CHAPTER 1
Introduction to price analysis in agriculture
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>
<thead>
<tr>
<th>Table 1.1. Lime prices and percentage of markup in pesos in Mexico.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Item</strong></td>
</tr>
<tr>
<td>Farm price (pesos per unit)</td>
</tr>
<tr>
<td>End consumer price (pesos per unit)</td>
</tr>
<tr>
<td>Percentage of markup on farm price</td>
</tr>
<tr>
<td>Percentage of markup on end consumer price</td>
</tr>
<tr>
<td><strong>Value</strong></td>
</tr>
<tr>
<td>1.1</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>627%</td>
</tr>
<tr>
<td>86%</td>
</tr>
</tbody>
</table>

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.

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**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).
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 technology.

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).
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 comportamiento de los precios en el corto, mediano y largo plazo. Esto facilita entender el comportamiento de los precios, ya que proporciona información que permite diferenciar entre factores temporales o de corto plazo y estructurales, ambos de los cuales afectan el comportamiento de los precios.

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.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Costa Rica</th>
<th>El Salvador</th>
<th>Guatemala</th>
<th>Honduras</th>
<th>Nicaragua</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price elasticity</td>
<td>0.212</td>
<td>-0.937</td>
<td>-0.233</td>
<td>-0.564</td>
<td>-0.591</td>
</tr>
<tr>
<td>Income elasticity</td>
<td>0.150</td>
<td>1.204</td>
<td>0.309</td>
<td>0.715</td>
<td>0.417</td>
</tr>
</tbody>
</table>

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).
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.

### Cross elasticity: substitute products and complements

<table>
<thead>
<tr>
<th>Variable</th>
<th>Black tea</th>
<th>Coffee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black tea</td>
<td>-0.393</td>
<td>0.125</td>
</tr>
<tr>
<td>Coffee</td>
<td>0.599</td>
<td>-1.022</td>
</tr>
<tr>
<td>Income elasticity</td>
<td>0.837</td>
<td>1.008</td>
</tr>
</tbody>
</table>

*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.
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:

\[ TC_1 = 80 + 5Q_1 \]
\[ TC_2 = 100 + 10.2Q_2 \]

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:

\[ R_1 = P \cdot Q_1 \]
\[ R_1 = (133.33 - 1.33Q) \cdot Q_1 \]

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

\[ R_1 = (133.33 - 1.33Q) \cdot Q_1 \]
\[ R_1 = (133.33 - 1.33(Q_1 + Q_2)) \cdot Q_1 \]
\[ R_1 = 133.33Q_1 - 1.33Q_1^2 - 1.33Q_1Q_2 \]

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, $Mg_2 = Mg_2C$

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

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

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

$Q_1 = 33,34$ 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:

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

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

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

$Q_1 = 50,21$ and $Q_2 = 21,18$
It has been observed that both the Stackelberg and Cournot 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**

<table>
<thead>
<tr>
<th>Market</th>
<th>Market concentration index*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agrichemicals</td>
<td>89% (C2)</td>
</tr>
<tr>
<td>Agricultural machinery</td>
<td>94% (C4)</td>
</tr>
<tr>
<td>Seeds</td>
<td>78% (C4)</td>
</tr>
<tr>
<td>Fertilizers</td>
<td>60% (C4)</td>
</tr>
</tbody>
</table>

*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.
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.
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.

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.

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.
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.

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:

- \( \pi \) = 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**

![Diagram showing market demand and firm demand curves](image)

*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.

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 \( M_R = M_C \) 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: \( M_R=850,000-3Q^2-0.9Q \)

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 \( M_R = M_C \) 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: \( M_R=850,000-3Q^2-0.9Q \)
And the marginal cost: \( M_C = 12Q + 2 \)

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: \( P = 850,000 -(530.14)^2 -0.45(530.14) \)

\( P = \text{USD} 568,713.02 / \text{ton of Roundup Ready} \)

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 \( P = M_C \)

Therefore: \( 850,000 - Q^2 - 0.45 = 12Q + 2 \)

\( Q = 915.74 \) (tons)

\( P = \text{USD} 110,078.17 / \text{ton of Roundup Ready} \)

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