-Cramon, 2004).

4.4 Cointegration test (Engle-Grangler)

We have so far only analyzed market integration based on a graphical approach; however, in order to identify integration it is necessary to perform certain statistical tests to verify the joint movement of any given series.

Two or more time series are cointegrated if they move together in the long term and their differences are stationary. This is why cointegration entails long-term balance.

There are different tests to identify cointegration, such as the one proposed by Engle-Granger, which is described as follows with the analysis of international rice prices in different markets by way of example.

Some general steps must be followed to perform this test, namely:

1. Perform a graphical analysis: if both series behave similarly they might be cointegrated.

2. Determine the order of integration of each series, i.e. how many differences are needed for any given series to be stationary.

The concept of stationarity is essential to analyze market cointegration as time series can be:

- Stationary, when mean and variance do not change over time. This is graphically shown in the time series values which begin to oscillate around a constant mean and the relevant variability is also constant over time.
- Non-stationary, when mean and/or variance change over time. Mean changes show long-term increase or decrease, hence the series data does not oscillate around a constant value.

3. Calculate the cointegration function where the changes in variable Y depend on those in the other variable (prices) and itself, and on the relationship between both variables.

$$\Delta Y_t = \varphi_1\, \Delta X_{t-1} + \varphi_2\, \Delta Y_{t-1} - \gamma\{Y_{t-1} - \beta_1 - \beta_2\, X_{t-1}\} + \omega_t$$

4. Test for unit roots on residuals to determine the order of integration

a. Ho = unit root[12], which means there is no cointegration.

b. H1 = no unit root, which means there is integration.

Below is an exercise with rice prices in different countries to illustrate the concept of market integration. We will analyze international rice prices in Vietnam and USA which, together with India, Pakistan and Thailand, are the major rice exporters (Food and Agriculture Organization of the United Nations, 2014). In addition, we will examine domestic rice prices in Colombia. Even though Colombia is not one of the main world rice producers, a Colombian citizen currently consumes an average of 39 kg/year of rice. Moreover, rice is considered to be a significant product in their market basket.

The following list describes the steps needed to perform Engle-Grangler's cointegration test with Gretl, which can be downloaded from http://gretl.sourceforge.net/win32/.

First, import the time series prices from Excel by clicking on: "Abrir" (Open)-> "Datos de usuario" (User Data) -> "Nombre del archivo" (File Name).

The data for the exercise is available for download

(http://mfiles.iica.int/CTL/ABPATD/Ejemplo_Gretl_Modulo4.xlsx).

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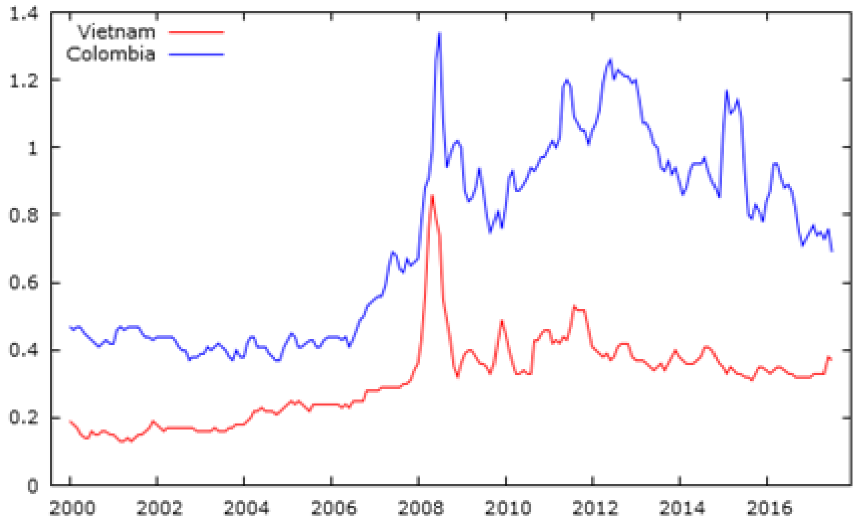
[12] If there is a "unit root" present in the time series, it is nonstationary as proven by the Dickey-Fuller test. If the residuals of a regression between two variables are stationary, it means that they have a long-term cointegration relationship.

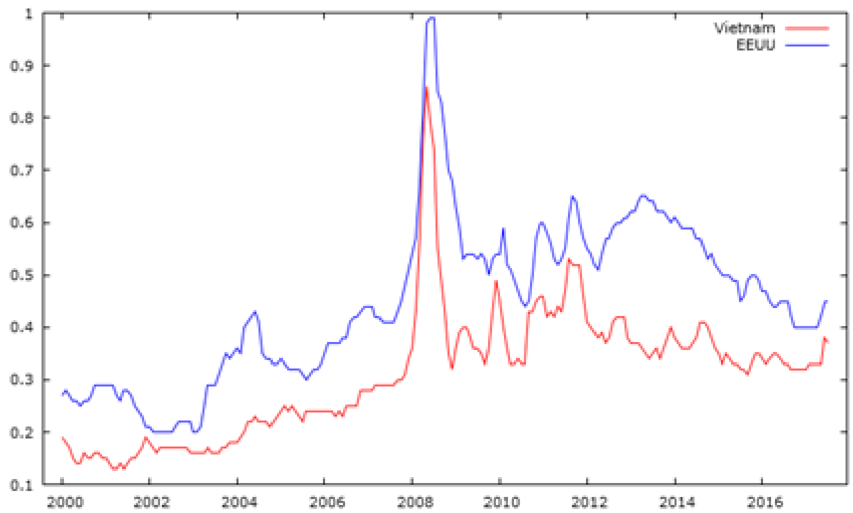
After importing the data, please proceed as follows:

1. Plot the two time series to be compared in a graphic.

In this case, we plotted the time series of Vietnam and Colombia in USD/100 lbs from the year 2000 to date. They are not very different from one another, so they might prove to be in equilibrium in the long term.

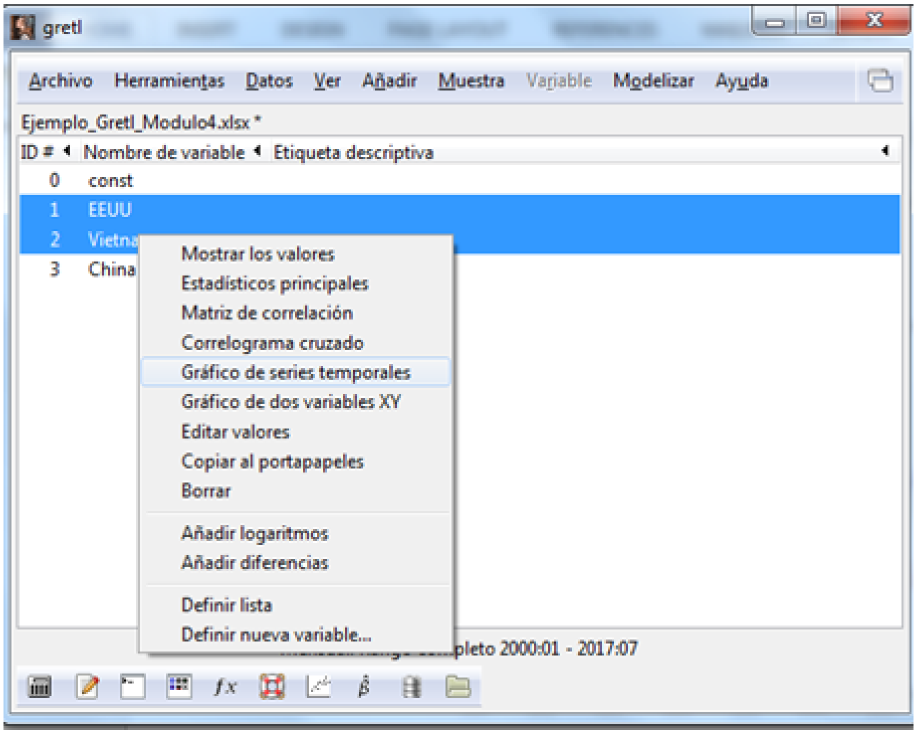


We have also outlined the time series with the prices of USA and Vietnam, which are expected to behave even more similarly since both countries are major rice producers, exporters and consumers.

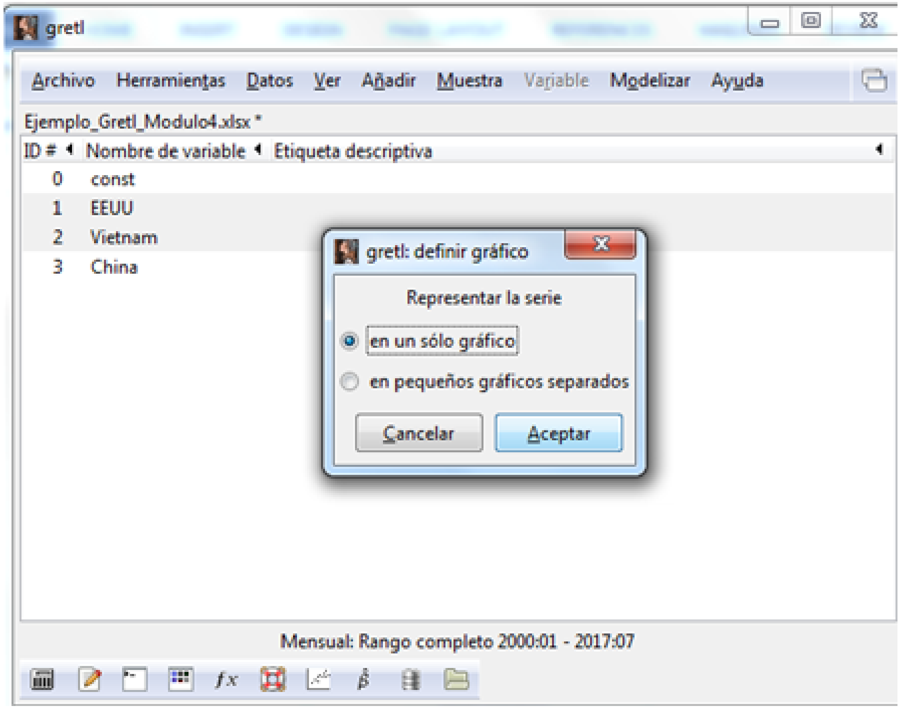


Plotting Graphics from Data in Gretl:

Choose the two series to be plotted from the home page (you can choose more than two series at the same time) -> right click on the selected variables -> choose "gráfico de serie temporal" (Time Series Plot) -> choose "sólo gráfico" plot only) -> click on OK.

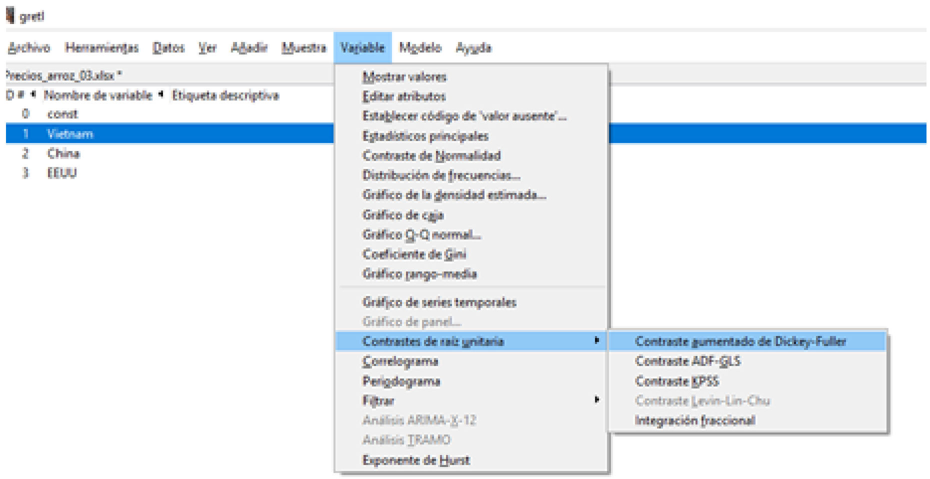


After clicking on “gráfico de series temporales” (Time Series Plot), choose the option “un solo gráfico” (plot only).

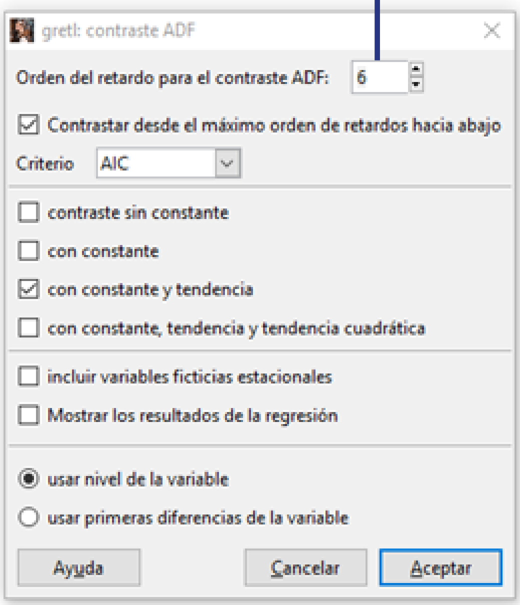


2. Finding the order of a time series. This entails finding the number of differences to make a stationary time series, for which a unit root test is required (Dickey-Fuller).

In Gretl, left click on the variable tab -> choose the option “variable” (variable) -> choose “contrastes de raíz unitaria”(unit root test) -> choose “contraste aumentado de Dickey-Fuller” (augmented Dickey-Fuller test).



After choosing the augmented Dickey-Fuller test, the following dialog box will appear:



Cubic root of the sample size.

In this case: n = 211, hence

$\sqrt[3]{211}=5{,}95 \sim 6$

The results obtained for each variable are as follows:

Augmented Dickey-Fuller Test for Colombia
Test down from 6 lags with AIC criterion
Sample size 207
Null hypothesis of Unit Root: a=1
With constant and trend
Including 3 lags of (1-L) Colombia
Model:(1-L)y=b0 + b1*t + (a-1) *y(-1) + ... + e
Estimated value of (a-1): -0.0281512
Test statistics: tau_ct (1) = 1.5448
Asymptotic p value= 0.8143
First-order autocorrelation coefficient of e: -0,002
Lagged differences: F(3, 201) = 19.931 [0,0000]

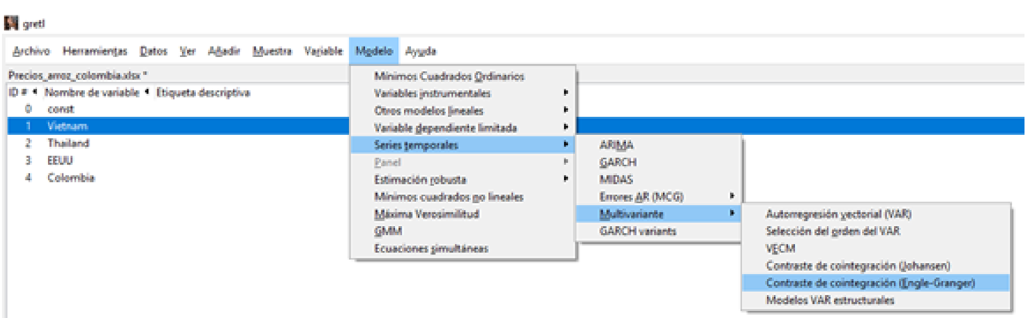
Augmented Dickey-Fuller Test for Vietnam
Test down from 6 lags with AIC criterion
Sample size 206
Null hypothesis of Unit Root: a=1
With constant and trend
Including 4 lags of (1-L) Vietnam
Model: (1-L)y=b0 + b1*t + (a-1) *y(-1) + ... + e
Estimated value of (a-1): -0.0621494
Test statistics: tau_ct (1) = 2.92447
Asymptotic p value= 0.1546
First-order autocorrelation coefficient of e: -0.012
Lagged differences: F(4.199) = 24.119 [0,0000]

Both values are higher than 0.05 so the hypothesis that there is a unit root in this series cannot be rejected. The presence of a unit root means that it is a non-stationary series.

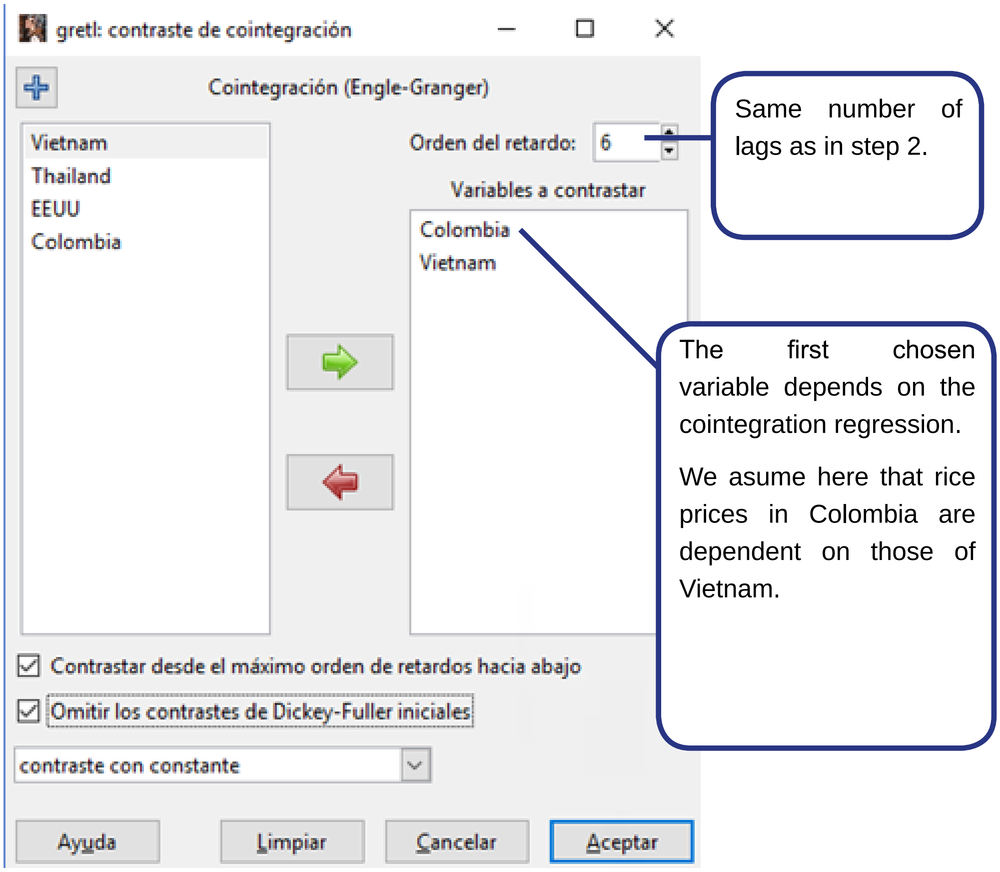
The series must be differentiated to obtain stationarity.

3. Calculate cointegration. In this case, since Vietnam is one of the world's main rice producers, its prices will be regarded as the independent variable, whereas Colombian prices will be the dependent variable.

To perform the Engle-Grangler test, choose "Modelo" (Model) -> "Series temporales" (Time Series) -> "Multivariante" (Multivariate -> "Contraste de Engle-Granger" (Engle-Granger Cointegration Test), as shown below:



The following dialog box appears after choosing the Engle-Granger Cointegration Test:



The following test results appear after clicking on the OK button.

Vietnam-Colombia Results

Stage 1: Cointegrating Regression
Cointegrating Regression
OLS, using the observations 2000:01-2017:07 (T=211)
Dependent variable: Colombia

	Coefficient	Standard Dev.	Statistical t	Value p
Const	0.156267	0.0306609	5.097	7.72e-07 ***
Vietnam	1.85047	0.0922503	20.06	1.31e-050***

Mean Dependent Variable	0.728246	SD Dependent Variable	0.279323
Sum of Squared Residuals	5.601087	SD Regression	0.163705
R-squared	0.658146	Adjusted R-squared	0.656511
Log-likelihood	83.45265	Akaike Criterion	-162.9053
Schwarz Criterion	-156.2016	Hannan-Quinn Criterion	-160.1955
rho	0.913625	Durbin-Watson	0.175859

Stage 2: Testing the Existence of a Unit Root in uhat
Augmented Dickey-Fuller Test for uhat
Test down from 6 lags with AIC criterion
Sample size 204
Null hypothesis of Unit Root: a=1

Model: (1-L) y= (a-1) *y (-1) + ... + e
Estimated value of (a-1): -0.0777848
Test statistics: tau_c (2) = 2.58486
Asymptotic p value= 0.2435
First-order autocorrelation coefficient of e: -0.023
Lagged differences: F (6.197) = 11.896 [0.0000]

In this case, the Ho cannot be rejected because the **asymptotic p-value** is higher than 0.05, so prices are not cointegrated. It is worth noting that Ho shows that Vietnamese and Colombian prices are not integrated, which means that they do not have a long-term correlation. This may be due to the fact that Colombia does not trade large quantities of rice with Vietnam so, in theory, Colombian prices do not necessarily have to be correlated with those of Vietnam.

The same procedure was applied to Vietnamese and American prices and the results obtained were as follows:

Vietnam-USA Results

Stage 1: Cointegrating Regression
Cointegrating Regression
OLS, using the observations 2000:01-2017:07 (T=211)
Dependent variable: Vietnam

	Coefficient	Standard Dev.	Statistical t	Value p
Const	-0.0157325	0.0105472	-1.492	0.1373
USA	0.722991	0.0222002	32.57	7.98e-084***

Mean Dependent Variable	0.309100	SD Dependent Variable	0.122458
Sum of Squared Residuals	0.518406	SD Regression	0.049804
R-squared	0.835381	Adjusted R-squared	0.834593
Log-likelihood	334.5380	Akaike Criterion	-665.0761
Schwarz Criterion	-658.3724	Hannan-Quinn Criterion	-662.3663
rho	0.888300	Durbin-Watson	0.228650

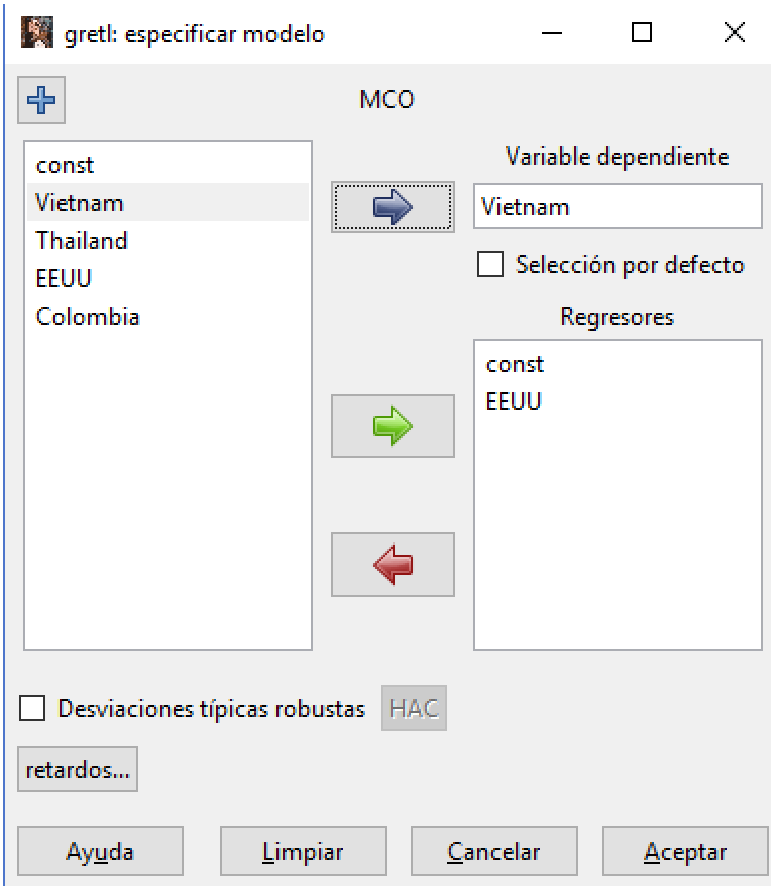
Stage 2: Testing the Existence of a Unit Root in uhat
Augmented Dickey-Fuller Test for uhat
Test down from 12 lags with AIC criterion
Sample size 200
Null hypothesis of Unit Root: a=1

Model: (1-L) y= (a-1) *y(-1) + ... + e
Estimated value of (a-1): -0.16332
Test statistics: tau_c (2) = 3.71491
Asymptotic p value= 0.01754
First-order autocorrelation coefficient of e: -0.010
Lagged differences: F (10, 189) = 5.791 [0.0000]

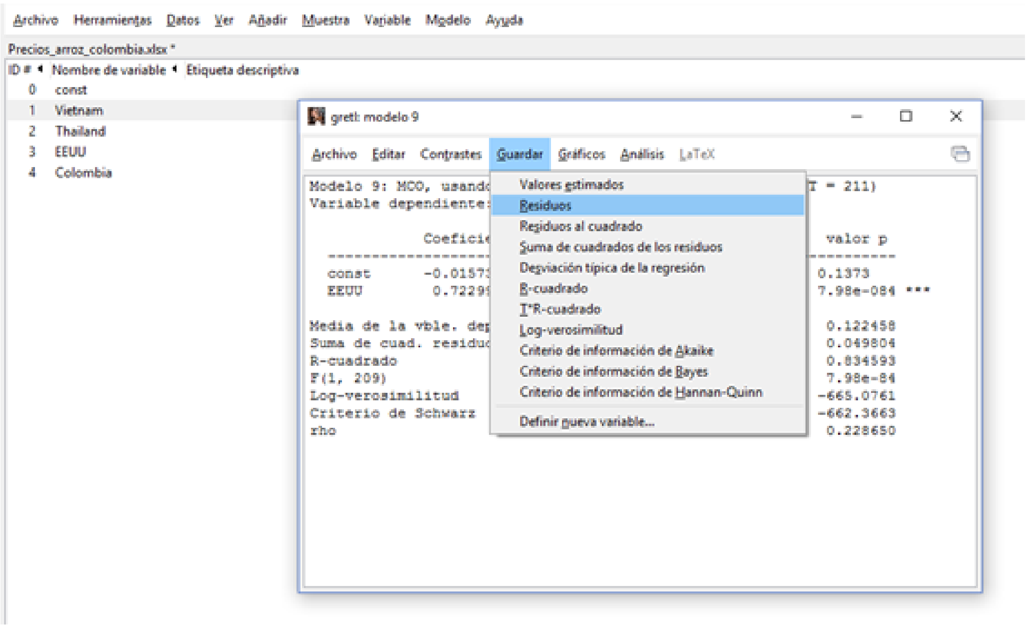
When it comes to comparing American and Vietnamese prices, the Ho is rejected since in this case, prices are cointegrated because the **asymptotic p-value** is lower than 0.05. As already mentioned, both USA and Vietnam are major rice producers, so they are both very well positioned in the market. Therefore, it is likely that both prices will behave similarly over time, since they mutually influence each other.

Based on the above results, let us now concentrate only on the last example (USA-Vietnam prices). The first regression is run with Vietnam as the dependent variable and USA as the independent one. The size of their economies indicates that USA could be a more significant player and, hence, influence to a certain extent the behavior of rice prices in Vietnam. The following steps should be taken for this purpose:

In Gretl: In the home page, choose “Modelo” (Model) -> then choose the ordinary least squares (OLS), run the regression and save the residuals.

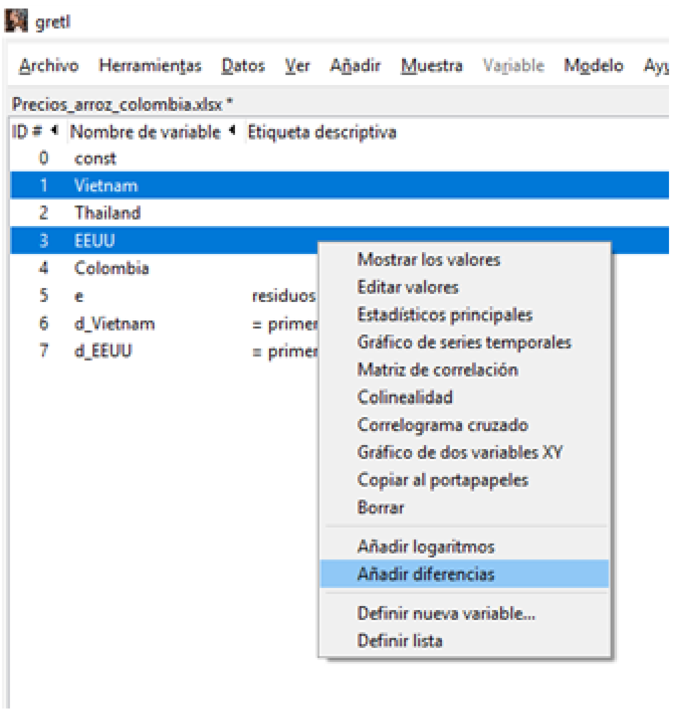


The regression by OLS must be equal to the previous one. To save the residuals, click on the “Guardar” (Save) button of the menu bar and then on “Residuos” (Residuals) as shown in the following screenshot:

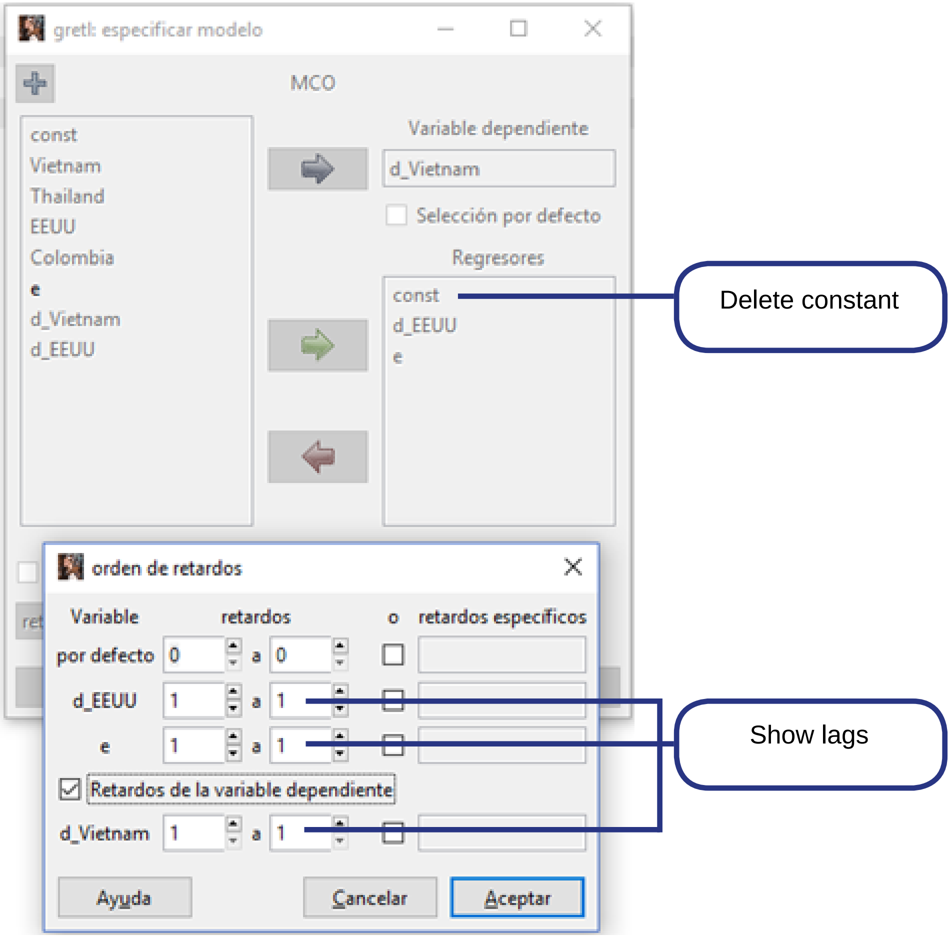


The saved residuals will then appear on the main page of the program. They were saved as “e” in this case. Two new series must also be created to show the first price differences for both USA and Vietnam.

In order to do this, right click on the original series and choose “añadir diferencias” (Add Differences). They will be displayed on the same screen as: d_Vietnam and d_EEUU (USA).



3. Finally, in order to calculate the error correction model, choose a new model and then "MCO" (OLS). In this case, however, the dependent variable will be d_Vietnam, whereas the independent variables will be the residuals (e) and the first price differences of USA (d_EEUU), as well as the lags[13] shown below.



[13]*A lag equal to 1 is assumed here.*

After clicking on “Aceptar” (OK) in this window, the regression coefficients shown below will be displayed by the program:

Model 10: OLS, using the observations 2000:03-2017:07 (T=209)
Dependent variable: d_Vietnam

	Coefficient	Standard Dev.	Statistical t	Value p
d_EEUU_1	-0.0407927	0.0835080	-0.4885	0.6257
e_1	-0.122188	0.0396430	-3.082	0.0023 ***
d_Vietnam_1	0.616798	0.0782569	7.882	1.84e-013 ***

Mean Dependent Variable	0.000909	SD Dependent Variable	0.030738
Sum of Squared Residuals	0.138061	SD Regression	0.025888
Uncentered R-squared	0.298113	Centered R-squared	0.297496
F (3, 206)	29.16480	P-value (F)	9.29e-16
Log-likelihood	468.6318	Akaike Criterion	-931.2637
Schwarz Criterion	-921.2367	Hannan-Quinn Criterion	-927.2097
rho	-0.017992	Durbin-Watson	2.028634

The highest p-value was variable 8 (d_EEUU_1)

The three stars (***) show the statistical significance of the coefficient associated with e_1 at 99% which, in this case, is significantly different from zero. Please remember that a test t is performed to determine whether a coefficient is different from zero (if p<0.05 -> the coefficient is different from zero). In this case, the p value is 0.0023; which is lower than 0.05. Based on the foregoing, it can be asserted that the value of the coefficient associated to e_1 is statistically significant in 99% of the cases.

If the value of the residuals (e_1) is significant, it means that in the event of a market shock, Vietnamese prices will fluctuate to restore their balance with those of the USA. However, if residuals were not significant, Vietnamese rice prices would be considered exogenous, i.e. non-responsive to USA price changes.

There follows a second regression where the first price differences in the USA are considered as dependent variables, and the residuals (e) and the first price differences in USA (d_EEUU) are regarded as independent variables. Please see the results below:

Model 12: OLS, using the observations 2000:03-2017:07 (T=209)
Dependent variable: d_EEUU

	Coefficient	Standard Dev.	Statistical t	Value p
d_Vietnam_1	0.318867	0.0670855	4.753	3.76e-06 ***
e_v2_1	-0.0650629	0.0264036	-2.464	0.0146 **
d_EEUU_1	0.249788	0.0707821	3.529	0.0005 ***

Mean Dependent Variable	0.000813	SD Dependent Variable	0.027818
Sum of Squared Residuals	0.100007	SD Regression	0.022033
Uncentered R-squared	0.379222	Centered R-squared	0.378689
F (3, 206)	41.94728	P-value (F)	3.35e-21
Log-likelihood	502.3283	Akaike Criterion	-998.6566
Schwarz Criterion	-988.6296	Hannan-Quinn Criterion	-994.6026
rho	-0.071449	Durbin-Watson	2.132344

If the value of residuals (e_v2_1) is significant, in the event of shock, American prices will move to remain balanced with Vietnamese prices. If the residuals were not significant, this would mean that US rice prices are exogenous and, hence, do not react to changes in Vietnam. In this specific case, we will see how both prices affect each other and, in case of shock, they both react to stay aligned. However, there might be situations in which there is only one country X responding to price changes in country Y. In such an event, it could be argued that prices in country X respond to changes in those of country Y, or in other words, the prices of country X follow those of country Y.

As already mentioned, in the event of a market shock we can identify which of the actors responds, since retailers will not always react to wholesalers' price increases by also raising theirs, and vice-versa. Identifying price that follow each other shows the market power of every player.

By way of illustration, there should be a constant margin between wholesalers and producers' prices, which is shown in Figure 4.14 as B_0 . Now let us imagine that the price of fuel rises (t_0), resulting in an increase in wholesalers' prices (P_m) and, hence, in an increase in the margin (t_0). Consequently, the market will attempt to maintain the pre-shock margin, so either wholesalers or producers will have to modify their prices to recover the previous balance. This case shows how producers begin to raise their prices to reach wholesalers' levels and recover their alignment before the shock. This particular example shows that producers' prices follow those of wholesalers.

Figure 4.14. Producers' Price Adjustment in Reaction to Higher Wholesalers' Prices

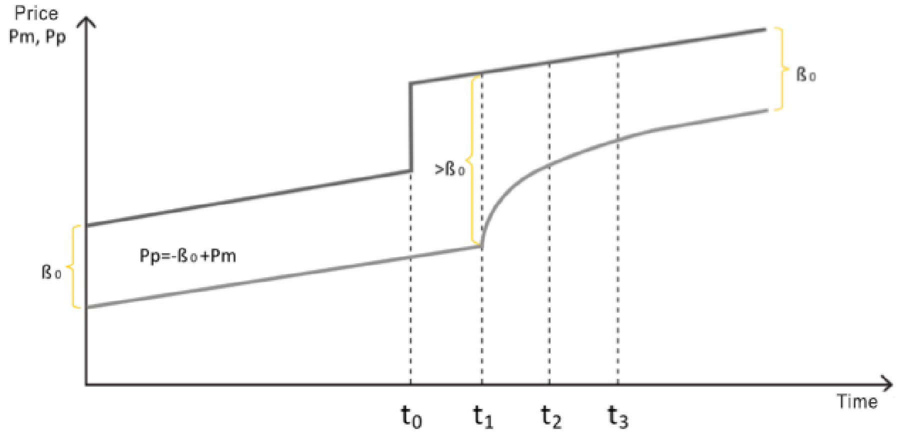
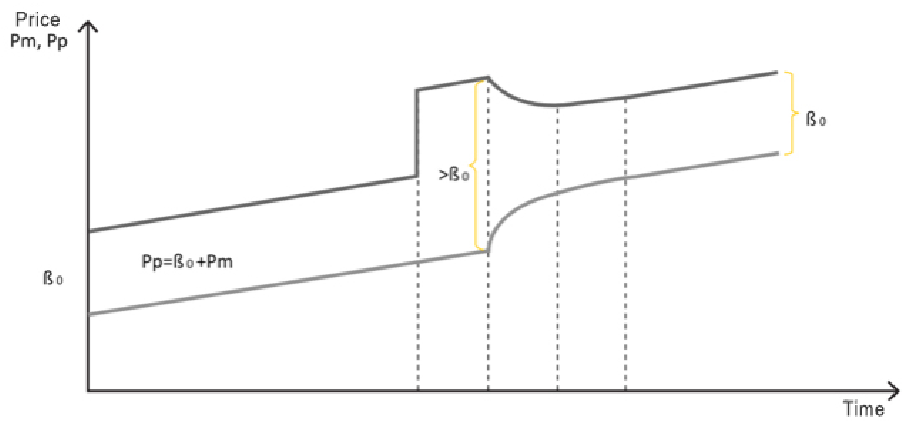


Figure 4.15 assumes another increase in wholesalers' prices. It shows the reaction of both wholesalers and producers' prices, and their mutual adjustment until they reach the margin (B_0) they had before the shock. Following this scenario, wholesalers' prices fall slightly and those of producers increase slightly so that in the mid/long term the shock is absorbed by both prices.

Figure 4.15. Adjustment of Producers and Wholesalers' Prices in Case of Shock



The following list describes relevant variables to explain the level of market integration:

1. **Size of the economy.** There are “big players” in almost every international market. For instance, in Europe (Gil & Goodwin, 2006), Germany plays a significant role in setting pork prices, since it is one of the most populated European countries and the largest importer, as well as exporter, of pork. On the other hand, it is one of the countries with the highest per capita pork consumption in the world. These features favour the assumption that any “smaller” country trading with Germany will have to comply with the conditions imposed by it and, thus, the pork prices of other countries will follow those set by Germany.

2. **Common border and common currency.** One of the variables that affect market integration is the common border, as suggested by Holst & Von Cramon-Taubadel (2013). It is likely that countries that share a common border will also be more integrated than those that do not, as is the case with countries that share a common currency.

3. **Belonging to a free trade area or a customs union.** It is presumable that the countries between which a trade agreement has been executed will trade more among themselves than with third parties. This variable is affected by time since, according to some conclusive findings by Holst & Von Cramon-Taubadel (2013), the amount of pork being traded among the old members of the European Union is larger than the trade that exists among new and old members.

4. **Self-sufficiency.** There are small countries whose economy satisfy only a small part of the local consumption and, hence, they depend heavily on imports. Generally speakingthese countries need to accept internationally agreed prices, hence their domestic prices are very much cointegrated with international ones. It is worth noting that in a relatively self-sufficient country, price transmission depends on the possibility of export/import in relation to new international prices.

5. **Applicable trade policies, such as fees and restrictions on imports or exports and price stabilization or regulation mechanisms.** Regarding price regulation, in Costa Rica, for instance, rice prices are regulated by law so that the introduction of any adjustments driven by abrupt international price changes will be slow.

Conclusions

In an increasingly globalized world, information flows are gaining ground when it comes to decision making. This also applies to the price data shared by the players in the agricultural sector. Globalization brings about, among other things, a greater flow of products, resulting in an ever growing number of business agreements intended to favor international trade.

Before performing cointegration tests, the price formation context must be examined to take into account legal, natural, geographical and other general aspects that may affect the import or export costs of the countries or regions in question.

Neglecting the above-mentioned aspects may lead to incorrect interpretation of the situation, especially when narrowing the scope to a mere graphical analysis. Therefore, it is essential to understand the relative significance of each market being assessed for both horizontal and vertical price analysis.

Statistical market integration tests are key to moving beyond the graphical analysis, such as the Engle-Grangler cointegration test used in this Chapter for this purpose. It is worth noting that a price cointegration analysis may be very useful for understanding the process of price formation through a value chain, as well as in two geographically different markets.

Practical Example: Potato in Bolivia

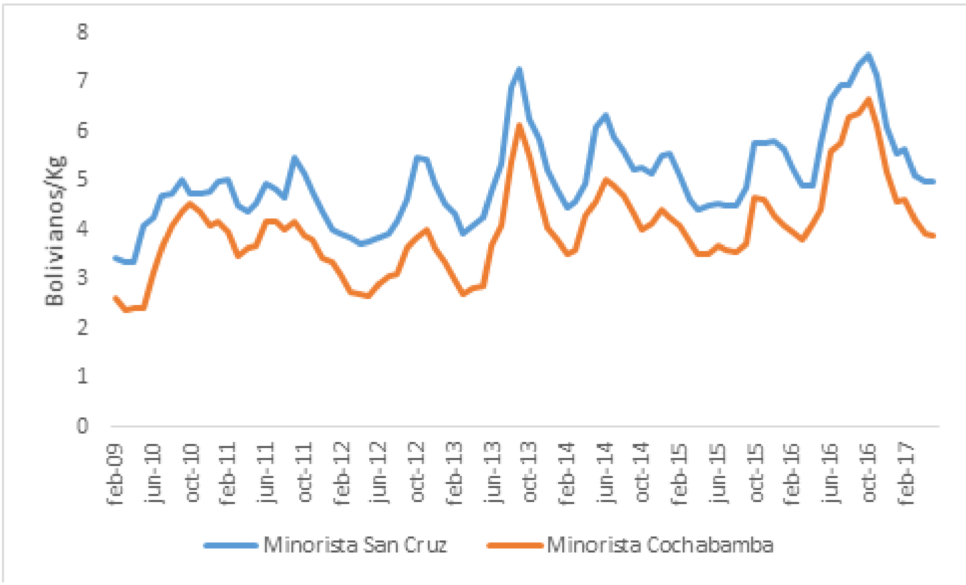
In Bolivia, potato production is economically and culturally significant, and is one of the country's major crops – over 200,000 farms grow it, accounting for over 900,000 people including farmers, their spouses and children in rural areas.

According to official figures, there are between 125 and 130,000 ha devoted to this crop in six departments, namely: La Paz, Cochabamba, Potosí, Oruro, part of Chuquisaca and Tarija; La Paz, Potosí and Cochabamba are the areas with the largest harvested area (30,000 ha; 28,000 ha; and 26,000 ha respectively) (INE 2011).

To understand vertical price transmission in the Bolivian potato market, a comparison was made between retail prices in Cochabamba, one of the largest potato producers, and those of Santa Cruz, a region that also produces potatoes but where demand is higher, particularly in terms of seeds and potatoes to satisfy consumption needs.

Based on the above conditions, it is presumable that the prices in Santa Cruz will be higher than those in Cochabamba. Firstly, only a portion of the seeds are produced in Santa Cruz so the rest needs to be shipped from other departments, thus increasing the price of inputs due to additional transportation and transaction costs, and finally impacting the final price of potatoes in the department. In addition, Santa Cruz also consumes potatoes produced in Cochabamba, which are more expensive due to the transportation costs. Figure 4.16 shows the potato retail price behavior in Cochabamba and Santa Cruz from 2010 to June 2017 in Bolivian Pesos per kilogram.

Figure 4.16 Behavior of Retail Prices in Santa Cruz and Cochabamba

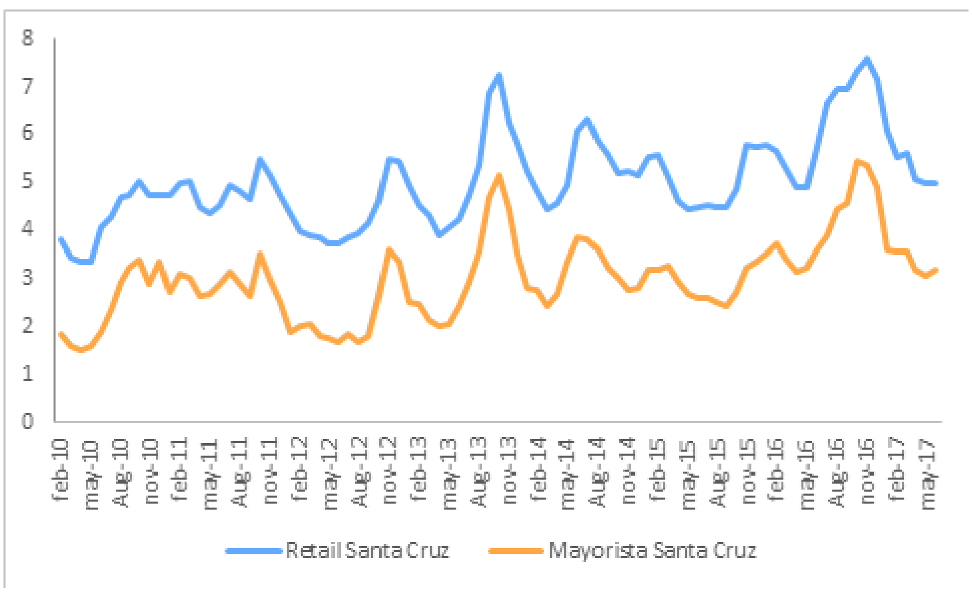


Source: Based on GIEWS 2017.

At first glance, both markets show a similar (almost symmetrical) behavior and, thus, should quickly adapt to changes. On the other hand, the margin between the prices in Santa Cruz and Cochabamba somehow confirms the single price hypothesis, i.e. that a single product will have different prices in two distinct markets, but that difference will only be determined by transaction costs.

Regarding vertical price transmission, we analyzed the retail and wholesale markets in Santa Cruz. The data was collected on a monthly basis during the period from 2010 to June 2017, and was expressed in Bolivian Pesos per kilogram. Figure 4.17 below shows the relevant price behavior.

Figure 4.17. Behavior of Retail and Wholesale Prices in Santa Cruz



Source: Based on GIEWS 2017

The figure above shows that the behavior of retail prices is similar to that of wholesale prices. Even if their margin rises and falls at some points, it can be argued that both price series behave in a similar manner in the long term with a more or less stable margin, and are therefore cointegrated. The Engle-Granger cointegration test was performed on potato retail and wholesale prices to confirm this hypothesis. A regression was run with retail prices as the dependent variable and wholesale prices as the independent one. Next, a Dickey-Fuller test was conducted on the residuals, resulting in a value-p below 0.05, thus showing standard residuals and, hence, a steady relationship between retail and wholesale prices in the long term. Consequently, it may be argued that both prices are cointegrated.

CONCLUSIONS

Throughout this manual we have considered the essential elements to analyze agricultural prices for decision-making purposes. Understanding the type of information required to draw valid conclusions is the first step in price analysis. Within this context, it is key to identify the link in the value chain to which the prices under analysis correspond, i.e. retailers, wholesalers or producers, since, as already argued, the prices of the entire supply chain may vary to different, extents based on the features of the market and its openness to international trade.

Agricultural markets are extremely complex and the price formation process may be influenced by many players who affect the drivers of supply and demand, and which in turn set prices in a given market. However, their impact is largely determined by the market structure. Therefore, before analyzing prices, it is advisable to examine the context surrounding producers and consumers in any given market. With respect to the analysis itself, it is essential to consider the relationship between prices and the quantities supplied/demanded from the perspective of both the supply and the demand. This is in fact one of the key and more widespread concepts of price analysis since it provides a suitable parameter for comparison, regardless of the units of measurement used.

A simple observation of price behavior is only the first step, after which a more thorough analysis is needed. Breaking prices down into their 4 basic components provides a better understanding of price fluctuations, resulting in more tools available for forecasting. Therefore, price breakdown can demonstrate to what extent (i.e. proportion) future prices react to those of previous periods and how (i.e. proportion) future prices depend on market randomness.

Transferring price information to farmers in a timely manner is key to promoting more efficient agricultural markets. For this purpose, IT tools should be disseminated and adopted by governments and producers so that both price analysts and producers can make more informed decisions regarding which crops to plant and when, and find better business opportunities.

Collecting reliable price data on a regular basis is vital to generating adequate technical analysis. It is worth noting, however, that price data collection can prove quite useless if this information is not made available in a timely manner to be analyzed by experts and scholars. Furthermore, even if information is made available at the right time, the conclusions of these technical analyses may sometimes be difficult to understand, so “translating” the results into graphics and colloquial language can be very helpful and will allow farmers to make informed decisions on seeding, selling or buying products on a daily basis.

It is worth noting that technical price analysis is based on the assumption that prices duly reflect all of the significant information available in any given market about a certain product of the farming sector. Conversely, in the agricultural sector there are other influential conditions that make prices imperfect and, thus, incapable of efficiently reflecting each and every event. This is why technical analyses require contextualization so that the outcomes are examined from a technical and contextual perspective, since the one supplements the other.

Understanding how markets are interrelated is key to determining how the prices of any given economy will react to the variation in international prices, or of those of another economy. This is why determining price cointegration and speed of transmission is becoming increasingly important for policymakers, who can rely on the technical and unbiased information provided by them to choose the best economic and trade policies to be adopted by a country. Moreover, the information on market cointegration facilitates forecasting the fluctuation in domestic prices, in the event of shocks in international markets. Therefore, if information is properly analyzed and communicated, producers can anticipate whether prices will rise or fall, which constitutes key information to estimate expenses and make decisions regarding which crops to plant to achieve consolidation or diversification.

Before running formal cointegration tests, it is worth examining the context in which prices are formed, since the results of such tests are only valid when they are interpreted in light of the different factors affecting price transmission, such as fees, quotas, phytosanitary measures, free trade agreements, among other factors.

Glossary

COMPLEMENTARY PRODUCTS: products whose characteristics are such that consumers consume them at the same time.

CONSUMER PRICE INDEX: indicator that measures the evolution of the average cost of a basket of goods that is representative of average household consumption in an economy.

COURNOT MODEL: economic model that explains the quantity of a product that firms supply under a scenario of imperfect competition, assuming that they decide on the quantity at the same time.

CROSS ELASTICITY: responsiveness of the quantity consumed of a product to changes in the price of a related (substitute or complementary) product.

CYCLE: component of a price that corresponds to the periodic repetition of a pattern. In the case of this manual on price analysis, it refers to the periodic behavior of prices.

DEMAND: quantity of products (goods or services) that consumers are willing to purchase under certain conditions. It depends on the product price, the income and tastes and preferences of consumers, government policy and product perishability, among other aspects.

EFFICIENT MARKET: market in which prices respond rapidly to new information and reflect everything that it is happening in it.

HORIZONTAL PRICE TRANSMISSION: linkages between the prices of a single product in different geographical regions.

INCOME ELASTICITY: responsiveness of the quantity demanded of a product to changes in consumer income.

INCOTERMS: international trade standards through which buyers and sellers accept the conditions of purchase and sale. They are used to define both the responsibilities and the costs of two parties involved in a commercial transaction.

MARKET CONCENTRATION: number of firms (or suppliers) of a good in a given market.

MARKET STRUCTURE: refers to the way in which suppliers and demanders interact in order to exchange goods and set prices. It also refers to the quantity of suppliers and demanders in a market. .

MONOPOLISTIC COMPETITION: market structure in which there are many suppliers and many buyers of a good. Each supplier has a small market share and sells a slightly different product (i.e., there is product differentiation in the market).

MONOPOLY: market structure in which a single supplier controls the entire market.

OLIGOPOLY: market structure in which there are few suppliers of a good and, therefore, each one exerts a great deal of market power and high control over prices.

OUTLIER: a value, in this case an atypical price; in other words, an observation that is far removed from the other data in a time series.

PERFECT COMPETITION: market structure in which there are many suppliers and many buyers of slightly differentiated products. Each supplier has a share of the market and is able to compete for it, but no single supplier has sufficient power to set prices.

PREFERENTIAL AGREEMENT: treaty or arrangement between two or more countries for the mutual reduction or elimination of tariffs.

PRICE ELASTICITY OF DEMAND: responsiveness of the quantity demanded to a change in its price.

PRICE ELASTICITY OF SUPPLY: responsiveness of the quantity supplied of a product to a change in its price.

SEASONALITY: component of a price that corresponds to the periodic variation of a time series, in this case in the short term (over the course of a year).

STACKELBERG MODEL: economic model that explains the quantity of a product that firms supply in a scenario of imperfect competition, assuming that there is a market leader (supplier) that is the first to decide on the quantity to be supplied.

SUBSTITUTE PRODUCTS: products whose characteristics are such that consumers perceive them as goods that may replace each other, as they perform the same function or meet the same need.

SUPPLY: quantity of a product (goods or services) that producers are willing to supply. It depends on the product price, climate, pests, diseases, the price of products that compete for the same resources, the prices of associated crops, government policies, and producers' expectations, among other aspects.

TREND: component of a price that corresponds to the long-term direction in which a market is moving. It may be upward or downward, depending on whether prices have been rising or falling.

VERTICAL PRICE TRANSMISSION: linkages between the prices of products throughout a value chain.

VOLATILITY: component of a price that corresponds to random (non-predictable) variations

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