PRICE FORECASTING METHODS FOR DUTCH HORTICULTURE

December 1995
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Hans van Kranenburg
SUMMARY

The primary focus of this thesis is the theoretical foundation of two quantitative approaches to forecast both the short-term and the long-term prices for horticultural commodities in the Netherlands. The first approach to obtain price forecasts is to set up an econometric price model. This approach relies on the relationships between market structure, exogenous processes, expectations, and behaviour. For the construction of an econometric price model the demand and the supply functions for horticultural commodities have to be known. However, little or no demand and supply functions are constructed for the Dutch horticultural commodities. Therefore, the demand and the supply functions for winter tomatoes in the United States of America, which have been developed by Shonkwiler and Emerson in 1982, are used to explain the theoretical foundation of an econometric price model for the Dutch horticultural commodities. The described econometric price model is a partial equilibrium-perfect competitive price model. This model is a simple one and has to be modified for each single commodity or group of commodities. Furthermore, the basic estimation procedures to estimate the unknown parameters in an econometric price model are explained.

The development of the aggregate acreage for a commodity plays a crucial role in the long-term price forecasts. On the other hand, for the short-term price forecasts the aggregate acreage of a commodity is fixed, and only the yield and the storage possibilities of a commodity are crucial. Since it is difficult to forecast the short-term prices for horticultural commodities with an econometric price model, it is probably better to use the price time-series forecasting approach. This approach only uses the past price values of a commodity to forecast the future price values of this commodity. It assumes that the identified price data-pattern will continue in the future.

Given the situation in Dutch horticulture it is recommended first to develop supply and demand models for the Dutch horticultural commodities separately, before the econometric price model for that commodity can be used to obtain price forecasts. For this moment it is recommended to use a qualitative method to forecast monthly or annual price developments for horticultural commodities, and for the daily or weekly prices the price time-series forecasting approach.
1. INTRODUCTION

1.1 Background

Horticultural commodity prices are extremely volatile. All horticultural commodity prices have shown fluctuations from year to year, and some horticultural commodity prices have even shown extreme swings from trough to peaks in just a few days. For the horticultural entrepreneurs whose earnings are dependent on the horticultural commodities, the price volatility may cause major problems for them. An understanding of the price movements is essential for the entrepreneurs, but also for the government and the banks. Entrepreneurs need to know the short-term price developments for their decisions to postpone the harvest one or two days or to keep a commodity in storage or not. If their expected prices for that commodity for the next period are higher than the current prices, then they may decide not to sell the commodity, but to keep it in storage for the next period. Their long-term price expectations are important for their planting and investment decisions. These decisions are mainly based on the expected profits for the next years. As a consequence, the aggregate supply for a commodity can change from year to year. Therefore, the planting and investment decisions of entrepreneurs play a crucial role in the long-term price developments of horticultural commodities.

With the help of the expected price developments the government can decide if it has to support the horticultural entrepreneurs or not. And banks have to know the expected price developments for their decisions of making loans to horticultural entrepreneurs. If the horticultural entrepreneur will pay his loan back, then the bank may decide to make a loan. Hence, the expected price developments of horticultural commodities will play a crucial role in the determination of the bank’s prospective that the entrepreneur will pay his loan back.

It can be concluded that it is important to forecast the future price developments for horticultural commodities as accurately as possible. Unfortunately, the used methods to forecast the horticultural commodity prices are probably not adequate enough, because, in general, the discrepancy between price forecasts and actual prices of horticultural commodities is big. The chance that horticultural entrepreneurs, government, or banks make wrong decisions, based on the forecasted prices, is assumedly high. Therefore, they are looking for a possibly more adequate price forecasting method.

1.2 Objective and scope of the study

Since doubts have risen about the reliability of the used methods to forecast the prices for horticultural commodities, there is a need for a study to compare different methods with each other, and besides to give the strong and the weak points of each method (see Mulder et al., 1995). This thesis is a part of that study. It will contribute to a solution of the reliability problem.

Neither a development of a price forecasting method nor a development of a forecasting technique shall be included in this thesis. This is beyond the scope of this study. It will only compare possible methods by looking at their theoretical foundations and by looking at their applications in forecasting the prices of horticultural commodities in the Netherlands.

The objective of this thesis is to gain insight in and to increase the understanding of how price forecasting methods for the Dutch horticultural commodities can be constructed. In particular, in a way that allows horticultural entrepreneurs, government, and
banks to forecast reliable prices for horticultural commodities with a relatively easy and convenient method.

1.3 Outline of the thesis

For a good and easy implementation of a methods comparison, it is necessary to understand micro-economic price theory. Chapter 2 describes the micro-economic price theory briefly. This chapter shows that the prices of commodities rely on the relationships between market structure, exogenous processes, expectations and behaviour of agents.

Given the differences in Dutch horticulture the population of Dutch horticulture is classified into eight different sectors. These eight sectors are described in chapter 3. For each sector the price developments of two or three of its commodities are presented in a figure. Furthermore, commodity characteristics, demand factors, supply factors, and market structure are given. This chapter plays a crucial role in the judgement about the application possibilities of methods to forecast the prices of horticultural commodities.

In chapters 4 and 5 two approaches are explained. Chapter 4 explains the econometric price model. In this model the demand model and the supply model of a commodity play a crucial role. However, little or no demand and supply models for Dutch horticultural commodities have been developed, and therefore, this chapter starts with the explanation how demand and supply models for horticultural commodities could be developed. Besides, it gives the basic procedures to estimate the unknown parameters in the models. To use the econometric price model for horticultural commodities the market has to be transparent. However, not all Dutch horticultural commodity markets are transparent, and therefore another approach, the price time-series forecasting approach, is explained in chapter 5. This approach obtains price forecasts by using only the past price values of a commodity. It assumes that the identified price data-pattern will continue in the future.

Concluding remarks are given in chapter 6, with special emphasis to the application of the methods to forecast the prices for horticultural commodities in the Netherlands.
2. MICRO-ECONOMIC THEORY 1)

2.1 Introduction

Every economic model is based on a theory, including the price models, which are explained in chapter 4. These price models are based on economic theory. This theory is the core of economic science. As is noted by Russell and Wilkinson (1979), 'it can be defined as deriving the implications of purposive behaviour of consumers, producers, and other economic agents from the interaction of tastes and the constraints facing them'. This chapter gives the elementary basis of the economic theory that is necessary to understand the price models of chapter 4. Section 2.2 gives the derivation for the demand functions. Consumers are assumed to be utility maximizers, and their demand functions can be obtained by maximizing their utility functions subject to budget constraints. On the other hand, producers are assumed to be profit maximizers, and their supply functions can be obtained by maximizing their profit functions given their technological constraints. Section 2.3 shows the derivation for the supply functions. The next section brings the demand and the supply functions together to obtain the equilibrium price for a commodity in a perfectly competitive market. However, not all markets have a perfectly competitive structure, and therefore, the basic knowledge of imperfectly competitive markets are described. Section 2.5 describes these kinds of markets briefly.

2.2 Demand function

Every day consumption households have to decide which bundle of commodities they would like to buy. The decisions are based on their preferences. They will choose the bundle that is preferred to all other bundles that can be purchased with their income. Certain assumptions about consumer preferences are needed to model the behaviour of a consumer. Appendix 1 describes the standard preference axioms. These axioms define a preordering on the choice set. The preference ordering can be represented by a function. This is only possible if the bundles can be numbered so that bundles with higher numbers would be preferred to those with lower numbers. A utility function (U(.)) measures all bundles of commodities (x, y), on a numerical scale, and a higher measure on the scale means the consumer likes the bundle more, i.e. for every bundle x, y this means that x > y if and only if U(x) > U(y).

Consumers will try to get the bundle that gives them the highest utility, but they are restricted by their incomes. For many problems, it is adequate to model consumers individually, each making his or her own decision subject to his or her budget constraint. The consumer is endowed with a given positive amount of income (Y), and can purchase any non-negative amount of the n commodities (bundle x = (x_1, ..., x_n)) at fixed positive prices, p = (p_1, ..., p_n). Hence, the consumer will choose the consumption bundle that is best according to his or her preferences, subject to the constraint that the total cost of bundle x is no greater than his or her income. This consumer's problem can be written as follows:

\[
\text{Max}_x \ U(x) - U(x_1, ..., x_n) \quad \text{s.t.} \sum_{i=1}^{n} p_i x_i \leq Y \land x_i \geq 0 \quad \forall i, 1, ..., n \quad (2.1)
\]

The solution to this problem is the system of Marshallian demand functions \( D_i(x, p) \), or in other words, the consumer’s uncompensated demand functions.

First, two extensions of the Marshallian demand functions will be given, before the effects that price or income can have on demand will be explained. The first extension is the indirect utility function. This function \( V(p, Y) \) says how much utility the consumer receives at his optimal choice(s) at prices \( p \) and income \( Y \). The Marshallian demand and the indirect utility function are related as follows:

\[
D_i(p, Y) = \frac{\partial V}{\partial p_i} \quad i, 1, ..., n. \tag{2.2}
\]

This relationship is called Roy’s identity.

Consumer’s choice can also be found in another way. Now, the consumer tries to minimize his or her expenditure \( E(p, u) \) given a level of utility. The dual problem can be written as follows:

\[
\min_x \sum_{i=1}^n p_i x_i \quad \text{s.t.} \quad U(x_1, ..., x_n) \geq u \land x_i \geq 0 \quad i, 1, ..., n. \tag{2.3}
\]

In this dual problem the determining variables are \( u \) and \( p \) and the solution to this problem is the Hicksian or compensated demand functions \( H_i(u, p) \). They show how the demand is affected by prices with constant utility. If the price of commodity \( i \) increases, then the amount of commodity \( i \) that the consumer had bought before is more expensive. The expenditure rises at precisely the rate \( H_i(u, p) \). Probably, the consumer will buy less of commodity \( i \) and more of other commodities 1). The cost of changes in the optimal bundle to buy is assumed to be zero 2). This results in the following relationship between the expenditure function and the Hicksian demand function:

\[
H_i(u, p) = \frac{\partial E(p, u)}{\partial p_i} \quad i, 1, ..., n. \tag{2.4}
\]

The expenditure function is also closely related to the first extension, because the inverse of the indirect utility function will give the expenditure function. And substitution of the expenditure function in the Marshallian demand function gives the Hicksian demand function 3),

\[
x_i = D_i(x, p) - D_i(E(u|p), p) \cdot H_j(u, p) - x_j \quad i, 1, ..., n. \tag{2.5}
\]

Appendix 2 summarizes these relationships in a figure.

The last part of this section deals with the price and income changes and their effects on the demand for commodities. A change in the price of a consumed commodity has two distinguishable effects on the consumer’s optimum. Assuming that the price of commodity \( i \) changes, what will happen to the demand for commodity \( j \) at given prices and income?

---

1) Commodity \( i \) is not a Giffen good. This is an inferior commodity of which the income effect is so large that it more than cancels out the substitution effect of a price change (Russell and Wilkinson, (1979, p. 68)), or in notation form \( \delta D(x, p) / \delta p < 0 \) for all \( p \).
2) See e.g. Kreps (1990, p. 55).
3) General properties of the Marshallian and Hicksian demand functions: Adding up, symmetry, negativity and homogeneity. See e.g. Deaton and Muellbauer (1980, pp. 43-4).
In the first place, a decrease (increase) in the price of commodity \( i \) makes the consumer better (worse) off since it expands (contracts) the budget set and allows (forces) the consumer to attain a more (less) preferred consumption bundle. Consequently, it raises (reduces) the consumer's real income in the sense that the consumer is able to purchase more (less) of every commodity because of the decrease (increase) in the price of commodity \( i \). This effect is called the income effect. But, there is an additional effect of a price change. A decrease (increase) of the price of commodity \( i \) makes its commodity less (more) expensive relative to other commodities. Even if the consumer's utility level is maintained by an income compensation, the consumer might still wish to substitute consumption of the commodities that have become relatively more expensive (cheaper) for the commodities that have become relatively more expensive (cheaper). This effect is called the substitution effect. A useful tool in showing these effects is the Slutsky equation. This equation relates the Marshallian demand and the Hicksian demand. It can be written as follows:

\[
\delta D(p, y) - \delta H(p, u) - \delta D(p, y) \frac{\delta D(p, y)}{\delta y} \quad i, j, 1, ..., n. \tag{2.6}
\]

The first term on the right-hand side represents the substitution effect and the second represents the income effect of the change in the price of commodity \( i \). Consequently, the sum of the income effect and the substitution effect gives the total effect of a price change.

The commodities can be classified on their response to a change. If a consumer purchases less of a commodity as his or her income grows, that commodity is called an inferior commodity. And if more is purchased as his or her income rises, the commodity is called normal, although the consumer can purchase relatively less of the commodity. The latter has become known as 'Engel's law'. Food consumption is a good example of this law.

Another useful tool to compare the responsiveness of the demand for commodities to changes in a price, income or other variables like advertising is the elasticity \(^1\). This measure for the responsiveness of demand to for example price or income changes is independent of the units in which the commodity is measured. In this section three elasticities will be explained. First, the own-price elasticity of demand is explained. It is defined as the proportionate rate of change in demand for the \( i \)th commodity in response to the proportionate rate of change in its price and can be written as follows:

\[
e_p(p, y) = \frac{\delta D(p, y)}{\delta p_i} \frac{p_i}{D(p, y)} \quad i, 1, ..., n. \tag{2.7}
\]

Secondly, the cross-price elasticity of demand is given. It is defined as the proportionate rate of change of demand for the \( i \)th commodity in response to the proportionate rate of change in the \( j \)th commodity price. In symbols:

\[
e_q(p, y) = \frac{\delta D(p, y)}{\delta p_j} \frac{p_j}{D(p, y)} \quad i, j, 1, ..., n. \tag{2.8}
\]

Finally, the income elasticity of demand for the \( i \)th commodity is defined as the proportionate rate of change in demand for the \( i \)th commodity resulting from a proportionate rate of change in income. It can be written as follows:

---

1) Ceteris paribus. Tracy gives some problems in determining the elasticities in his book 'Food and agriculture in a market economy' (1993, pp. 50-1).
\[ \varepsilon_i(p, Y) = \frac{\delta D_i(p, Y)}{\delta Y} \cdot \frac{Y}{D_i(p, Y)} \quad i, \ldots, n. \]  
\hspace{1cm} (2.9)

Figure 2.1 shows the possible outcomes of the elasticities for foodstuff and their meanings. The demand for commodity \( i \) is elastic if the absolute value is greater than 1, and inelastic if the absolute value is smaller than 1. (In)elastic means that the demand for commodity \( i \) changes (less) more than proportionate in response to a change in the price or income. Furthermore, the figure presents that commodities \( i \) and \( j \) are substitutes (complements), if the cross-price elasticity has a positive (negative) value.

<table>
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<td>( \geq 1 )</td>
<td>luxury commodity</td>
</tr>
<tr>
<td>((0, 1))</td>
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</tr>
<tr>
<td>((-1, 0))</td>
<td>inferior commodity</td>
</tr>
<tr>
<td>( \leq -1 )</td>
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**Figure 2.1 Elasticities of demand**

Until now, a single consumer's demand has been considered. Seeing that the economy consists of many consumers, it is interesting to know the aggregate demand. The aggregate demand at prices \( p \) will be the sum of the individual demands given their individual incomes. Hence, the aggregate demand function for commodity \( i \) can be found as follows:

\[ Demand_{total,i} = D_{tot}(p, Y) = \sum_{m=1}^{M} D_{m,i}(p, Y_m) \]  
\hspace{1cm} (2.10)

where \( M \) is the total number of consumers in the economy, and \( Y_m \) is the individual income of the \( m \)th consumer.

The aggregate demand function will have the same characteristics as the individual demand functions under several assumptions 1).

2.3 Supply function

In the neoclassical economic theory, the firm is an entity, just like the consumer. The consumer has an objective function, utility, that is maximized subject to a budget constraint and any constraints on feasible consumption. On the other hand, the firm has an objective function, profit, that it maximizes subject to constraints imposed by its technological capabilities 2). This technological constraint reflects all conceivable combinations between inputs and outputs that are technologically feasible. A firm buys its inputs, transform these inputs into other products and tries to sell its outputs. Of course, some of the outputs of a firm may be inputs for another firm. These commodities are known as intermediate commodities.

1) See e.g. Deaton and Muellbauer (1980, pp. 161-5).
2) See Kreps (1990, p. 233).
If the firm knows its technological capabilities, it has to adopt a production plan. Since the producer tries to maximize profits, he or she will never choose a technologically inefficient production bundle \( z = (z_1, z_2, \ldots, z_n) \) so long as all the prices are strictly positive. According to Russell and Wilkinson (1979), 'a production bundle is technologically efficient if there is no alternative bundle in the technological set with less net input of some commodity and no more net input of other commodity'. Consequently, the entrepreneur will eliminate the technologically inefficient production bundles. The technologically efficient production bundles are represented by the net production function of a firm. This function gives the values of all \( n \) commodities but one value of the input-output vector \( z, z_j \) has (at most) one value that makes the remaining net outputs bundle technologically efficient. There is a one-to-one correspondence between the \( n-1 \) dimensional vector and the scalar \( z_j \). In other words, the technologically efficient bundles are represented by the efficient function, \( f_j \), that is defined as follows:

\[
z_j - f_j(z_1, z_2, \ldots, z_{j-1}, z_{j+1}, \ldots, z_n)
\]

(2.11)

where \( z \) is the \( n \)-dimensional vector that represents the feasible input-output combination for the firm. Hence, a bundle \( z \) is technologically efficient if and only if \( z_j = f_j(z_1, z_2, \ldots, z_{j-1}, z_{j+1}, \ldots, z_n) \). The net production function \( F(z) \) can be found by rewriting the efficient function in the following way 1):

\[
F(z) = z_j - f_j(z_1, z_2, \ldots, z_{j-1}, z_{j+1}, \ldots, z_n) = 0
\]

(2.12)

Given the net production function, the producer \( h \) will choose a production bundle \( z_h \) at positive prices, \( p = (p_1, p_2, \ldots, p_n) \) that yields the level of profits. The profit (or net revenue) of the producer is defined as the difference between gross revenue from the sale of produced commodities and the gross cost of commodities used in production. This producer's profit-maximization problem for firm \( h \) can be written as follows 2):

\[
\pi_h(z_h) = \max_{z_h} \left( \sum_{i=1}^{n} p_i z_{h,i} - \max_{z_h} \left( \sum_{i=1}^{n} p_i \min(0, z_{h,i}) \right) \right) \quad \text{s.t. } F_h(z_h) = 0
\]

(2.13)

The function \( \pi_h(z_h) \) is called the profit function of firm \( h \) 3).

The solution of this problem is the system of net supply functions or net input demand functions \( (S_{hi}(p)) \). These functions generate optimal amount of input and output commodities given any set of positive prices 4).

1) It is assumed is that the function \( F \) is twice differentiable, and that the technological set is strictly convex. See e.g. Kreps (1990, p. 238).

2) If prices will depend by assumption on the level of the firm's activities \( z \), then the prices are written as \( p(z) \). This results in the following profit-maximizing problem for firm \( h \):

\[
\pi_h(z_h) = \max_{z_h} \left( \sum_{i=1}^{n} p_i(z_h) z_{h,i} - \max_{z_h} \left( \sum_{i=1}^{n} p_i(z_h) \min(0, z_{h,i}) \right) \right) \quad \text{s.t. } F_h(z_h) = 0
\]

In the continuation of this section it is assumed that the prices do not depend on the firm's activities, in other words the prices are given.

3) Properties of the profit function are that the function is homogenous of degree one in prices, that the function is continuous in \( p \), and that the function is convex in \( p \). See e.g. Kreps (1990, p. 244).

4) These functions are continuous and homogeneous of degree one. See e.g. Kreps (1990, p. 251).
Supply function can also be found in another way. Now, the firm tries to minimize its cost of inputs that the firm needs for the production of its output. This dual problem starts with the derivation of the relationship between the least-cost combination of inputs and output. The cost function of commodity i will show this relationship, and it is defined as follows: \( C(x, w) \) where \( w \) is the price vector of the inputs, and \( x \) is the amount vector of outputs. As Russell and Wilkinson (1979, p. 161) noted, 'the cost function specifies the minimum cost of producing \( x \), with given input prices \( w \), when the producer is free to choose the optimal (cost-minimizing) rate of input utilization that is technologically feasible'. Using this cost function in the profit maximization problem of the firm, the supply function for commodity i can be found. The profit maximization problem can be defined as follows:

\[
\pi_i(x) = \max_{x} \left[ R_i(p, x_i) - C_i(x_i, w) \right]
\]

where \( R_i(p, x_i) \) is the revenue function for firm \( h \) and is defined as the product of the output price with the produced quantity of the output by firm \( h \), or in symbols \( p \cdot x_i \). The solution to the first order condition for the maximization problem of \( h^* \) firm says that the price of the output is equal to the \( h^* \) firm marginal cost of output production. Hence, the first order condition of the profit maximization problem of firm \( h \) is then defined as follows:

\[
p = MC_i(x, w)
\]

where \( MC_i(x, w) \) is the marginal cost of production of \( h^* \) firm. This condition says that a level of output should be chosen by firm \( h \), so that the output price is equal to its marginal cost of production. Marginal cost of production is defined as the extra cost needed by increasing output with one extra unit. The supply function for firm \( h \), \( S_h(p, w) \), can be obtained by inverting the FOC (2.15) in \( x \). This supply function is the same as the supply function that is derived from the production function.

The last part of this section deals with the price changes and their effects on the supply of the commodities. A change in the price of one of the supplied commodities can have three distinguishable effects on the supply of other commodities. Assuming that the price of commodity i changes, what will happen with the supply of commodity j? In the first place, a decrease (increase) in the price of commodity i will reduce (increase) the supply of commodity i, because the commodity's own price and its supply are positively related. A change in the price of commodity i does not always have an effect on the supply of the other commodities. This means that the supply of the commodities is not related in any way. But, if a decrease in the price of commodity i increases the supply of commodity j, then the commodities are related. In this case, the \( i^* \)th and the \( j^* \)th commodities are known as substitutes. This relationship between these two commodities can be written as follows:

\[
\frac{\partial S_j(a, w)}{\partial p_j} \cdot \frac{\partial S_i(a, w)}{\partial p_i} < 0 \quad i, j = 1, ..., n.
\]

It is also possible that a decrease in the price of commodity i reduces the supply of commodity j. In this case, the two commodities are known as complements. This relation can be written as follows:

---

1) Kreps gives three properties for the cost function in his book 'A Course in Microeconomic Theory' 1990, p. 251. The three properties are: 1 \( C(x, w) \) is homogeneous of degree one in \( w \) for each fixed output vector, 2 \( C(x, w) \) is non-decreasing in \( w \) for each fixed output vector, and 3 \( C(x, w) \) is concave in \( w \) for each fixed output vector.
Until now, the supply by a single firm has been considered. Since the economy consists of many firms, that produced commodity \( i \), it is interesting to know the aggregate supply. The aggregate supply at output price \( p \) and input prices \( w \) will be the sum of the individual supply functions of the firms. Hence, the aggregate supply function for commodity \( i \) can be found as follows:

\[
\frac{\delta S_i(p,w)}{\delta p} \cdot \frac{\delta S_i(p,w)}{\delta p} > 0, \quad i=1,...,n. \quad (2.17)
\]

where \( H \) is the total number of firms in the economy, \( p \) is the price of the output, and \( w \) is the price vector of inputs.

2.4 Equilibrium price

2.4.1 Introduction

This section will bring the demand and the supply functions together to obtain the equilibrium price for commodity \( i \) in a perfectly competitive market for the commodity. The equilibrium price that will be obtained can be a partial equilibrium price or a general equilibrium price. If the equilibrium price of a commodity is derived under the assumption that all other commodity prices in the economy are fixed, then the equilibrium price is a partial equilibrium price. But, in general, a change in the price of commodity \( i \) may effect both its own supply and demand as well as the demand and supply of other commodities. Therefore, it is better to determine the price equilibria in all commodity markets simultaneously. These obtained equilibrium prices are known as the general equilibrium prices.

Subsection 2.4.2 describes the partial equilibrium price, and subsection 2.4.3. describes the general equilibrium prices.

2.4.2 Partial equilibrium price

The partial equilibrium analysis of a market of a single commodity \( i \) keeps everything fixed that is outside the model. In addition, it is assumed that the market is a perfectly competitive market. In other words, it is assumed that the commodities are homogenous, and that they can be exchanged freely, that producers and consumers can enter or exit the market freely, and that they have full access to information concerning the price, commodity characteristics and availability, and, finally, that they act as price-takers 1).

Market equilibrium price of commodity \( i \) in a perfectly competitive market can be found by setting the aggregate demand for commodity \( i \) equal to the aggregate supply of commodity \( i \). As Kreps (1990, pp. 265-6) noted, 'Equilibrium in a perfectly competitive market is given by a price \( p \) for that commodity, an amount purchased by each consumer, and an amount supplied by each firm, such that at the given price each consumer is purchasing his or her preferred amount and each producer is maximizing profits, and the sum of the amounts purchased equals the sum of the amounts supplied'. Hence, the market equilibrium of commodity \( i \) can be defined as follows:

\[
\text{Supply}_{\text{total},i} - S_{\text{tot}}(p,w) = \sum_{k=1}^{H} S_k(p,w)
\]  

where \( H \) is the total number of firms in the economy, \( p \) is the price of the output, and \( w \) is the price vector of inputs.

1) In economic literature the markets for most agricultural commodities are considered perfectly competitive markets. See e.g. Russell and Wilkinson (1979, p. 216).
The partial equilibrium price of commodity \( i \) is determined under the assumption that each market is independent of what happens in all other markets in the economy. Since the interdependence between commodities in both the consumption and the production side, it is plausible to assume that the resultant set of partial equilibrium prices are not consistent. Consequently, the equilibria of all markets have to determine simultaneously. The general equilibrium analysis tries to determine the equilibrium prices and quantities of all commodities demanded and supplied simultaneously.

In a competitive general equilibrium exists a price vector, an allocation of commodities among consumers and an allocation of commodities among producers so that each consumer maximizes his or her utility at given prices and income that the consumer has generated by those prices and profit shares, and each producer maximizes his or her profit. Besides, the aggregate consumption of any commodity equals the sum of the aggregate supply of that commodity. The solution to this system gives the equilibrium prices in the economy.

2.5 Market structures

2.5.1 Introduction

The previous sections were based on the assumption that the commodity market is a perfectly competitive market. As Russell and Wilkinson (1979, p. 251) noted, 'in many markets this assumption approximates reality closely enough to yield accurate predictions'. However, not all commodity markets have the structure of perfect competition. Other types of market structures are monopoly, oligopoly, and monopolistic competition. This section describes these market structures briefly.

In subsection 2.5.2 the monopoly is described. This kind of market structure is characterized by a single producer of a particular commodity. If a market has more than one producer, but not so many as to justify neglecting the influence of the actions of anyone upon the price, it is known as an oligopoly. Subsection 2.5.3 describes this market structure. The last market structure, the monopolistic competition, is described in subsection 2.5.4. This market is characterized by a large number of producers of slightly differentiated commodities. As a consequence, each producer is a monopolist with respect to his own commodity. Nevertheless, the producer is subjected to competitive pressures from producers of closely related commodities.

2.5.2 Monopoly

A monopoly market consists of many consumers and just one producer of a particular commodity for which there are no perfect substitutes. The single producer is called the monopolist. Consumers are assumed to behave in the same way as in the perfectly competitive situation, hence they are assumed to act as price-takers. Therefore, the aggregate demand function of a commodity is the sum of all individual demand functions for that
particular commodity. On the other hand, the monopolist takes the input prices as given, and he determines the price for his output. Although the monopolist is the sole producer of that commodity, he must take the availability of substitutes into account in his pricing policies, because all commodities are substitutes for one another in the sense that they all compete for the consumer's purchase.

According to Russell and Wilkinson (1979, p. 254), 'the essential characteristic of a monopolistic market is that the demand curve for the monopolist is the entire market demand curve'. This means that if the monopolist changes his production of the commodity, the price of the commodity changes. Therefore, the monopolist cannot construct the price of the commodity as a parameter. A profit-maximizing monopolist will determine his price so that he maximizes his profit given his cost function of producing x units of output, C(x). Since the price level of a commodity determines the consumer's demand for that commodity, the output variable in the cost function has to be replaced by the consumer's demand function for that commodity. The profit-maximizing problem of a monopolist can then be defined as follows 1):

\[ \pi(D(p)) = \max_p [pD(p) - C(D(p))] \]

The solution to this profit-maximizing problem gives the market price for the commodity that maximizes the monopolist's profit 2).

With the previous maximizing problem it is assumed that the monopolist produces only one commodity, but what will be the market price if the monopolist produces more than one kind of commodity? Assuming that the monopolist produces n commodities over which he has monopoly power and where the cost of producing the output is C(x₁, x₂, ..., xₙ), then the profit-maximizing problem of a multiproduct monopolist can be defined as follows:

\[ \pi(D(p)) = \max_{p} \left[ \sum_{i=1}^{n} p_iD(p) - C(D(p), D_2(p), ..., D_n(p)) \right] \]

where \( p \) is the \((n \times 1)\) vector of prices. The solution to this problem gives the prices of the \( n \) commodities 3).

2.5.3 Oligopoly

If a market has more than one producer, but not as many to be able to act as price-takers, then this market structure is known as an oligopoly. In an oligopolistic market situation, when a producer determines his commodity price, he has to take into account how his action affects his rivals. If his action has a detrimental effect on his rivals, then the rivals react as soon as possible to their rival's action. The reaction of a rival is different in every oligopolistic market, because the interdependence between producers in a market will never be the same. Consequently, a single theory of oligopolistic equilibrium does not exist. As Russell and Wilkinson (1979, p. 279) noted, 'the equilibrium (if it exists) depends crucially upon the particular behavioral assumption which is made regarding the producer's attitudes towards interdependence. There are as many market solutions to oligopoly problems as there are assumptions regarding the behaviour of producers in such markets'. A valuable analytical framework within which the oligopolistic markets can be analyzed is game theory. However, game theory is beyond the scope of this thesis, but the

2) In this maximization problem it is assumed that the monopolist knows the demand function perfectly.
3) See e.g. J. Tirole (1990, p. 74).

2.5.4 Monopolistic competition

If commodities sold in markets are considered by the consumer to be differentiated, each producer experiences some of the elements of a monopoly. At the same time, the commodity differentiation is not complete, and therefore, each producer also experiences some of the effects of competition from producers of close substitutes. This market situation is known as monopolistic competition. A consequence of this situation is that every producer tries to create a separate market for his own product. The profit-maximizing producer will determine his commodity price so that he maximizes his profit given his cost function. But the producer cannot set his price too high, because otherwise the consumers will buy the commodity's substitutes. On the other hand, if the producer is making a profit, then entry of new producers to the market will occur. And if the producer is making losses, he will leave the market. As a consequence of free entry and exit, every producer in the market is assumed to make zero profit. In this situation, there is no incentive for any producer to change his price, because any other price change would generate losses 2). Nevertheless, a producer can make a profit if he develops a new commodity or if he reduces the commodity's production cost.

1) A solution to a game - the situation in which the players are involved - is a set of strategies chosen by the players in which no player can increase his or her payoff by changing his or her strategy under the assumption that the strategies of the other players remain fixed.

2) See e.g. J. Tirole (1990, pp. 287-289).
3. CHARACTERISTICS OF DUTCH HORTICULTURAL MARKETS

3.1 Introduction

For making price predictions it is important to know the characteristics of Dutch horticulture, because the price predictions have to be justified economically. Therefore, it is better to describe Dutch horticulture first, before the price prediction methods are explained.

Given the differences in Dutch horticulture the population is classified into eight different types of farming 1). These eight types of farming are: bulb growing, growing of (cut-)flowers under glass, growing of vegetables under glass, growing of pot plants under glass, tree nursery, outdoor growing of vegetables, mushroom farming, fruit growing. Every section in this chapter describes a sector, and each section is divided into five parts. The first part describes the nominal price developments of some commodities or group of commodities that are cultivated in that sector. The second part describes the commodity characteristics. This part shows that most commodities in Dutch horticulture are heterogeneous. Part three and four of the sections describe the demand and supply factors, respectively. The described information has to be used in the construction of demand and supply models for a commodity or group of commodities. The last part is about the market structure. This part presents the transparency of a market and implies the possibilities to predict the prices of commodities. The final section in this chapter summarizes the most important characteristics of each sector.

3.2 Bulb growing 2)

3.2.1 Price developments

Bulb growing is one of the most important outdoor growing sectors in Dutch horticulture. Its net value added of the production is 12 per cent of the total value in the horticulture. Although the net value added of production is known, the price values of the bulbs are not published. The reason is that the bulbs are generally not sold at auctions in the Netherlands. In spite of the secret of the price values, price values were allowed to be printed in a figure. The bulb prices of tulips and hyacinths are printed in figure 3.1. This figure shows that the prices have the same movements from the beginning of the eighties, although the price fluctuation of hyacinths is larger. Besides, both the tulip price trend and the hyacinth price trend show a slight increase.

---

1) The stratification is based on the annual accounting in Dutch agriculture (VAT).
2) This section is mainly based on V.C. Bouwman, Bollenmodel, Een dynamisch vraag- en aanbodmodel van Nederlandse bloembollen, Den Haag, LEI-DLO, 1993; Onderzoekverslag 117.
3.2.2 Commodity characteristics

Considering the area of production, about 16,000 ha, the most important bulbs are: tulips, hyacinths, daffodils, gladioluses, liliums and irises. Almost half of this bulb area has been used for the production of tulips (see Bouwman, 1993). Two sorts of bulbs, gladioluses and liliums, have to be planted in spring and can be harvested in autumn of the same year. However, the other four kinds of bulbs have to be planted in the autumn and can be harvested in the summer of the next year.

Other characteristics of the bulbs are that they can be used as a final and as an intermediate product. If the bulbs are used for private decoration, e.g. in house or in the garden, then they are final products. But, if the bulbs are used for growing flowers and new bulbs with the aim to sell them, then they are intermediate commodities. Furthermore, the bulbs are heterogeneous products because of the wide range of colours, size and the various kinds of bulbs.

Finally, bulbs can be stored for several months. The most recent technological development is that the bulbs can be frozen and saved for almost one year.

3.2.3 Demand factors

The demand for bulbs can be divided into two parts, namely demand for final products and for intermediate products. The latter demand can be derived from the supply of flowers and new bulbs. This can be explained by the assumption that the supply of flowers and bulbs are equal to the consumer's demand for flowers and bulbs. In the Netherlands the aggregate demand is dominated by the demand for intermediate products and export. The share of export of the total Dutch bulb production is more than 60% 1). Also,
the export of bulbs can be divided into final and intermediate products. The proportion of final to intermediate products differs for every importing country.

Household income has an important influence on the demand for bulbs, because this commodity is a luxury good. And for the entrepreneurs the profitability of their commodities is an important factor in determining the demand for intermediate products.

Another significant factor is the fashion or trend. This also affects the prices of bulbs and the prices of their substitutes, such as shrubs, although, in general, the demand for bulbs has a low price elasticity. Nevertheless, the prices of bulbs and of their substitutes are significant factors in determining the demand for bulbs (see Bouwman, 1993).

3.2.4 Supply factors

The Netherlands is the foremost producer and net exporter of bulbs in the world. Imports of bulbs to the Netherlands are relatively low, except for the import of daffodils from the United Kingdom. These daffodil bulbs are used as inputs by Dutch entrepreneurs. As described in section 3.2.1 the harvest seasons of bulbs vary, and therefore, the bulbs are supplied at different periods. The supply of the bulbs depends on the total production area of bulbs and on the physical production per m² 1). A deciding factor in the physical production per m² is technological development. In the short term the technology is exogenous, but it will play a significant role in the medium and in the long term.

Another significant determinant is the weather. When it rains a lot in the harvest period, it will be difficult for the entrepreneur to harvest the bulb production. And if the bulbs stay in the ground too long then they will putrefy. Consequently, this leads to a smaller supply of bulbs in that particular year. Of course, the weather conditions will never be the same in the bulb regions.

A change in the assortment of bulbs does not go so fast, because a switch from one kind of bulbs to another needs extra investments. For example, a change from daffodils to lilliums needs an extra investment of about 75,000 Dutch guilders per ha 2).

Finally, the number of entrepreneurs and the specialized bulb growing farms have decreased since 1975, whilst the total bulb area has increased. Hence, the average area per farm has increased (see Bouwman, 1993).

3.2.5 Market structure

Bulb growers are often individual entrepreneurs. Many of them are traders, exporters and growers at the same time. Most of the bulbs are not sold at auctions in the Netherlands, but by private contracts. The entrepreneur can sell the bulbs, when they are still in the ground, or directly after the harvest or preparation. Used selling methods of produced bulbs and their respective approximate shares are agencies (70%), private contracts (10%), auctions (5%). Entrepreneurs keeps about 15% of their bulb production as seed-bulb for the next season (see Bouwman, 1990).

1) The physical production per m² is defined as the production of commodity divided by total areal of the commodity.

2) See Bouwman, 1990.
3.3 Growing of (cut-)flowers under glass

3.3.1 Price developments

The Netherlands is the foremost exporter of (cut-)flowers in the world. Its share in the world trade of flowers is about 60%. Almost all (cut-)flowers are traded at auctions in the Netherlands. Consequently, the auction prices of (cut-)flowers are a good indication of real (cut-)flower prices. Figure 3.2 presents the price developments for tulips, freesias, and gerberas from 1966 till now. Tulips and freesias show a similar smooth price development, whereas the price development of gerberas is more explosive. The price of gerberas has increased quite rapidly, but since 1983 the price is declining. Probably, this can be explained by the fact that the high price of gerberas was an incentive for entrepreneurs to cultivate gerberas. Consequently, the supply of gerberas has increased. Figure 3.2 illustrates that the price developments of (cut-)flowers are not similar.

![Figure 3.2 Price development of tulips, freesias, and gerberas](image)

Source: Tuinbouwcijfers 1968-1994, LEI-DLO & CBS.

3.3.2 Commodity characteristics

Considering the volume and the value of production, the most important crops are: roses, chrysanthemums, carnations, tulips, liliums, freesias and gerberas (see Kijne et al., 1992). Although only the seven most important kinds of flowers are mentioned, the assortment range of flowers is vast. The range contains about eighty different sorts of flowers. Besides, there is also a great variation in one kind of flower with respect to colour, size, length, quality etc. An example is roses; roses can be small, big, red, white etc. Consequently, the flower is a heterogeneous commodity. Furthermore, it is possible to conserve

---

a flower by drying it, although the market share of durable flowers is insignificant.

Another difference between flowers is the growing season. Some flowers can be
grown several times a year, for example chrysanthemums; their life cycle is about four
months. However, the life cycles of other flowers can be several years. For instance it takes
about seven years to cultivate roses.

The definition of flowers is not clear, because some people say that foliage and
mosses can also be defined as flowers.

3.3.3 Demand factors

The demand for flowers can be divided into two components, namely in domestic
demand and export. Export is the most important component, since its share in the aggre­
gate demand is about 80%. Germany, France and the United Kingdom are the most im­
portant export markets. In 1991 their shares were 49, 14 and 10% respectively (see Kijne
et al., 1992). Of course, in the importing countries the consumers have different prefer­
ences. For example, the Netherlands exports relatively many tulips and few carnations to
France, but, on the other hand, many carnations and few tulips to the United Kingdom.
The high market share of Germany can be explained by the following factors: the geo­
graphical position, population, high level of welfare and German culture.

Generally, the consumption of flowers increases at special days like Mother's Day,
Easter, Christmas etc. This illustrates that flowers are luxury commodities. But Bouwman
and Trip (1990) have shown that the luxury degree of (cut-)flowers differs between coun­
tries. They have calculated a negative income elasticity for the Netherlands and a positive
income elasticity for France 1). The demand differences between countries can be ex­
plained by social environment, age, welfare and income per capita of these countries.

Furthermore, prices of flowers and their substitutes are very important. If the prices
of the Dutch flowers are higher than the prices of the country's own production, then the
consumers will buy their own flowers. A country's own flower production seems to be the
most significant competitor of the Dutch flowers. Consequently, the influences of the ex­
change rates are important for the export. Other luxury products like fruit, potplants and
chocolate are also competitors of flowers. Consequently, their prices and the prices of
flowers are important in the determination of the demand for flowers.

3.3.4 Supply factors

Dutch aggregate supply of the flowers can be divided into two components. The first
component is domestic supply. It is by far the most important component in the supply
function. Import of flowers is the other component in the aggregate supply. The foremost
exporters of flowers in the world to the Netherlands in 1991 are, in order of their market
share (see Kijne et al., 1992): Israel (38%), Spain (15%) and Kenya (14%) 2). Furthermore,
the supply is affected by the available area for the production of flowers. Probably, the
available land depends on the profitabilities of flowers and their substitutes. Development
of the total available area is not the only significant factor in determining the supply of
flowers. Another important factor is the physical production per m². This factor depends
on the technical and technological developments in the growing of flowers under glass
sector. But, the supply of flowers is more or less given in the short term (this period is
smaller than one year). Consequently, the supply of flowers is inelastic in the short term.

Since flowers are cultivated in glasshouses, the energy price also affects the entrepre­
nueur's decision about what he will cultivate under glass. If the price of energy is high, then
the entrepreneur can decide that he or she will cultivate other flowers or their substitutes

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1) Bouwman and Trip have assumed that the domestic market in the Netherlands is a rest
market. In other words, the buyers at auctions in the Netherlands try to export the flowers,
and what will remain from their supply is for the domestic market. Many arguments
against this assumption can be given, hence if this assumption realistic?

2) The United Kingdom is only a significant exporter of daffodils. About 90% of its bulb and
flower area is used for the cultivation of daffodils (see Bouwman and Trip, 1990).
under the condition that they need less energy. The probability that the energy price will increase in the future is significant, because nowadays, the protection of the environment is a hot item.

Both specialized farms and other farms in Dutch horticulture cultivate flowers. The specialized farm does not use its whole area for cultivating one sort of flower, although the concentration depends on the kinds of flowers that are cultivated under glass. For example, it seems that the area available for roses is relatively larger than the available area for liliums.

The cultivation of flowers under glass has been concentrated in the province of South Holland, about 60% (see Kijne et al., 1992).

3.3.5 Market structure

Almost all flowers of the aggregate Dutch supply, about 95%, are traded at auctions in the Netherlands 1). The buyers of flowers at auctions are wholesale dealers. The number of wholesale dealers, buyers, is quite large in the Netherlands. Because of the telecommunications developments, auctions will become more efficient and faster. According to Alleblas et al. (1990) these new developments will probably decrease the market costs in the future.

3.4 Growing of vegetables under glass 2)

3.4.1 Price developments

Nowadays, the growing of vegetables under glass is an advanced cultivation process in the Netherlands. Many European countries are using the developed Dutch techniques and technologies for growing their own vegetables. The development of new cultivation techniques and technologies was stimulated by the price rises of indoor vegetables in the last two decades. Figure 3.3 shows the price rises of the three most important vegetables under glass. In particular paprikas have demonstrated rapid price rises, although the price has fallen in the last five years. In these two decades the demand for these commodities has increased even more than the supply of these commodities. The plotted prices in the figure are auction prices. Since almost all vegetables that are cultivated under glass are traded at auctions in the Netherlands, auction prices are good indicators of the price developments.

1) Auctions in the Netherlands are renowned for efficiency, being equipped with pushbutton bidding systems. In contrast to the usual auction system, the dealer sets in motion a hand on a dial starting above the price he or she expects. Each lot goes to the first prospective buyer to press his or her button when the hand reaches the highest price he or she is prepared to bid. The system is quick and transparent (Tracy, 1993, p. 69).

3.4.2 Commodity characteristics

Considering the value of sales the most important vegetables under glass are: tomatoes (45%), paprikas (21%), cucumbers (21%) and lettuces (6%) (see Mulder, 1991). In general, the quality level of Dutch vegetables is very high. From the four commodities mentioned above cucumbers are almost homogeneous, although there always exist differences between cucumbers e.g. in quality and shape always remain. Because of the differences in same kind of commodity, colour, quality etc., the others are heterogeneous commodities. Examples are the different kind of tomatoes, namely round tomato, cherry tomato and the difference in colour of paprikas namely red, green, yellow and black. These commodities are generally luxury commodities.

3.4.3 Demand factors

The demand for vegetables that are grown under glass, can be split into two components: domestic demand and export. The latter accounts for almost 75% of the aggregate Dutch demand for vegetables. Germany is the foremost importer of Dutch vegetables.

Since the European markets of vegetables are competitive, the Dutch growers have to improve the quality of their products, otherwise they will lose their European market shares. Spain is relatively the most important competitor of Dutch commodities in Europe. Because of the luxury characteristic of the vegetables the income and the prices of indoor vegetables and of their substitutes play a significant role in the demand for these commodities. Furthermore, it seems that the consumers of vegetables are sensitive to advertising. This means that the elasticity of advertising is an important determinant in the demand function. In practice, the auctions in the Netherlands try to influence the behaviour of the consumers with their common marketing policies.

Other significant factors are probably: level of welfare, quality, fashion, environmental awareness. Nowadays, the consumers prefer the more environment-friendly cultivation methods and their commodities. The last important factor is the weather condition. Empir-
ically, it has been shown that the demand for fruit-vegetables is greater in warm periods than in cold periods (see Mulder, 1991).

### 3.4.4 Supply factors

The Dutch aggregate supply of these vegetables can be split into two components. The first component is domestic supply. It is by far the most important component in the aggregate Dutch supply. Import is the other component. It is also possible to divide the supply of vegetables into vegetables cultivated in heated glasshouses and cold glasshouses. For the first group the price of energy is an important determinant in the supply function.

In the last two decades the cultivation methods for vegetables under glass in the Netherlands have changed significantly. The growing methods for these commodities became more intensive, for example substrate technique, automation of the climate in the glasshouses. Consequently, the physical production per m² has increased. And because of the consumer's environmental awareness the entrepreneurs have to develop more environment-friendly methods. Hence, the technological, technical and biological developments are important factors in the supply functions. Unfortunately, not all the technological changes improve the flexibility of assortment change. The substrate technique leads to less flexibility in the glasshouses. Furthermore, it has made the cultivation period of some vegetables longer. Consequently, the supply of these vegetables is more spread over a longer period.

The last significant determinant is area. Although the total area has decreased in the last years, the available area of heated glasshouses has increased in the Netherlands. And the average area per farm has also increased. The latter can be explained by the fact that the number of farms has decreased (see e.g. Mulder, 1991).

Cultivation of vegetables under glass is concentrated in four Dutch provinces. These provinces are: South Holland (64% in 1989), North Brabant (12%), Gelderland (12%) and Limburg (4%) (see Mulder, 1991). In addition, every province cultivates a different assortment of vegetables. South Holland cultivates relatively more paprikas and tomatoes and the province North Brabant strawberries and cucumbers.

In general, the cultivation of vegetables under glass takes place at specialized farms. Most of the specialized farms are heated glasshouses, since the number of heated glasshouses is about five times the number of cold glasshouses in the Netherlands. Of course, the specialized entrepreneurs also cultivate other horticultural commodities, although their share in the total production of the specialized entrepreneurs is relatively small.

### 3.4.5 Market structure

Almost all vegetables cultivated under glass, between 90 and 95%, are traded at auctions in the Netherlands. In the last decade the buyers of the vegetables have been more concentrated. They have tried to get more grip on the markets. This has lead to a new market, the direct (private) contract between buyers and sellers, although this market is in its early beginning. The auctions have responded to this development with a service strategy. The buyers can ask the auctions if they will buy commodities with the desirable quality and package for them.
3.5 Growing of pot plants under glass 1)

3.5.1 Price developments

Cultivation of pot plants under glass is related to the cultivation of flowers and vegetables under glass. It is relatively easy to change from the cultivation of vegetables to (cut-)flowers and then to pot plants. Because of the special technical cultivation methods that are needed to cultivate pot plants, the other way around is difficult and expensive. Since the change from pot plants to the cultivation of other horticultural commodities is difficult, the entrepreneur is very interested in the price developments of pot plants. Figure 3.4 shows the price developments of two pot plants, azaleas and begonias. The price development of begonias shows a slowly increasing trend, whereas the price of azaleas has increased rapidly from the mid seventies till the mid eighties. After the mid eighties the azalea price decreased. This figure illustrates that the price developments of pot plants are not similar.

The prices that are used are auction prices. They are good indicators of the price developments, because about 80% of the pot plants are traded at the auctions.

![Graph showing price developments of azaleas and begonias](image)

**Figure 3.4** Price development of azaleas and begonias

Source: Tuinbouwcijfers 1968-1994, LEI-DLO & CBS

3.5.2 Commodity characteristics

Pot plants can be divided into three groups. The three types are: leaf plants, bed plants, and flowers. Every type has a vast assortment range, since every group contains at least fifty various kinds of plants and plants with different lifetimes. Since some kinds of flowers can flower only once in their lifetime, they have to be sold when the flowering time is near, otherwise consumers will not buy these flowers anymore. Leaf plants, however, do not have this problem and therefore may have longer lifetimes.

1) This section is mainly based on V.C. Bouwman, Potplantenmodel: Een dynamisch vraag-en aanbodmodel van Nederlandse potplanten, Den Haag, LEI-DLO, forthcoming.
Other characteristics of pot plants are the different kinds of colours and the decorative function. In particular the flowers will be used for decorative purposes. Hence, the pot plants are heterogeneous commodities.

3.5.3 Demand factors

Taking the current European market share of the Netherlands into account, about 20%, export plays a significant role in the aggregate Dutch demand for pot plants (see Bouwman, forthcoming). The foremost importer of Dutch pot plants is Germany, followed by France, Italy, the United Kingdom and Belgium. The other component of aggregate demand is domestic demand. It accounts for about 20% of the total Dutch demand for pot plants.

Generally, consumers prefer the three types of pot plants for different purposes. Most of the time the flowers and the leaf plants are used for decoration in houses. And the bed flowers are often used in gardens and flower boxes. The selling period of the latter is mainly in spring and autumn. Of course, weather conditions in these periods have a significant effect on the demand for these plants. The demand for flowers depends on the flowering season. Consumers only buy these flowers when the flowering season is near.

Household income is also an important determinant in the demand for pot plants, since these commodities can be used for decorative purposes. Other significant factors are fashion and trend. They affect the prices of pot plants and of their substitutes, in particular (cut-)flowers and bulbs.

3.5.4 Supply factors

Belgium, Germany and Denmark are the main exporters of pot plants to the Netherlands. The last two countries export flowers in particular and Belgium mainly leaf plants to the Netherlands. The import of pot plants is a component of the aggregate Dutch supply, although the share is small compared with domestic production share. The supply of leaf plants depends on their prices. If the prices are very low the entrepreneur can decide not to supply his production of leaf plants. Consequently, the supply of larger leaf plants will be greater in the succeeding year. But, the supply of flowers depends on how many times the plant will flower. If this flowering period is only once, the entrepreneur will always supply his flowers irrespective of the price level. Since the cultivation period of pot plants is almost one year, the entrepreneur cannot extend his pot plant production immediately. The supply of the pot plants depends on the available area. In the last decades the total available area for pot plants has increased, and this is a main cause of the increased production of pot plants in the Netherlands. Another important factor of the increased production is the higher physical production per m². Two of the main determinants of the physical production per m² are the technological and technical developments. About half of pot plant nurseries has a system of growing on benches, the other half grows from the ground.

Furthermore, the composition of supply depends on the profitability of the different kinds of pot plants. By this, the profitability is a significant determinant of the supply function. Other significant determinants are the prices of substitutes and environmental policies. Nowadays, the environment-friendly production methods are preferred in society.

The South Holland glass district is the foremost production centre for pot plants in the Netherlands, followed by Aalsmeer and Lent. Nurseries outside the production centres are mostly in a weaker position. They are smaller and less specialized than the nurseries in the centre. About 92% of the Dutch pot plant nurseries were specialized in the cultivation of pot plants in 1990.

3.5.5 Market structure

The market of pot plants is transparent, although many growers of pot plants are also traders or exporters at the same time. The transparency can be explained by the fact
that the growers are obligated to trade their products at auctions in the Netherlands, because they are members of the auctions. Most of the pot plants, about 80%, are sold at the auction, the other part by private contracts (see Bouwman, forthcoming).

3.6 Tree nursery 1)

3.6.1 Price developments

Since the biggest part of the sales are private, little is known about the total supply and total demand for tree nursery stock. The structure of the market can be described as monopolistic competition. Besides, little is known about the prices of trees and perennials, because the nurseries sell most of their own commodities directly instead of at auctions. The only prices that are known are the average Dutch export prices of trees and shrubs. Figure 3.5 shows the development of average Dutch export prices. From 1970 till 1988 the average price of trees and shrubs has increased, whereas from 1988 the average price has declined.

![Figure 3.5 Price development of trees and shrubs](image)

Source: CBS.

3.6.2 Commodity characteristics

Although the assortment of trees and perennials is vast, these commodities can be classified into eight types. The classification is: forest and hedging plant material, ornamental trees, fruit trees, ornamental shrubs, conifers, herbaceous perennials and rose bushes. Some kinds of trees or perennials can be used as final and as intermediate commodities. The rose shrub can be bought for the decoration of a garden, but it can also be bought with the aim to cultivate commercial roses. The latter is described in section 3.3.

Another example are the fruit trees, because a fruit grower needs new young trees or new varieties to replace old trees.

Other characteristics of these commodities are the quality, the cultivation periods and methods. Most of the nursery stock commodities are luxury products, except the intermediate commodities and the forest plant material. Furthermore, all tree nursery commodities are heterogeneous.

3.6.3 Demand factors

The demand for trees and perennials can be divided into two components, demand for final products and for intermediate products. The latter can be derived from the supply of final products; examples are the supply of fruit and roses. About half of the aggregate Dutch supply is traded at domestic market and the other half is traded with the other members of the European Union. Germany, the United Kingdom and France are the main importers of the Dutch supply, since their common share of the Dutch export is about 68% (see Jonkheer et al., 1992). The export of trees to the other countries depends on the country's own production. Importing countries use the Dutch trees and shrubs to complete their own assortment range.

Both domestic demand and export depend on the season. The demand for these commodities has two peak periods: in spring and in autumn. Furthermore, the weather conditions will also have influence on the demanded quantities in that particular year.

Household income is another important determinant in the demand for trees and for shrubs, because many of the tree nursery commodities are luxury goods. And for the entrepreneurs the profitability of their commodities is an important determinant in the demand for intermediate products. Trend and fashion may also play a significant role in the demand. They affect the prices of these commodities and their substitutes, for examples bulbs and plants. Furthermore, recommended prices exist for fruit trees, ornamental trees, ornamental shrubs and conifers, although they are not compulsory for the suppliers.

3.6.4 Supply factors

Because the share of import is very small (6% in 1990) the domestic production dominates in the aggregate Dutch supply. The import comes mainly from the European countries, in particular Germany and Belgium (see Jonkheer et al., 1992). Domestically, the production capacity of nurseries is unevenly distributed. A small number of nurseries have a relatively large share in the production of these commodities. Most of these nurseries grow their own starting material, although there is a trade in starting material. A further partition of the demand is possible, since the commodities can be divided into final and intermediate commodities.

In the last years the cultivation methods of tree nursery commodities have become more intensive. Important developments within the tree-nursery sector are the cultivation of trees in pots and containers and the cultivation in cabriolehouses. These developments have extended the sale and planting season of these commodities, hence the technological and technical changes are important determinants in the supply function. Unfortunately, the new cultivation methods are not applicable to all kinds of trees. Because of the current environmental policies these cultivation methods have to become more environment-friendly. Besides, these policies affect the total available cultivation area for trees in the Netherlands. The Dutch production of trees also depends on the available area. But total available area cannot change immediately, because the cultivation period of trees such as fruit trees is at least two or three years. The assortment decision of the entrepreneurs depend on the profitability of the commodities.

Six production centres can be distinguished. These centres are: Region Boskoop, West-North Brabant, Middle-North Brabant, Region Opheusden, East Groningen and North Limburg. Each region has its own characteristics and assortment. The biggest nurseries can be found in the second and in the fifth region.
3.6.5 Market structure

Although the market of tree nursery commodities is characterised by many buyers (private persons, professional users and governments) and sellers, the market is untransparent. The main reason is that the nurseries sell most of their own commodities directly instead of at auctions. Auctions are mainly orientated towards the ornamental shrubs and conifers. Approximately 15% of the nurseries are cultivating on contracts (see Jonkheer et al., 1992). Besides, nurseries can cultivate special varieties of commodities. They can create a new segment on the market. Finally, vertical integration takes place in this sector, since nurseries are also wholesale dealers, gardeners, and garden centres, which are the main distributors to the consumers. In 1991 approximately 55% of the Dutch nurseries were specialized in cultivating trees and shrubs (see Jonkheer et al., 1992).

3.7 Outdoor growing of vegetables 1)

3.7.1 Price developments

In comparison with the other Dutch horticultural sectors, except tree nursery, a large share of the output sale of this sector has been sold on the domestic market. Auctions in the Netherlands play the most important role in the trade of these commodities. Consequently, the gathered data from the auctions are reliable. Hence, auction prices are good indicators for the price developments of outdoor growing vegetables. Figure 3.6 presents the price developments of three outdoor growing vegetables. This figure shows that the prices of sprouts fluctuate around a constant, and the prices of asparagus fluctuate around a positive trend. For broccoli, the data are available since 1982. The price development of broccoli demonstrates a negative trend. This figure illustrates that there is no significant relation between the prices of vegetables.

![Price development of asparagus, broccoli, and sprouts](image)

*Figure 3.6 Price development of asparagus, broccoli, and sprouts
Source: Tuinbouwciijmers 1968-1994, LEI-DLO & CBS.*

3.7.2 Commodity characteristics

Although there is a vast range of outdoor vegetables, they can be classified into five groups. The classification is as follows: fruit crops (e.g. strawberry, asparagus), stalk crops (e.g. broad bean, French bean), leavy crops (e.g. endive, chicory), cabbages, and carrots. Further distinctions between these commodities are possible, since some commodities need an intensive cultivation treatment, for example strawberries, and others do not, in particular cabbages, and the outdoor vegetables can mainly be cultivated in two seasons. The main cultivation seasons are in summer and in winter.

Most of the vegetables are necessary commodities for human beings, but a small fraction of the assortment are luxury commodities. Examples of the luxury commodities are strawberries and asparagus. From this, we learn that outdoor vegetables are heterogeneous.

3.7.3 Demand factors

Weather condition is an important determinant in the demand for outdoor vegetables, because it affects the demanded quantities of Dutch vegetables. The Netherlands will export more outdoor vegetables to the other Western European countries, in particular to Germany, France, the United Kingdom and Belgium, where the winters are cold, summers are hot and dry, autumns are wet and springs are too warm and too dry. Furthermore, it seems that the share of Dutch export to the other European countries is higher for the winter outdoor vegetables, especially cabbages and carrots, than for the summer outdoor vegetables. But, in general, the export position of the Dutch outdoor vegetables can be characterized as filling the gaps in the foreign markets. In 1988 about 30% of the aggregate Dutch supply was exported, and the rest was supplied to the domestic market (see Mulder, 1989). The domestic consumption pattern in a year depends on the weather conditions, for example if the summer is warm, then the consumers will consume more vegetable salads than in a wet summer. This is known as the short-term substitution effect. There also is a long-term substitution effect between outdoor and indoor vegetables. In the last decades the consumer's tendency has changed through the welfare increment. Nowadays, consumers prefer more vegetables that contain less calories and that are cultivated environment-friendly.

Generally, the demand for outdoor vegetables is price inelastic. This means that an increase in the price induces a less than proportionate increase in the demand for the commodity. Exceptions are luxury vegetables like strawberries and asparagus. The demand for these vegetables is elastic. Furthermore, the demanded quantity of outdoor vegetables is sensitive to advertising. Advertising aims to persuade consumers and make the demand less responsive to price changes.

Finally, a further distinction in the demand for outdoor vegetables is possible: fresh vegetables are required by consumers and vegetables with preserving qualities by preserves manufactures.

3.7.4 Supply factors

The aggregate Dutch supply of vegetables is dominated by domestic supply, although the import cannot be neglected. Spain, Italy and Greece are the main competitors of the Netherlands. The import to the Netherlands depends on the weather conditions in exporting countries and in the Netherlands. If the weather is extremely bad abroad (in the Netherlands), then the import share with respect to the Dutch aggregate supply will decrease (increase) in that year.

Other significant factors in the determination of the supply are the available area and the physical production per m². The developed technology and techniques have made the cultivation treatment of vegetables more intensive. Besides, they have influenced the cultivation seasons of some vegetables. Nowadays, asparagus can be cultivated in May instead of the original month June. Furthermore, the cooling technique has improved, and now it is possible to store vegetables for several days. Unfortunately, these develop-
ments damage the environment. The consumers become more aware of the deterioration of the environment and are demanding more environment-friendly cultivated outdoor vegetables. Hence, the environmental awareness of the society plays an important role in the total available supply.

The vegetable assortment of a grower depends on the soil and on the profitability of vegetables. Labour costs have a relatively large share in the total costs of a grower of outdoor vegetables. Also the price of the starting material affects the profitability of a vegetable significantly. Most of the starting material has been bought by specialized entrepreneurs in these kinds of commodities.

Considering the climate, soil and history, the most important cultivation provinces of outdoor vegetables are: North Brabant, North and South Holland, Limburg and Flevoland. In general, the cultivation of the outdoor vegetables takes place at specialized outdoor growing farms and at agricultural farms.

3.7.5 Market structure

The market of outdoor vegetables is characterized by many buyers and sellers. About 70% of the aggregate Dutch supply has been traded at auctions in 1988 (see Mulder, 1989). Hence, auctions in the Netherlands play the most important role in the trade of outdoor vegetables. In the last decade the demand side has shown some concentration, seeing the increased power of the multiple-shop organizations. They prefer to buy the vegetables directly from the growers and not at auctions. The preserving manufacturers have used the direct contract system for a long time.

3.8 Mushroom farming 1)

3.8.1 Price developments

The mushroom farming sector is a special sector in comparison with the other horticultural sectors, because its products are quite homogeneous. This is the reason that 'Tuinbouwcijfers' 2) gives the average annual data of mushrooms only. The annual average price of mushrooms fluctuates around a constant value. Figure 3.7 shows the annual price development of Mushrooms from 1966 till now. The constant value can be explained by the fact that the aggregate demand for mushrooms has grown proportionately to the aggregate supply of mushrooms. Nowadays, the aggregate supply is about eight times the supply of 1966.

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2) 'Tuinbouwcijfers' is made by the Agricultural Economics Research Institute (LEI-DLO), and Central Bureau of Statistics Netherlands (CBS). In the publication the annual horticultural data are printed.
3.8.2 Commodity characteristics

Although mushrooms can differ in respect to size (giant, medium or small) and colour (white or brown) the literature always generalizes mushrooms. This can probably be explained by the homogeneous character of mushrooms. But a classification is possible according to quality. There are three quality categories: first, second, and third class.

Other characteristics are the short cultivation period of about 8 weeks and the possibility to preserve the mushrooms.

3.8.3 Demand factors

The demand for mushrooms can be divided into two components, domestic demand and export. The members of the European Union are the foremost importers of Dutch mushrooms, in particular Germany, France, Belgium, Italy, Denmark and the United Kingdom. Because of the applications of the mushrooms a further distinction in demand is possible. The market can be divided into a market for fresh mushrooms and one for preserved mushrooms. In general, the mushrooms from the first and second quality classes are supplied to the fresh mushroom market and from the third quality class are used in the preserving industry. The domestic market is dominated by the fresh mushroom, because the market for preserved mushroom in the Netherlands is almost negligible. But markets for these products cannot be neglected abroad. Something can be said about the price elasticities of these markets. In the Netherlands both the demand for preserved mushrooms and the demand for fresh mushrooms have inelastic price elasticities. Furthermore, the demands are competitive, consequently, the cross-price elasticity of these two kinds of mushrooms is an important determinant in the demand. But, export markets are not so homogeneous, since export demand for preserved mushrooms is price inelastic and the export for fresh mushrooms is price elastic (Kortekaas et al., 1987).
Finally, the consumers preferences depend on the fashion, hence the trend is an important determinant in the demand. Besides, demand for mushrooms is sensitive for substitutes. An example of a substitute is the oyster mushroom.

### 3.8.4 Supply factors

The aggregate Dutch supply can be divided into two components, namely domestic production and import, although the share of import is relatively small in comparison with the share of domestic production. Import to the Netherlands has come from the other members of the European Union, and not from Asian countries that also cultivate mushrooms. These countries are not allowed to export to the European Union, because the European Union protects its own mushroom farming.

Soil is an important factor for the quality of mushrooms. If the mushroom farmer cultivates his mushrooms in fresh compost, then, in general, these mushrooms have a high quality. They can be classify in qualities classes one or two. But, if the mushrooms are cultivated in re-used compost, then, mostly, they belong to the third quality class. The latter kind of compost has accelerated the cultivation process of mushrooms. A farmer can cultivate mushrooms approximately five times a year. Consequently, the supply of mushrooms is more or less continuous.

Technological, technical, biological and organizational developments have also affected the supply of mushrooms. Other kinds of mushrooms, extra feeding of mushrooms, extension and intensification of area have increased the physical production of mushrooms per m². And mechanical harvesting has reduced the labour costs, that have the greatest contribution in the total costs of mushrooms. Hence, these developments are significant determinants in supply.

Considering the number of mushroom farms in the Netherlands in 1991, the most important provinces are: Limburg (269), Gelderland (268) and North Brabant (253). In 1991 there were a total of 836 mushroom farms in the Netherlands (see Tuinbouwcijfers, 1992). And most of the entrepreneurs, that cultivate mushrooms, are specialized in doing this.

### 3.8.5 Market structure

The market of mushrooms has not been characterized by transparency. The various trading systems in this sector have caused this. Preserving manufacturers are always buying the mushrooms in advance via the private contract system, and not at auction. Sometimes the wholesale dealers use the contract system, but most of the time they are buying the mushrooms at auctions. Another main cause of the untransparency of the market is vertical integration in this sector. A mushroom farmer can also be trader and exporter at the same time.

### 3.9 Fruit growing 1)

#### 3.9.1 Price developments

Differences in entrepreneurial annual income of about Hfl. 50,000.- are quite normal in this sector. No other sector in horticulture shows such fluctuations in entrepreneurial incomes as the fruit growing sector. This is caused by the climate sensitivity and the structure of this sector. The aggregate supply of fruit in a particular year depends on the weather condition in that year. Hail, for example may destroy the fruit crop; in other words supply of fruit will become less in comparison with other years. And by a constant demand for fruit, the prices of fruit will rise in these situations. Figure 3.8 presents the

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extreme fluctuations of apples and pears. This figure shows that the price developments of apples are more or less the same as the price developments of pears. Both price developments show a positive trend.

The prices that are used are auction prices. They are good indicators for the price developments, because about 70% of the fruit is traded at auctions.

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**Figure 3.8 Price development of apples and pears**

Source: Tuinbouwcijfers 1968-1994, LEI-DLO & CBS.

3.9.2 Commodity characteristics

Considering the area of production, fruit can be classified into: apples, pears and others (cherries, plums, etc.). Their share in area are 72, 23, and 5% respectively (see Tuinbouwcijfers, 1992). A further distinction is possible between old and new crops, because this sector is characterized by a high newly developed crop rate. It also illustrates the vast assortment of fruit and the heterogeneous characteristic of fruit.

Another characteristic is the possibility to store fruit, in particular apples. Not all apples, such as Elstar and Cox Orange are not suitable to store, because they will lose their quality. And the quality of fruit is an important determinant in the consumer's buying habit. There are other ways to preserve fruit. The first method is to preserve fruit in cans and the second one is to squeeze the fruit. If fruit is used as input in the last two industries, then it is an intermediate commodity.

It is difficult to say that fruit is a luxury commodity. Preserved fruit in cans and fruit juices, however, are more luxury commodities.

3.9.3 Demand factors

A great amount of Dutch fruit production has been sold on the domestic market. Of course, the Netherlands exports fruit to other countries, mainly to the other members of the European Union. It seems that the Netherlands is a net exporter of pears and a net importer of apples (see Tuinbouwcijfers, 1993). Hence, the aggregate Dutch demand can be divided into two components, namely domestic demand and export. Differences in the applications of fruit make a further distinction in demand possible. First, the demand for
fresh fruit. Secondly, the demand for preserved fruit by preserving manufacturers. And thirdly, the demand for fruit juices by the food industry. The last two demands are derivations of the supply of these kinds of products.

The demand for fresh fruit depends on several factors of which quality is one of them. Consumers prefer fruit of a high quality. If one kind of apple has a lower quality, then the consumer will change his or her fruit choice and he or she will buy another kind of apple, with a higher quality. This is possible, because the product range has increased in the last decades. Also the colour, shape and size of fruit are important determinants in the consumer's buying decision. For example, a consumer will sooner buy a shiny round apple, than a strange looking one.

Furthermore, it seems that both export and domestic demand for apples and for pears are price inelastic. On the other hand, the demand for plums and for cherries is more price elastic. But, the demands of all sorts of fruit are affected by advertising and packaging, because the consumers of fruit are sensitive to advertising and packaging. Hence, the promotion elasticity is an important instrument for the determination of the demands for all kinds of fruit.

3.9.4 Supply factors

The aggregate Dutch supply can be divided into two components, namely import and domestic production. France, Germany, Italy and Belgium are the main European exporters to the Netherlands, and furthermore, countries like Argentina, Chile and Brazil export to the Netherlands. Most of the Dutch import has been (re-)exported to other countries.

Both the quantity of import and the quantity of domestic production depend on the weather condition in the particular year. The weather is the most important determinant in the aggregate Dutch supply, although it can differ between regions and between countries. For example, if the blossom is frozen in spring fruit yield will be smaller.

The fruit growing sector does not respond to demand changes immediately. It takes about two years before a tree will give its fruit, and the tree will stay in an orchard for at least nine years. Consequently, the supply of fruit is given in the short term, and can be changed in the medium and the long term. What kinds of fruit trees are to be planted depends on the newly developed commodities and the trend in consumer's choice. If an entrepreneur makes a wrong decision about the plantation, then he will supply an unpopular kind of fruit for more than nine years, with the consequence of losing his market share. The entrepreneurs buy their starting material from the tree nurseries (see section 3.6).

Other important determinants in the supply are area and physical production per m². The latter depends on the technological, technical and biological developments in this sector. Besides, the developed cooling systems have enlarged the supply period of all kinds of fruit. Nowadays, the supply period of some sorts of apples is almost one year.

The fruit orchards are concentrated in five Dutch provinces. These provinces are: Gelderland, Utrecht, Zeeland, North Brabant and Limburg (see Tuinbouwcijfers, 1992). And most of the Dutch production of fruit comes from the fruit growers, who are specialized in growing fruit.

3.9.5 Market structure

Although about 70% of all fruit is traded at auctions in the Netherlands, the formation of the prices of fruit depends on the total supply of fruit in the European Union. In general, the price movements of fruit in the other member states of the European Union are almost the same. This can be explained by the absence of trading barriers between the member states and the possibility to store fruit for several months. Furthermore, the market of fruit is characterized by many buyers and sellers, although the last decade the demand side has shown some concentration. The main cause of the concentration movement is the increased power of the multiple shop organizations. Also, the supply side demonstrates a concentration movement, since some fruit growers are selling their fruit to wholesale dealers and exporters when the fruit still has to be picked.
3.10 Summary

This section summarizes the main characteristics of the eight Dutch horticultural sectors. The main characteristics of each sector are presented in table 3.1. The first column contains the eight sectors. The corresponding row gives the characteristics of that sector.

Since this thesis is about price prediction in Dutch horticulture, it is important to know if the price data are available. The second column of table 3.1 demonstrates the availability of price data. If they are available for the sector commodities, then the cell contains the letter 'a' (available), and if they are not available then 'u' (unavailable) is written in the cell.

The next three columns are a summary of the commodity characteristics. If the commodities are used as final (intermediate) commodity, then the capital letter 'F' ('I') is written in the cell. Besides, in all the subsections about the commodity characteristics in this chapter it is mentioned that the commodities in a sector are heterogeneous or not. The letter 'x' in the fourth column says that the commodities of a sector are heterogeneous. This letter is also used to say if it is possible to store the commodities. If the cell contains the letter 'x', then it is possible to store the commodities. The sixth and the seventh columns denote the demand characteristics. The sixth column gives the price elasticity, and the seventh column shows the importance of the export. If a cell contains ++ then the export is a very important component in the aggregate demand. A cell with one + says that the export is not so important. On the other hand, a country that exports can also have imports. Import is a component of the aggregate Dutch supply. The importance of import in the aggregate Dutch supply is presented in eighth column of table 3.1. The meaning of + and ++ in this column is exactly the same as for export. Another characteristic of the supply is the flexibility. Column nine demonstrates the supply flexibility. If the supply is fixed in the short run, then it is denoted with s.r, and fixity for medium and long run are denoted by m.r and l.r respectively. The supplied quantity of a commodity depends on weather conditions in the particular year. Some LEI-DLO publications have presented that the demanded quantities of particular commodities like cutflowers are also affected by weather conditions. Column ten shows whether the weather conditions affect supply and demand. The meaning of the capital letter 'S' ('D') is that the supplied (demanded) quantity of a commodity is influenced by weather condition.

Column eleven gives the specialization rates of sectors. If the cultivation of commodities takes place at specialized farms in a sector, then this rate has a high value. Appendix 3 gives the calculations of these specialization rates.

The last columns in table 3.1 describes the transparency of the markets. This automatically implies the availability of data and the possibility to construct a price model for a commodity or group of commodities.
Table 3.1  Summary of eight Dutch horticultural sectors

<table>
<thead>
<tr>
<th></th>
<th>Price</th>
<th>Final / intermediate</th>
<th>Heterogeneous</th>
<th>Storability</th>
<th>-E&lt;sub&gt;n&lt;/sub&gt;</th>
<th>Export</th>
<th>Import</th>
<th>Fixed supply</th>
<th>Weather</th>
<th>Specialized farms %</th>
<th>Market</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulbs</td>
<td>n.a.</td>
<td>F/I</td>
<td>×</td>
<td>&gt;0</td>
<td>++</td>
<td>+</td>
<td>s.r.</td>
<td>s.r.-m.r.</td>
<td>S</td>
<td>54</td>
<td>untrans-</td>
</tr>
<tr>
<td>Cutflowers</td>
<td>a</td>
<td>F</td>
<td>×</td>
<td>&gt;0</td>
<td>++</td>
<td>+</td>
<td>s.r.</td>
<td>s.r.-m.r.</td>
<td>D</td>
<td>93</td>
<td>transparent</td>
</tr>
<tr>
<td>Indoor vegetables</td>
<td>a</td>
<td>F</td>
<td>×</td>
<td>&gt;0</td>
<td>++</td>
<td>+</td>
<td>s.r.</td>
<td>s.r.-m.r.</td>
<td>D</td>
<td>75</td>
<td>transparent</td>
</tr>
<tr>
<td>Pot plants</td>
<td>a</td>
<td>F</td>
<td>×</td>
<td>&gt;0</td>
<td>++</td>
<td>+</td>
<td>s.r.</td>
<td>s.r.-m.r.</td>
<td>76</td>
<td></td>
<td>transparent</td>
</tr>
<tr>
<td>Tree nursery</td>
<td>n.a.</td>
<td>F/I</td>
<td>×</td>
<td>×</td>
<td>&gt;0</td>
<td>++</td>
<td>+</td>
<td>m.r.</td>
<td>S</td>
<td>65</td>
<td>untransparent</td>
</tr>
<tr>
<td>Outdoor vegetables</td>
<td>a</td>
<td>F</td>
<td>×</td>
<td>&gt;0</td>
<td>+</td>
<td>+</td>
<td>s.r.</td>
<td>S/D</td>
<td>19</td>
<td></td>
<td>transparent</td>
</tr>
<tr>
<td>Mushroom</td>
<td>a</td>
<td>F/I</td>
<td>×</td>
<td>&gt;0</td>
<td>++</td>
<td>+</td>
<td>s.r.</td>
<td></td>
<td>94</td>
<td></td>
<td>transparent</td>
</tr>
<tr>
<td>Fruit</td>
<td>a</td>
<td>F/I</td>
<td>×</td>
<td>&gt;0</td>
<td>++</td>
<td>++</td>
<td>m.r.-l.r.</td>
<td>S</td>
<td>59</td>
<td></td>
<td>transparent</td>
</tr>
</tbody>
</table>

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4. PRICE-PREDICTION METHODS FOR HORTICULTURAL COMMODITIES

4.1 Introduction

An approach to obtain price predictions is to set up an econometric price model. The framework of an econometric price model relies on the relationships between market structure, exogenous processes, expectations, and behaviour. The price predictions obtained with an econometric price model are generally justified economically. This chapter describes the econometric price model approach. But, before the price model can be illustrated, demand and supply models have to be known. Unfortunately, in general, no demand and supply models for Dutch horticultural commodities are known, therefore a simple demand and supply model for the Dutch horticultural commodities is used to understand the theoretical foundation of an econometric price model. The demand and supply model in this chapter is based on the demand and supply model for winter tomatoes in the United States that has been developed by Shonkwiler and Emerson 1) in 1982. Their model has been generalized for Dutch horticulture. And the price model in this chapter is found with the partial equilibrium identity.

The first subsection of section 4.2 describes the general demand equation for Dutch horticultural commodities. For the short-term price prediction the planted acreage of a commodity is fixed, and then the yield of that acreage and the storability possibility, which is explained in 4.2.4, are the most important determinants for the predictions of the short-term prices. However, this chapter is mainly based on the long-term price predictions, and hence, the planted acreage plays a crucial role in the price predictions. Subsection 4.2.2 describes both the yield and the acreage equation. The previous subsections are combined in subsection 4.2.3. This subsection presents a partial equilibrium-perfect competitive price equation based on various assumptions about the grower's price expectations of a commodity. His price expectations for commodities play a crucial role in his planted acreage decision.

Of course, these equations have to be estimated, and therefore section 4.3 describes several basic estimation procedures; besides, it also presents the method to construct a price prediction interval. The last section of this chapter describes the application of the econometric price models for Dutch horticultural sectors.

4.2 Model specification

4.2.1 Demand model

This section starts with the description of the demand equation. As has been said in chapter 2, consumers are assumed to be utility maximizers, and their demand functions can be obtained by maximizing their utility functions subject to their budget constraints. The market demand function for each commodity can then be obtained by adding up the demand functions of all consumers for that particular commodity 2). Hence, a choice must be made regarding the functional form of the utility functions for all the consumers. In this chapter the functional form that is adopted on the demand side is the Cobb-Douglas


2) Of course, under certain conditions, see e.g. Deaton and Muellbauer, 1980.
utility functions 1). Maximization of the Cobb-Douglas utility functions subject to consumer's budget constraints yields the demand functions that are used in this chapter. Appendix 4 gives the derivation of the demand functions that are applied in this chapter. For a more complete derivation, see e.g. A. Parikh and D. Bailey 'Techniques of Economic Analysis with Applications' (1990) for the derivations of the demand functions.

Another important point to note is where the commodity consumption is measured. According to Palaskas (1994) commodity consumption takes place when the commodity is first produced. For food consumption this implies that its measurement takes place at the processing or packaging stage, and not when the final consumer purchases the product. A consequence of this measuring point is that the link between the final consumer and commodity consumption of the intermediary is indirect. Since the measuring points in horticulture are the auctions in the Netherlands, the proposal of Palaskas will be applied in the formulation of the demand equation for horticultural commodities.

Every horticultural commodity has a specific demand function. Chapter 3 has described commodity characteristics of each sector. Furthermore, it has also presented probably the most important demand factors for a commodity. This section presents a simple demand equation for the horticultural commodities in general. Since it is beyond the scope of this study to test the variables in the equation for each commodity, it only illustrates which factors could be important in the demand equation for horticultural commodities. Hence, using the information about the demand factors of the commodities that has been gathered in the previous chapter, the demand for horticultural commodities can be assumed to depend on their own real prices, the prices of their substitutes, (real-)disposable household income. Each demand equation can be extended with variables, which are specific to the particular commodities. Expenditure of advertising can be constructed in the demand equation for commodities for which the demand depends on advertising. Also, the temperature can be a significant factor in the demand equation, because during hot (cold) weather the consumer will demand less (more) of a commodity, but more (less) of another commodity. Habit formation and changes in tastes are also important. At the most simple level, these may be modelled by inclusion of a time trend. But if the model is based on the assumption of rational expectation, then the time trend would be useless. This can be explained by the rational expectation hypothesis, which assumes that the rational economic agents will always anticipate on the perfect and complete information that is available in period $t$. If the demand demonstrates a seasonal pattern, then dummy variables can be used to imply the seasonal fluctuations in the demand equation. A general demand equation with all variables in logarithms is defined as follows:

$$D_{it} = \alpha_0 + \alpha_1 P_{it} + \alpha_2 P_{it}^S + \alpha_3 Y_t + \alpha_4 E_t + \alpha_5 T + \alpha_6 T + \sum_{k=1}^{N} w_k H_{it} \cdot v_t \quad (4.1)$$

where:
- $D_{it}$ = quantity of commodity $i$ demanded in period $t$;
- $P_{it}$ = price of commodity $i$ in period $t$;
- $P_{it}^S$ = price of substitute in period $t$;
- $Y_t$ = disposable income of household in period $t$;
- $E_t$ = expenditure on advertising in period $t$;

A Cobb-Douglas utility function is a special function of the constant elasticity of substitution (CES) utility function. A CES utility function with two commodities, $X_1$ and $X_2$, can be defined as follows: $U = Y(\alpha X_1^{\gamma} + (1-\alpha)X_2^{\gamma})^\delta$ with $\gamma > 0$, $0 < \alpha < 1$, $\rho > 1$, $\rho = 0$, and $\beta > 0$ where $\alpha$ is the consumer's weighting parameter of the commodities, the constant elasticity of substitution is given by $1/(1+\rho)$, and $\delta$ is the degree of homogeneous of the CES utility function. If $\rho = 0$ then the CES function will become a Cobb-Douglas function. According to Parikh and Bailey (1990, p. 201) is the Cobb-Douglas unnecessarily restrictive. They said that the unitary own-price and income elasticities of demand and zero cross-elasticities of demand of Cobb-Douglas utility functions are obviously inconsistent with econometric evidence on demand elasticities. A major disadvantage of a CES-function is its non-friendly structure, and therefore, it is recommended to use the more restrictive Cobb-Douglas function.
Temp, = temperature in period t;
T = time trend;
H = dummy variable;
\( v_t \) = error in period t.

There are several reasons to include an error term in the equation. Cowling et al. (1970, pp. 55-6) give three reasons for the inclusion of the error term in the estimation of a demand function. First, in the demand equation only those variables are included that are thought to be most important in explaining the demand for horticultural commodities, and the effect of the excluded variables can be represented by the error term. It is assumed that these omitted factors affect the demand both positively and negatively, so that the expected value of the error term is zero. Secondly, there is some degree of randomness in human behaviour that necessitates the inclusion of a random error term. Thirdly, it is not possible to measure the demand for commodities exactly, so that the error term includes the measurement error.

Dutch exports are not involved in the developed demand model, although they contribute significantly to the total demand for a horticultural commodity. The aggregate demand in period t is given by adding the export component (Ex,t) to the demand model. As a working hypothesis, the exports are assumed to be exogenous in this model. This assumption may be challenged, because the exports depend on different factors, like the weather conditions in importing countries, crop diseases, transportation costs, exchange rates etc. 1). But to keep the model within a manageable size, this assumption is definitely advantageous in this thesis. The aggregate demand of commodity i in period t is then given by the following equation:

\[
\text{Demand}_{\text{total},t} = \text{Domestic Demand}_{t} + \text{Export}_{t}
\]

4.2.2 Supply model

4.2.2.1 Introduction

For horticultural commodities, time lags exist between the decision to produce and the actual realization of the production. The time lags may be caused by delayed or incomplete responses of the economic agents to changes in the economic or technical conditions. Permanent price changes may not be recognised immediately, and the decisions to adjust supply take time to make and to implement. Besides, adjustment incurs costs, which may deter immediate and complete response to changes in the economic conditions. An inevitable lag in the production of horticultural commodities is biological delay. Given the biological delays immediate adjustment will not always be feasible. As has been noted in the previous chapter, biological lags can be different between the various horticultural commodities. For example, the biological lag of the fruit growing sector is at least more than two years, whereas the biological lag of the outdoor growing of vegetables sector is less than one year. Because of these delays the entrepreneur has to base his future production decision on expected prices. The annual or current horticultural production depends on the yield of the planted area. Hallam (1990, p. 53) has defined it more precisely saying that the area planted will determine potential supply.

---

1) Since Dutch export depends on so many different factors, it is recommended to devote a complete study on the influences of economic, social and climatic factors.
for any given yield level. The supply of commodity \( i \) in period \( t \) is then given by the identity 1):

\[
\text{Supply}_{it} = \text{Area}_{it} \cdot \text{Yield}_{it}
\]

(4.3)

Therefore, the best way to analyse the supply side is to decompose it into an acreage function and a yield function. The essential insight is that the planting decision precedes the yield (or harvesting) decision, and that only at harvest time the market prices of the horticultural commodities will become known. For the short-term and the medium-term price predictions only the yield equation is essential, because in these terms the total acreage of a commodity is fixed. But for the long-term price development the acreage equation plays a crucial role.

4.2.2.2 Yield equation

At harvest time the only decision that the entrepreneur has to make is how much effort he would like to devote to harvesting. As a consequence, the commodity yields are strongly correlated to the intensity of the efforts and the number of times the crops are harvested. Besides, not all the horticultural commodities mature uniformly (Shonkwiler and Emerson). The harvesting decision is assumed to depend on the current price that is known at this time, and the cost of harvesting, e.g. labour, and packing. A possible variable in the yield equation can be the ratio of the price to wage rate. Shonkwiler and Emerson have used this variable in the determination for the yield of the winter tomatoes in the United States, because they said that the harvesting decision of tomatoes depends on the tomato crop and the market conditions. The yields of the commodities are also affected by the weather conditions in the particular period, especially for the commodities which are growing outside. Consequently, the climatic factors have to be involved in the yield equation. Examples of the climatic factors are amount of rainfall, hail, temperature and total sunshine in the growing period of the commodities. Furthermore, the technology and techniques have changed over the years. With the time trend it is possible to catch these developments in one variable. An alternative method is to make use of a dummy variable. If it is clear that an important innovation is introduced in a period, then the dummy variable can be defined as zero before the introduction period and one thereafter. Probably, input factors are also significant in the determination of the yield of horticultural commodities. Fertilizers and pesticides can be used for the production of the commodities. Besides, for the indoor commodities the energy prices are important factors in the yield equation. The general yield equation with all variables in logarithms can be defined as follows:

\[
\text{YLD}_{it} = \beta_0 + \beta_1 \cdot \text{Price}_{it} \cdot \text{L}_{it} + \beta_2 \cdot \text{W}_{it} + \beta_3 \cdot \text{F}_{it} + \beta_4 \cdot \text{I}_{it} + \mu_t
\]

(4.4)

where: \( \text{YLD}_{it} \) = yield of commodity \( i \) in period \( t \);
\( \text{L}_{it} \) = wage rate of commodity \( i \) in period \( t \);
\( \text{P}_{it} \) = price of commodity \( i \) in period \( t \);
\( \text{W}_{it} \) = amount of rainfall / hail or temperature in period \( t \);
\( \text{I}_{it} \) = amount of input, like amount of fertilizers or pesticides, for commodity \( i \) in period \( t \);
\( \text{F}_{it} \) = dummy variable for commodity \( i \);
\( \mu_t \) = error in period \( t \).

1) This identity is applicable to livestock too. The term 'area' in the identity equation has to be replaced by the term 'livestock' population. Hallam describes the egg production in his book 'Econometric modelling of agricultural commodity markets'. He has made use of the livestock identity.
Appendix 5 explains the yield equation. Unfortunately, the yield function for tree crops is more complicated, because the yield depends on the age of a tree. As Palaskas (1994, p. 17) noted, 'no crop is produced until the tree reaches a certain age, a'. Yield then rises and is subsequently sustained at a high level until the tree ages resulting in a slow decline. However, a small positive yield may be obtained even from very old trees. But, there is a maximum age, a', at which a tree will be cropped since it may pay to uproot it at an earlier date. This can be explained by the fact that the tree can be abandoned once there is no cropping plan that give positive net present value of revenues over harvesting and felling costs (Palaskas, 1994).

4.2.2.3 Acreage equation

The decision to plant must be made well before the market time. This is the reason that the planted acreage decisions would be based on expectations. Nerlove's supply model 3) is applied in finding the acreage equation. He was the first, who had combined the partial adjustment and the adaptive expectation models in an agricultural supply model. As has been noted in the beginning of the explanation of the supply equation, the delays, costs or habit persistence cause an adjustment to changes in economic and technical conditions will go over a sequence of time periods. The partial adjustment model has been developed to exhibit the process of gradual adjustment 4).

Since the core of this thesis is price prediction of horticultural commodities and the total acreage of a commodity in the next years plays a crucial role in the long-run price development of a commodity, and therefore, it is necessary to give the general acreage equation.

Because of the partial adjustment the planted acreage of horticultural commodities in period t depends on the planted acreage in period t-1. The planted acreage also depends on the horticultural commodity grower's possession of land. If much of the land that is used to cultivate horticultural commodities is rented, then the grower is interested in the interest rate. For the planted area decision, the growers always look at the profitability of horticultural commodity and those of its substitutes. The best of the profitabilities of its substitutes - the profitabilities that the entrepreneur does not get- is called the opportunity cost of that commodity. Unfortunately, at the time that the acreage decision has to be made the commodity prices and its costs are unknown. As a consequence, the grower has to base his decision on the expected prices and the costs of production. For convenience's sake, the costs of production and opportunity costs are assumed to be exogenous in the equation. A general acreage equation with all variables in logarithms is defined as follows:

\[ A_t = A_{t-1} + \text{Opportunity Cost} \]

where \( y(a) \) is the age-yield function and \( N_{a} \) is the number of tree planted in year \( t-1 \). A more practical approach is to take capacity as proportional to area planted instead of \( N_{a} \).


The partial adjustment model describes the change of the supply from one period to the next as some proportion, \( \delta \), of the difference between the current level and the desired level of supply, \( S_0 \), or in an equation, \( S_t - S_{t-1} = \delta(S_0^* - S_{t-1}) \). If the adjustment parameter, \( \delta \), is one then the adjustment will be complete within the current period. Since the desired variable, \( S_0^* \), is unobservable, it must be expressed as a function of variables which can be observed. Nerlove had used the adaptive expectation model for the determination of the desired supply.
\[ A_{ts} = Y_0 + Y_1 A_{ts-1} + Y_2 P_{ts} + Y_3 R_{ts} + Y_4 O_{ts} + Y_5 C_{ts} + \eta_t \]  

(4.5)

where:  
- \( A_{ts} \) = planted acreage of commodity i in period t;  
- \( A_{ts-1} \) = planted acreage of commodity i in period \( t-1 \);  
- \( P_{ts} \) = expected price of commodity i for period t;  
- \( R_{ts} \) = interest rate in period t;  
- \( O_{ts} \) = opportunity costs of commodity i in period t;  
- \( C_{ts} \) = production costs of commodity i in period t;  
- \( \eta_t \) = error in period t.

Imports from other horticultural commodity producing countries to the Netherlands are not included in the developed supply response model, although the imports have a significant contribution in the total supply of a horticultural commodity in the Netherlands 1). The aggregate supply is given by adding the import component to the supply response model. As a working hypothesis, the imports are assumed to be exogenous in this model, although this assumption may be challenged. The aggregate supply of commodity i in period t is then given by the following identity:

\[ \text{Supply}_{\text{total}}_{ts} = \text{Supply}_{ts} + \text{Import}_{ts} \]  

(4.6)

4.2.3 Price models

4.2.3.1 Long term partial equilibrium-perfect competitive price model

A general structural model for horticultural commodities is almost finished. This system has to be closed and this can be done by applying the identity equation that the quantity demanded of commodity i is equal to the aggregate supply of that commodity in period t. This is known as the partial equilibrium condition. It is impossible to construct the general equilibrium, because there are so many things unknown an uncertain in reality, and therefore, the partial equilibrium condition is preferred to the general equilibrium condition. The partial equilibrium identity for commodity i is then defined as follows:

\[ \text{Demand}_{\text{total}}_{ts} = \text{Supply}_{\text{total}}_{ts} \]  

(4.7)

To rewrite the partial equilibrium identity the market clearing price equation for commodity i can be found. Besides, this equation gives a possibility to predict the expected market clearing prices for commodity i. The market clearing price equation for commodity i is derived from equations (4.1), (4.4), and (4.5):

\[ P_{ts} = (\alpha_1 - \beta_1)^{-1}(\alpha_0 - \beta_0 - \nu) - \alpha_2 P_{ts} - \alpha_3 Y_{ts} - M_{ts} - E_{ts} - \alpha_4 E_{ts} \]
\[ - \alpha_4 T_{ts} - \alpha_4 T - \sum_{j=1}^{K} w_j H_{ij} - \beta_1 L_{ts} - \beta_2 W_{ts} - \beta_3 L_{ts} - \beta_4 F_{ts} \]
\[ + \nu_1 A_{ts-1} + \nu_2 P_{ts} + \nu_3 R_{ts} + \nu_4 O_{ts} + \nu_5 C_{ts} + (\nu_4 - \mu_t - \eta_t) \]

(4.8a)

1) For the import can be said the same as for the export, that it is recommended to devote a study on the Dutch imports of horticultural commodities.

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or alternatively,

\[ P_{lt} = X_t \beta + \gamma_t P^e_{lt} + \epsilon_t \]  

(4.8b)

where \( X_t \) is a \(((16+N) \times 1)\) vector with exogenous variables for period \( t \), \( \beta \) is a corresponding \(((16+N) \times 1)\) vector of parameters, and \( \epsilon_t \) is the aggregate error of the general price equation for period \( t \).

As has been shown in section 4.2.2, the grower's planted acreage decision depends on the expected price of the commodity. Since the expected price is unobservable, it has to be expressed in known observables. If the total acreage of commodity \( i \) is known, then its long-term price development can be predicted. Appendix 4 describes three grower's alternatives for determining his expected price for commodity \( i \), and hence, the future availability of acreage for commodity \( i \). Besides, this appendix presents for every alternative the equation to predict the long-term prices for commodity \( i \). The three alternatives are naive expectations, adaptive expectations, and rational expectations.

4.2.3.2 Short-term partial equilibrium-perfect competitive price model

Horticultural commodities can be stored for at least some period of time, and therefore, the introduction of the possibility of storage can be necessary for the prediction of the short-term price development of commodity \( i \). However, over a sufficiently long time the inventory movements will tend to average out, but on a monthly, weekly, or daily basis there is likely to be complicated and possible structurally unstable dynamics resulting from the unobserved inventory movements. Hence, the storage possibility of commodity \( i \) may play a significant role in the determination for the short-term price of commodity \( i \). As Palaskas (1994) has been noted, 'in terms of short term modelling, inventories provide the crucial forward link'. The short-term price of commodity \( i \) depends directly on both inventory demand in period \( t \) and inventory demand of period \( t-1 \). Hence, the short-term market clearing price development reflects not only the current supply and the demand conditions, but also the supply and the demand in all future periods. A household can decide to demand more of commodity \( i \) than it actually needs in that period. Its decision depends on the difference between the current price and the expected price for the next period, e.g. a week. If the current price is higher (lower) than the expected price of commodity \( i \) for the next period, then there are fewer (more) inventories on hand before the next period's supply. Hence, the inventory demand is determined by the difference between the current and the expected future price of commodity \( i \). Muth (1961) had assumed that the inventory demand was a linear function of the anticipated short-term price increase from period \( t \) to period \( t+1 \). The derivation of this relationship was based on the assumption that inventories were held by risk-averse expected utility maximizers. The inventory demand derived by Huntzinger (1979) is more complete. He had also included the average cost of storing a quantity of commodity \( i \) from period \( t \) to period \( t+1 \). Combining these determinants of inventory demand in one function, a general inventory demand equation can then be defined as follows:

\[ Q_{it} = \delta_1 + \delta_2 P^e_{it+1} + \delta_3 P_{it} + \delta_4 C_{it} + \pi_t \]  

(4.9)

where: \( Q_{it} \) = inventory demand of commodity \( i \) in period \( t \);
\( P^e_{it+1} \) = expected price of commodity \( i \) for period \( t+1 \);

1) The Muth's simplified inventory demand is defined as follows: \( l_i = \alpha (P^e_{it+1} + P_{it}) \), where \( \alpha = -\Phi'(0)/\Phi'(0)\sigma^2_{it} \). The parameter \( \alpha \), which measures the sensitivity of inventory demand to anticipated price change, is a function of the degree of risk aversion and the conditional variance of prices. The coefficient decreases as the households become less risk averse and also decreases as the conditional variance of prices decreases.

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\( P_{it} \) = price of commodity \( i \) in period \( t \);
\( CS_{it} \) = storage cost of commodity \( i \) from period \( t \) to period \( t+1 \);
\( \Pi_{it} \) = error in period \( t \).

This general structural model of horticultural commodities with inventories is almost finished. The system has to be closed and this has to be done by applying the partial equilibrium identity. This means that the aggregate demand for commodity \( i \) is equal to the aggregate supply of commodity \( i \) in period \( t \). The partial equilibrium identity is defined as follows:

\[
D_{\text{total}} \, t \, \cdot \, Q_{it} \, - \, \text{Supply}_{\text{total}} \, t \, \cdot \, Q_{it+1}
\]  
(4.10)

As is shown above the aggregate demand is composed of the consumption demand for commodity \( i \) and the inventory demand for that commodity in period \( t \), whereas the aggregate supply is equal to the current total production of commodity \( i \) in period \( t \) and the previously held inventories of that commodity. And every period short-term prices adjust so that the aggregate demand is equal to the aggregate supply. Finding of the equation for the short-term prices in this model is more difficult than in the model without storage. The partial equilibrium condition gives a short-term price equation that contains current and expected values of prices of various periods. Huntzinger (1979) had derived three prototype equilibrium equations for the prices under the assumption that both consumers and producers make inventory decisions as rational economic agents. Furthermore, he had adopted the assumptions that the production came from a large number of identical firms each small relative to the market. And, that the production required \( h \) periods with the quantity determined at the start of the process. Under these assumptions he could provide an equation for the current period, one for the next \( h-1 \) periods with \( 0 < j < h \), and for periods after \( h \), \( j \geq h \). Appendix 5 presents these three price equations of Huntzinger.

Unfortunately, conventional methods cannot be used to estimate this model with storage, because the expected prices are not observed, and the equations contain expected exogenous values for all future periods. Besides, a general problem of all rational expectations models is the non-uniqueness of rational expectations equilibria, because they have generally an infinite number of solutions. The main problem is to find a method that is able to pick the unique stable solution path for the model. According to Lahti (1989), 'in practice the uniqueness has been obtained by assuming that the models in questions are linear and by assuming stability of the paths of expectations of variables'. Since not all statistical methods are appropriate for the estimation of the equations or the system, because the used methods will not always be consistent with the characteristics of economic data, it seems useful to explain various estimation procedures. Therefore, the next section will describe the most common statistical procedures to estimate a linear price regression model.

1) See e.g. Huntzinger (1979), Buiter (1982), and Lahti (1989).
4.3 Estimation procedures 1)

4.3.1 Ordinary least squares estimation

This section starts with the simple linear price regression model, because the understanding of this simple price model provides the foundation of all existent estimation procedures. The price model has to reflect the interrelationships among economic variables. In this thesis the interrelationships between the price of a commodity and the economic variables like consumption, production and income. Besides, it also has to capture the nature of many economic data relating to the economic processes and institutions. Given the gathered sample data the price model must be consistent with the underlying multivariable sampling process by which the data are or could have been generated. The simple linear price regression tries to reflect the interrelation between the explained variable, price of commodity $i$, and the explanatory variables. Equation (4.8) reflects the partial interrelationship between the price of commodity $i$, the explained variable, and the variables on the right hand side, which are the explanatory variables. In the general case, the simple linear price regression can be defined as follows:

$$p = X\beta + e$$  \hspace{1cm} (4.11)

where each vector is a column vector of $T$ elements. The explained price variable, $p$, is expressed as a linear combination of the sample explanatory variables, $X$, and a distribution error term, $e$. In vector notation, $p$ is a $(T \times 1)$ vector of observations, $X$ is a $(T \times k)$ non-stochastic matrix of $k$ known values of explanatory variables, where the first column contains only ones, that represents the intercept in the regression, $\beta$ is a $(k \times 1)$ vector of unknown parameters, and $e$ is a $(T \times 1)$ vector of unobservable random errors. The latter measures the discrepancies between the linear combination and any actual sample realization of the prices of commodity $i$. Hence, the linear combination is an attempt to describe within a stochastic context how the explained price variable is related to the explanatory variables. The specification of the underlying stochastic context is very important for the conversion of an economic price model into a statistical econometric price model. Besides, the stochastic assumption determines the choice which estimation procedure is likely to be the best one. This is necessary, because the central problem of the linear price regression is to obtain an estimate for the unknown $\beta$ vector. The standard assumption is to assume that the $e$ terms have zero means and that they are identical and independent distributed (homoscedasticity). If the specification of the price regression model is done in the right way, then it is reasonable to assume that both the positive and the negative discrepancies from the expected value will average out at zero, and therefore, the expected error term will have the zero value. This stochastic assumption concerning the unobserved error terms together with other assumptions underlie the sampling process. The first price model assumptions are the weak assumptions, and they can be written in the following notation form 2):

---


2) The used symbols $\text{Var}(.)$ and $\text{Cov}(.)$ are defined as variance and covariance respectively. For the definitions of these terms see e.g. Van der Genugten (1988).
As long as the error terms are independent of the explanatory variables, the probabilities of the explanatory variables are irrelevant, since the conditional distribution of the error term under explanatory variables does not depend on these variables. The last assumption is that the elements of the unknown parameter vector do not vary from one time period to another. The statistical econometric price model is built on the foregoing system of assumptions, and therefore, it is a simplification of the reality.

Given the system of assumptions, the central problem, estimation of the $\beta$ vector, can be solved. The estimate of $\beta$ will be represented by the vector $b$. Of course, the estimate, $b$, is an approximation of the true $\beta$, because the estimation is only based on a sample of data. It seems logical to choose a way of using these data to obtain an estimate that makes the systematic part $(X\beta)$ as perfect as possible. As a consequence, it makes the errors as small as possible. A possible method is to choose the least square principle. This method minimizes the sum of the squared residuals or errors ($S(\beta)$). It is formulated as follows:

$$S(\beta) = \min_b \sum_{t=1}^{T} e_t^2 = \min_b \|p - Xb\|^2$$

After the derivation of the first order condition (FOC) of the $S(\beta)$ expression and setting the FOC equal to zero, the optimal estimate vector of $\beta$, $b$ can be found. This can only be done if the matrix $X$ is of rank $k$ 1). This implies that the square symmetric matrix $X'X$ is non-singular, and the inverse for $X'X$ exists 2). The solution to the estimate of the unknown parameter vector $\beta$ is unique and the minimizing vector $b$ is called the ordinary least squares (OLS) estimator. The OLS estimator is defined as follows:

$$b = (X'X)^{-1}X'p, \quad \text{with} \quad X' = \text{transposed matrices}$$

Hence, the OLS procedure gives an estimate of the unknown parameter vector given the available sample observations. This procedure is a linear function of the observable random price vector $p$, and therefore, $b$ is also a vector of random variables. A statistical property of the OLS estimator is the unbiasedness, that is, $E(\beta - b) = 0$. In other words, on average the OLS estimator, $b$, yields the true parameter $\beta$. Another important property of the OLS estimator is that no other linear unbiased estimator can have a smaller sampling variance than those estimators derived with the OLS procedure. Hence, the OLS estimators are the best linear unbiased estimators (BLUE). As Judge et al. (1988, p. 205) have been noted, 'no other estimator has a superior sampling performance, where the criterion for superiority is minimum variance or maximum sampling precision.'

Since the unknown parameter vector, $\beta$, of the linear price regression model can be estimated with the OLS procedure, another unknown parameter, the variance ($\sigma^2$) of the elements of the (random) vectors $p$ and $e$, can be obtained. The estimation of the variance is based on the sum of the differences between the observable price of commodity $i$, $p_i$, and the predicted price $X\beta$.

---

1) There exists no multicollinearity, or in other words, no explanatory variable is a linear combination of the other explanatory variables in the regression.

and its least squares counterpart \( p_o = X \cdot b \) in quadratic form \((e'e)\). The resulting quadratic estimator \((s^2)\) for the unknown scalar parameter \( \sigma^2 \) can be calculated with the following formula 1):

\[
s^2 = \frac{1}{T-k} e'e
\]  

(4.15)

The square root \( s \) is called the standard error of the estimate, and may regarded as the standard deviation of the \( p \) values about the regression plane. Unfortunately, \( s^2 \) is a random parameter, and, consequently, the estimate will vary from sample to sample. However, it can be shown that the \( s^2 \) is an unbiased estimator (see e.g. Van der Genugten (1988)).

Since an estimate of the variance of \( e \) and \( p \) can be provided with (4.15), an estimate for the unknown variance-covariance matrix \((\Sigma_e)\) for the OLS estimate \( b \) can also be obtained. The variance-covariance matrix is defined as follows:

\[
\Sigma_e = \sigma^2 (X'X)^{-1}
\]  

(4.16)

The diagonal elements of \( \Sigma_e \) contain the variances for the elements of \( b \), and the off-diagonal elements contain the covariances for these variables.

Of course, it is important to know at which degree the linear price regression has succeeded in reducing the unexplained error variance of \( p \). The literature contains several methods for doing this. Most statistical computer programs, like SAS and SPSS, automatically calculated the \( R^2 \), \( R^2 \), and \( \text{adj} \ R^2 \) measures. The latter method, adjusted \( R^2 \), is the best measure of these three. This measure of suitability considers also the number of variables in a linear price regression model, and is defined as follows 2):

\[
\text{Adj} \ R^2 = 1 - \frac{e'e / (T-k)}{(p'p - Tp^2) / (T-1)}, \quad \text{with } p = \text{mean of } p.
\]  

(4.17)

The weak system of assumptions that was made at the beginning of this section is not sufficient (for small samples) for the construction of confidence intervals and the constraint tests for prices. Therefore, it seems necessary to construct a strong system of assumptions, which automatically implies the weak system. Furthermore, another estimation procedure will be explained, the maximum likelihood method.

4.3.2 Maximum likelihood estimation

In the previous subsection no assumption was made about the form of the distribution of the random error vector, \( e \). The weak system of assumptions will be extended by specifying \( e \) to be a vector of normally distributed random variables with mean zero and variance \( \sigma^2 \). Hence, the strong system of assumptions for the linear price regression model can be defined as follows:

1) See for proof e.g. Judge et al. (1988, pp. 205-8).  
2) Unfortunately, the use of \( R^2 (=1 - |e'|^2 / |p'p|^2) \) and \( \text{adj} \ R^2 \) for regression specification purposes can have serious statistical consequences, see e.g. Judge et al. (1988, chapter 20).
This additional assumption about the multivariate density function for $e$ also implies the multivariate normal density function for the price, $p$, with mean vector $X \beta$ and variance-covariance matrix $\sigma^2 I_T$. Because the observations are assumed to be independent drawings, the joint density function can be expressed as the product of the density functions of all observations. The joint probability density function is called the likelihood function. The likelihood function which involves the unknown parameters $\beta$ and $\sigma^2$ given the observations, $p$ and $X$, can be defined as follows:

$$L(\beta, \sigma^2; p, X) = (2\pi \sigma^2)^{-T/2} \exp \left( -\frac{(p - X\beta)'(p - X\beta)}{2\sigma^2} \right).$$

The unknown parameters $\beta$ and $\sigma^2$ can be estimated with the maximum likelihood (ML) principle. This method chooses these values for the estimates, $\hat{\beta}$ and $\hat{\sigma}^2$, which maximize the likelihood function given the sample price data of commodity $i$, $p$. The first step towards finding the maximum likelihood estimators for $\beta$ and $\sigma^2$ is to write the function $L(\beta, \sigma^2; p, X)$ in the log form. Then differentiating the log-likelihood function partially with respect to $\beta$ and $\sigma^2$ and setting the FOC equal to zero. The solution to the FOC gives the estimator for the unknown parameters $\beta$ and $\sigma^2$. Given these assumptions the ML estimator of $\beta$ is identical to the OLS estimator, and, consequently also an unbiased estimator. The ML estimator of $\sigma^2$, however, differs from the unbiased OLS one, but a simple adjustment of ML estimator will give the best unbiased estimator for $\sigma^2$ (see e.g. Judge et al., 1988 pp. 224-5).

The asymptotic properties say that the least squares estimators possess the property of consistency and that there is a basis for hypothesis tests and interval estimates when the errors are not normally distributed. These properties make it possible to use approximations, when there are many observations (i.e. for a large sample). This means that $T$, the number of observations, is very large. With the help of the central limit theorem it is possible to approach the results which are obtained under the assumption that $e$ is a vector of normally distributed variables. The results are that the least squares estimators $\hat{\beta}$ and $\hat{\sigma}^2$ possess the desirable asymptotic property of consistency. An estimator is consistent when its bias and variance go to zero as $T \rightarrow \infty$. Furthermore, when the error vector $e$ is not normally distributed, it still satisfies $E(e) = 0$ and the error components of $e$ are independent and identically distributed. Finally, with the central limit theorem it can be shown for the estimators whose distributions are unknown in small samples, that they have a known distribution in large samples. In large sample the t-distribution converges to the standard normal distribution.

1) See e.g. Johnston (1984, p. 274).
2) The proofs of the asymptotic properties can be found in e.g. Van der Genugten (1988, chapter 8), and Judge et al., (1988, pp. 264-270).
Price prediction is one of the possibilities of a linear price regression model. Because this thesis is about the price determination of the horticultural commodities, it seems sensible to construct the prediction intervals for the commodity prices. Considering the strong assumptions it is possible to construct the prediction price intervals which contain the explained price variable with probability \((1 - \alpha)\). The first two intervals are constructed under the assumption that the explanatory variables are known with certainty.

A point price forecast is of little use unless it is supplemented by a measure of precision. This measure makes it possible to contain the price forecast in an interval form. The unknown parameters \(\beta\) and \(\sigma^2\) in the interval are replaced by their estimates \(b\) and \(s^2\), and the prediction interval with probability \((1 - \alpha)\) for the value of the explained price variable in the forecast period \(T+h\), \(p_{T+h}\), is defined as follows:

\[
x_{T+h}b = t_{T-k,\alpha/2}(X'X)^{-1}x_{T+h} \cdot 1, \quad h=1,2,\ldots
\]  

(4.20)

where \(x_{T+h}\) is the vector that contains the values of the explanatory variables for period \(T+h\), and \(t_{T-k,\alpha/2}\) is the \(t\)-distribution with \(T-k\) degrees of freedom and critical value \(\alpha\). Hence, this price interval predicts with probability \((1 - \alpha)\) that the value of the explained price variable is contained within it.

An alternative is to set up an interval for the expected value of the explained price variable for the forecast period \(T+h\). The reason is that the explained price variable of the forecast period \(T+h\), \(p_{T+h}\), contains an error term, \(u_{T+h}\), that is essentially unpredictable. A \((1 - \alpha)\) percent confidence interval for the expected price value in the forecast period can be defined as follows 2):

\[
x_{T+h}b = t_{T-k,\alpha/2}(X'X)^{-1}x_{T+h}, \quad h=1,2,\ldots
\]  

(4.21)

Comparison of these two price intervals shows that the price confidence interval is smaller than the price prediction interval. This difference is caused by the error term of \(p_{T+h}\) that is not involved in the definition of the price confidence interval.

The two intervals, (4.20) and (4.21), are built under the assumption that the values of the explanatory variables, \(x_{T+h}\), in the forecast period are known with certainty. It seems more realistic to postulate some uncertainty about the explanatory variables, and therefore, to use the expected values of the explanatory variables, \(x'_{T+h}\), for the forecast period \(T+h\). Unfortunately, it is no longer possible to determine exact intervals by using the \(t\)- and normal distributions. But a good approach for the determination of the price prediction interval is to use the Chebyshev inequality 3). The interval procedure is as follows: the probability that the observed price value in the forecast period will fall outside the price interval \(x'_{T+h}b \pm \alpha s_{T+h}\) does not exceed \(1 / (\alpha^2)\). An appropriate calculation formula for the variance of \(p_{T+h}\) is defined as follows:

\[
s_{x_{T+h}}^2 \cdot s^2 \cdot x'_{T+h}\text{Var}(b)x_{T+h} \cdot b'\text{Var}(x'_{T+h})b - \text{trace}(\text{Var}(b)\text{Var}(x'_{T+h}))
\]  

(4.22)

1) For the derivations of the prediction intervals see e.g. Johnston (1984, pp. 193-200).
2) See for the derivation e.g. Judge et al. (1988, p. 252).
3) This interval method is suggested by M.S. Feldstein in The Error of Forecast in Econometric Models when the Forecast-Period Exogenous Variables are Stochastic, Econometrica, 39, 1971, pp. 55-60.
4.3.3 Generalized least squares estimation

By the specification of the previous estimation procedures of the linear price regression model, it was assumed that the elements of the random error vector were uncorrelated and had identical variance, \( E(e' e) = \sigma^2 I \). Although this assumption is consistent with many sampling processes by which data are generated in economics, it is also inappropriate in many other cases. There are cases where the variances of the elements of the random error vector, \( \sigma^2 \), are not similar. This is known as heteroscedasticity. Besides, it is quite realistic to assume that the matrix \( X \) contains lagged explained price variables and lagged explanatory variables, like the price equations in section 4.2. This can imply that the impact of the error of period \( t \) on the explained price variable will not always be completely instantaneous, and therefore, the errors from different periods may be correlated. This special kind of correlation is called autocorrelation. The circumstances just mentioned are violations of the assumption that the elements of the random error vector are uncorrelated and identically distributed. As a consequence, the OLS estimation method is no longer the best estimation procedure for the linear price regression model, and this means that another estimation procedure is needed for the estimation of its unknown parameters. This subsection describes the generalized least squares (GLS) procedure.

The GLS estimation will be explained under the assumption that the variance-covariance matrix of the random error vector is \( E(e'e) = \sigma^2 \Psi \), where \( \Psi \) is a known real positive definite symmetric matrix. The first step to provide best linear unbiased estimators is to transform the simple linear price regression so that the transformed random error vector will get the OLS variance-covariance matrix \( \sigma^2 I \). Since the transformed linear price regression satisfies the assumptions of the OLS procedure, its unknown parameters, \( \beta \) and \( \sigma^2 \), can be estimated with the OLS procedure. These two steps are called the GLS procedure. This results in the following GLS estimator of \( \beta \):

\[
\hat{\beta}_{GLS} = (X'\Psi^{-1}X)^{-1}X'\Psi^{-1}y
\]

(4.23)

with the variance-covariance matrix given by:

\[
\Sigma_{GLS} = \sigma^2 (X'\Psi^{-1}X)^{-1}
\]

(4.24)

If the matrix \( \Psi \) is known, then the GLS estimator of \( \beta \) is the best linear unbiased estimator for the linear price regression model. Besides, the GLS estimation of \( \sigma^2 \) is also an unbiased estimator, and the variance estimator is defined as follows:

\[
\sigma^2_{GLS} = \frac{(y - X\hat{\beta}_{GLS}')(\Psi^{-1}(y - X\hat{\beta}_{GLS}))}{T - K}
\]

(4.25)

The GLS estimator is the same as the ML estimator, if an extra assumption is added, namely the assumption of normality for the error terms.

Through the introduction of the assumption of a general covariance matrix for the error, the elements of the future random error vector may be correlated with those of the past elements of \( e \). Consequently, the past observations may contain some information about the possible future error values. Since one of the assumptions of the GLS procedure is that the variance-covariance matrix \( \Psi \) is known, it seems logical to assume that the future variance-covariance matrix of the future error vector, \( \sigma^2 M \), and the matrix of the covariances between the elements of the past and the future random error vector, \( \sigma^2 V \), are known. This further assumption makes it possible to derive the best linear prediction

1) A matrix \( B \) is defined as positive definite if \( x'Bx > 0 \), and \( x \) is a column vector.
2) See e.g. Judge et al. (1988, p. 358).
for \( \beta \), \( (T \times 1) \), and the variance-covariance matrix for the prediction error \( \Lambda (T \times T) \). The best linear prediction for \( \beta \), is defined as follows:

\[
p_{\hat{\beta}} = X_{\hat{\beta}}^{WAS} \cdot V^{\Psi^{-1}} (\rho - X_{\hat{\beta}}^{WAS}),
\]

where \( X_{\hat{\beta}} \) is a known matrix of possible future explanatory variables \( (T \times T) \). And the variance-covariance matrix for the prediction error is defined as:

\[
\Lambda = E(e_{e}'e_{e}) - \sigma^2 (M - V^{\Psi^{-1}}V \cdot (X_{\hat{\beta}} - V^{\Psi^{-1}}V) (X_{\hat{\beta}} - V^{\Psi^{-1}}V)).
\]

Given the three variance-covariance matrices, \( \Psi \), \( M \), and \( V \), BLUE predictor for price, \( \beta \), and the variance-covariance matrix for the prediction error, it is possible to construct the confidence price intervals for the predictions. For the construction of the price intervals see subsection 4.3.2.

### 4.3.4 Estimated generalized least squares estimation

In practice, the variance-covariance matrix \( \Psi \) is often unknown, and for this reason the GLS estimator no longer a feasible one for the linear price regression model. Nevertheless, the GLS procedure can be maintained after replacing the unknown \( \Psi \) with an estimated variance-covariance matrix \( \Theta \). This estimation procedure is known as the estimated generalized least squares estimation (EGLS). The method for constructing \( \Theta \) depends on the assumptions made about its structure. In general, \( \Psi \) contains \( [(T(T+1) / 2) - 1] \) different unknown parameters, which are the diagonal elements and half of the off-diagonal elements, minus the constant \( \sigma^2 \). If the unknown \( \Psi \) is estimated, and the GLS procedure is applied, then the used techniques are justified asymptotically 1). In practice, the EGLS procedure is often applied to the estimation of the unknown parameters of a linear price regression that has heteroscedastic or autocorrelated problems. Heteroscedasticity exists when the diagonal elements of \( \Psi \) are not all identical, i.e. \( E(e_{e}^2) = \sigma^2 \). It is important to test for heteroscedasticity, because when the heteroscedasticity is mild, the GLS estimation is better than the EGLS. This can be explained by the fact that the EGLS estimate of \( \beta \) depends on the estimated variances of \( \sigma^2 \), which will contain sampling errors. However, the EGLS estimate will become considerably better than the GLS as the degree of heteroscedasticity will increase. A test for heteroscedasticity is the multiplicative heteroscedasticity test. It tests if the variances are related in a multiplicative fashion. The Breusch-Pagan test is useful for testing if each variance may be a function of more than one explanatory variable, but it does not necessarily impose the multiplicative specification. The final test, the Goldfeld-Quandt test, tests if it is possible to order the observations according to the increasing variances under the assumption that heteroscedasticity exists 2).

The other problem, autocorrelation, implies that the total effect of a random error is not instantaneous, but is also felt in future periods. In practice, the assumption for autocorrelation seems a reasonable one for many economic price relationships. The most common form of autocorrelation is the first-order autoregressive process, \( e_e = \rho e_{e-1} + \nu_e \) and it can be tested with the asymptotic test. This test provides a quick means for assessing the likelihood of autocorrelation. Unfortunately, it is not necessarily an accurate guide in finite samples, therefore it is not as powerful as the Durbin-Watson test. The Durbin's h-test is a possible solution to this problem 3).

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1) See e.g. Judge et al., (1988, pp. 352-6).
2) These three tests are explained in e.g. Judge et al. (1988, pp. 370-3), and Johnston (1984, pp. 298-302).
3) See e.g Judge et al. (1988, pp. 394-401), and Johnston (1984, pp. 313-321).
The estimation procedures of the linear price regression model are based on the assumption that the explanatory variables are non-stochastic, although the variables are generally stochastic in nature. Therefore appendix 8 describes the estimation procedure for a linear price regression model with stochastic variables. Furthermore, this appendix presents an estimation procedure to estimate several price equations simultaneously.

4.4 Application

In general, no demand and supply models are developed for the Dutch horticultural commodities in the Netherlands. As a consequence, it is difficult to predict the long-term price developments for these commodities with an econometric price model. Therefore, this chapter has described the basic foundation to construct an econometric price model for Dutch horticultural commodities and various estimation procedures to estimate the unknown parameters in these price models.

The econometric price model that is presented in the previous sections is a partial equilibrium-perfect competitive price model, and therefore, the competitive market clearing prices for the commodities can be predicted. A perfect competitive price model is preferred in horticulture, because most Dutch horticultural markets have a perfect competitive market structure. The sectors with a perfect competitive structure are cutflowers under glass, vegetables under glass, outdoor vegetables, pot plants under glass, and fruit growing. The other three Dutch horticultural sectors have an imperfect competitive structure. Their markets are untransparent, and besides, for many of their commodities the necessary data to construct a price model are not available. Therefore it is not possible to predict the short-term prices or the long-term prices for these commodities with an econometric price model.

In this chapter the accent lies on the long-term price development of horticultural commodities. For the prediction of the long-term prices the expected acreage plays a crucial role, since the grower's decisions for planting a particular commodity must be made well before the market time. For this, the growers base their decisions on their future price and cost expectations of the horticultural commodities. Unfortunately, the grower's expectation periods which are involved in the growers planting decisions of horticultural commodities are not uniform. As has been noted in the previous chapter, a fruit grower has to use expectations for several future periods, and a tomato grower uses only one period expectation. This can be explained by the fact that a fruit tree will stay in an orchard for more than nine years and furthermore, its yield depends on the age of the tree, whereas a tomato plant is used for one harvesting period only.

Furthermore, the future prices of commodities which are cultivated outdoors depend on the weather in that particular year. If the crop of an outdoor growing commodity will be destroyed by for example hail then the price of that commodity will rise. In general, it can be said that it is impossible to predict weather conditions in a country or in a region. Consequently, it is difficult to predict the long-term prices for these commodities.

In this chapter a little is told about the short-term price developments of horticultural commodities and the crucial factors for the prediction of the short-term prices. This is done because the storage possibilities of horticultural commodities play a crucial role in the short-term price developments. In reality, it seems difficult to determine the stored amount of a commodity and besides, the storability possibility differs per commodity. Other important factors which make the prediction of short-term prices with an econometric price model difficult are missing information and partial adjustment. It may be said that the horticultural commodity markets are not perfectly transparent in the short-term. This does violence to the rational expectation assumption. Furthermore, horticultural entrepreneurs can not adjust immediately on price changes, and therefore, it is difficult to model their behaviour. This study does not examine these factors, although they are probably very important for the short term price predictions. These factors make it difficult to predict the short-term prices for the horticultural commodities, and therefore, it is perhaps better to look for another approach to predict the short-term prices. An alternative method to predict the prices is to use the price time-series approach. The next chapter describes this approach.
5. PRICE TIME-SERIES FORECASTING MODELS

5.1 Introduction

An alternative approach to obtaining price forecasts is to use only the past price values of commodity i to predict the price values of that commodity. This method is known as the time-series forecasting method. It assumes that the identified price data pattern will continue in the future, hence the price pattern is extrapolated in order to produce price forecasts. The time-series method is not based on the underlying economic mechanism, but on statistical tools only, although it is possible that the provided price forecasts from price time-series model are superior to the predictions from an econometric price model. This can be explained by the fact that in general, the information about the underlying sampling mechanism is incomplete, and hence, the economic and the econometric price models are at best rough approximations of reality. Alternative time-series approaches for prices are explained in this chapter. The first section presents the univariate price time-series model. It can be used to forecast either discrete price data or continuous price data. However, the price data must be measured at equally spaced, discrete time intervals (hourly, weekly, or monthly). Besides, the univariate price models can be used to forecast both seasonal and non-seasonal price data. These models are useful when sufficient historical price data are available. Unfortunately, in some situations, especially when the amount of available historical price data is limited, the price time-series regression models are useful. According to Bowerman and O'Connell (1987) these models have been found useful when the amount of historical price data is limited. Section 5.3 presents the price time-series regression models.

The univariate price models and the price time-series regression models would not be useful in forecasting the changes in prices that might result from a change in another economic factor that may affect the price development of commodity i. The multiple time-series models can be used to forecast the price of commodity i that is related to one or more other time-series. These models will consider the changes in correlated time-series in the prediction of the price of commodity i. Section 5.4 explains the multiple time-series model. Since it is always interesting to apply a model using real data, section 5.5 demonstrates an example of the price time-series forecasting models. Monthly prices of mushrooms since 1986 till 1994 are used in the example.

5.2 Univariate price time-series model

5.2.1 Introduction

Univariate price time-series models can be grouped into three basic classes. The three classes are the autoregressive model, the moving average model, and the autoregressive-moving average model. This section starts with the description of the first group, the autoregressive model. Subsection 5.2.2 gives the necessary condition that is needed for the construction of an autoregressive price model. When the price time-series satisfies this condition the construction and the estimation of the autoregressive model is explained. If the autoregressive price model will have too many lagged price parameters, the model can be transformed into a smaller model. The new developed price model is known as the...

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moving average price model. Subsection 5.2.3. describes the construction of this kind of price model.

There are price time-series where the price time-series can be represented neither by an autoregressive nor by a moving average model, but they can be represented by a combination of these two classes. Subsection 5.2.4 explains an autoregressive-moving average price model. It presents a general price time-series model for both non-seasonal and seasonal price data. Furthermore, a brief explanation of a price prediction interval is given.

5.2.2 Autoregressive price model

As Bowerman and O'Connell (1987) have been noted, 'a time-series is a chronological sequence of observations on a particular variable'. It is assumed that the price observations are realizations of random price variables, and that the observed price values are only a part of an infinite sequence of random price variables. Hence, the price sequence is a realization of the stochastic price process.

The autocovariance is an important tool in describing the stochastic structure of the price time-series, because it measures the linear dependence between the elements of a single price process. If the autocovariance between historical price from period t-k and the price in period t is zero, then the historical price from period t-k has no influence on the determination of the price in period t.

A necessary condition for the price forecasting is the stationarity property of the price process. This property guarantees that there are no fundamental changes in the structure of the stochastic price process that causes price prediction difficulties. If the stochastic price process \( p_t \) has the properties that the covariance between two elements depends only on their distance in time, a constant mean, and a finite variance, it is called a stationary price process. Hence, a stochastic price process \( p_t \) is defined in statistical notation form as follows:

\[
E(p_t) = \mu \quad \text{for every } t \\
\text{Var}(p_t) < \infty \quad \text{for every } t \\
\text{Cov}(p_t, p_{t+k}) = E((p_t - \mu)(p_{t+k} - \mu)) - \gamma_k \quad \text{for every } t, k
\]  

where \( \mu \) is the mean of the stochastic process \( p_t \) and \( \gamma_k \) is the covariance of \( p_t \) and \( p_{t+k} \) that does not depend on the time point \( t \), but only on the time difference between the two price variables in the price equation. The mean, variance and covariances are independent of time. Consequently, a stationary price process tends to return to its mean and fluctuates around it within a more or less constant range. On the contrary, a non-stationary price process would have a different mean at different points in time.

Assuming that \( p_t \) is a stochastic price process, and that \( p_t \) may depend in a linear way on its historical price values, in the general case this linear dependence between the future price and the historical price values can then be defined as follows:

\[
p_t = \theta_1 p_{t-1} + \theta_2 p_{t-2} + \ldots + \theta_w p_{t-w} + \epsilon_t
\]  

or in lag operator notation \( L \),

\[
(1 - \theta_1 L - \theta_2 L^2 - \ldots - \theta_w L^w) p_t = \epsilon_t
\]
where \( p_t \) is a member of the stochastic price process, \( e_t \) is white noise, that is, \( E[e_t] = 0 \) for all \( t \) and \( E[e_t^2] = 0 \) for \( s \neq t \), and \( L \) is defined as \( L p_t = p_{t-1} \). This form is known as an autoregressive price model of order \( w \), which is abbreviated as \( AR(w) \). The order of an autoregressive price process can be identified with statistical tools. First, it has to be shown that \( p_t \) is a stationary price process, because otherwise the price model will show an explosive movement. The stationarity of a price process, with bounded means and variances, can be demonstrated with equation (5.2b). If all roots of the lagged polynomial have a modulus \( |\lambda| = 1 / |\beta| > 1 \), then the stochastic price process is stationary 2). In practice, if the autocorrelations of \( p_t \) taper off slowly or do not die out, then the time series values should be considered non-stationary 3).

Assuming that \( p_t \) be a stationary price process, then the partial autocorrelation coefficients \( r_{w,w} \) can be used to identify the order of an \( AR \) price process. These coefficients measure the correlation between \( p_t \) and \( p_{t-w} \) not accounted for by an \( AR(w-1) \) process. Of course, the partial autocorrelation coefficients have to be tested on their significance. To test the significance of the coefficients the distribution of their estimators has to be known, although for large samples it is shown that the estimated \( r_{w,w} \) are approximately normally distributed with mean zero and variance \( (1 / T) \) for every order larger than \( w \), and where \( T \) is the sample size. Consequently, a 95% confidence interval for \( r_{w,w} \) can be approximated by the interval \( (r_{w,w} - 2 / \sqrt{T}, r_{w,w} + 2 / \sqrt{T}) \) 4). An \( AR \) price process is of order \( w \), if the estimate of \( r_{w,w} \) falls within \( \pm 2 / \sqrt{T} \).

Since the \( AR(w) \) is a linear statistical price model and let \( e_t \) a Gaussian white noise process, then the unknown parameters \( \theta = (\theta_1, \theta_2, ..., \theta_w) \) can be estimated with the least squares methods from chapter 4. The price variables in the equations are replaced by their observed values, and hence, the price model can be defined as follows:

\[
p_w = X_w' \theta_w + \epsilon
\]

where \( p_w = (p_{w+1}, p_{w+2}, ..., p_T)' \), \( \epsilon = (e_{w+1}, e_{w+2}, ..., e_T)' \), and

\[
\begin{align*}
X_w &= \begin{bmatrix} p_w & p_{w-1} & \cdots & p_1 \\
p_{w+1} & p_w & \cdots & p_2 \\
p_{w+2} & p_{w+1} & \cdots & p_3 \\
\vdots & \vdots & \ddots & \vdots \\
p_{T-1} & p_{T-2} & \cdots & p_w \\
p_T & & & \\
\end{bmatrix} \\
\theta_w &= (X_w'X_w)^{-1}X_w'p_w
\end{align*}
\]

The least squares estimator for the unknown parameters \( \theta \) can then be defined as follows 5):

\[
\hat{\theta}_w = (X_w'X_w)^{-1}X_w'p_w
\]

with the variance-covariance matrix for large size samples given by:

\[
\Sigma_{\theta_w} = \frac{1}{T} (X_w'X_w)^{-1}
\]

---

1) If the \( e_t \) are also normally distributed than they are called a Gaussian white-noise process.
2) It is important that \( |\beta| < 1 \), because otherwise the variance of the price process may not be finite, which would violate the condition for stationarity. See Judge et al., (1988, p. 679).
3) See e.g. Bowerman and O'Connell (1987, pp. 31-42).
4) See e.g. Judge et al. (1988, p. 685).
5) For derivations see e.g. Judge et al. (1988, pp. 682-4).
By the specification of this estimation procedure it is assumed that the sample mean is zero. Unfortunately, in practice this is not always the case. If the mean of the price data is not zero, then the non-zero sample mean has to be subtracted from all price observations. An alternative method is to use an intercept in the price regression model. This means that a vector with ones is added to the matrix X_w.

### 5.2.3 Moving-average price model

When a stationary stochastic price process, p_t, cannot be represented by a low-order AR price process, it is better to search for a more adequate representation of p_t, because the use of too many price parameters for prediction may lead to inefficient price forecasts. If the price process has a high-order AR representation, it can be transformed in a lower-order process. The transformed representation is a weighted sum of q elements of the white-noise random error, and is called a moving average price process of order q, which is abbreviated as MA(q) 1). A moving-average price process of order q is written as follows:

\[ p_t = e_t + \lambda_1 e_{t-1} + \lambda_2 e_{t-2} + \ldots + \lambda_q e_{t-q} \]  

or in lag operator notation \( L \),

\[ p_t = (1 + \lambda_1 L + \lambda_2 L^2 + \ldots + \lambda_q L^q) e_t \]

The order of an MA price process can be identified with the autocorrelations of the process \( p_t \). In Judge et al. (1988, p691) the general autocorrelation function of an MA(q), \( \rho_k \), is given, and it is defined as follows:

\[ \rho_k = \frac{\sum_{j=0}^{q} \lambda_j \lambda_{k-j}}{\sum_{j=0}^{q} \lambda_j^2} \quad \text{for } k=0,1,\ldots,q \quad \rho_k = 0 \quad \text{for } k>q \]  

The order of an MA price process corresponds to the maximum k for which \( \rho_k \) is nonzero. In practice, to determine whether a particular \( \rho_k \) is non-zero the sample autocorrelations are used. Of course, the sample autocorrelations, \( r_k \), have to be tested on their significance. The significance of \( r_k \) is often tested by checking whether they are falling inside the approximate 95% price confidence interval \( \pm 2/\sqrt{T} \), where T is a sufficiently large sample size. If the sample size is not large, recheck the significance of \( r_k \) according to Bartlett’s or Dufour and Roy formula, when \( r_k \) falls inside the \( \pm 2/\sqrt{T} \) interval 2).

The unknown parameters of a moving average price process, \( \lambda \) and \( \sigma^2 \), can be estimated with the maximum likelihood method under the assumptions that MA(q) is invertible and \( e \) are normally distributed. However, if the original price sample does not have mean zero, the price sample mean should be subtracted from the original price observations, and then the price process can be estimated.

1) See for transformation of an AR representation in an MA one e.g. Judge et al. (1988, p. 690).
2) See e.g. Judge et al. (1988, pp. 692-3).
5.2.4 Autoregressive-moving average price model

The identification of a data generating price process of a given data set of prices can show a combination of both autoregressive and moving average representation. A price process that involves an AR(w) and an MA(q) component is called an autoregressive-moving average process of order (w, q), which is abbreviated as ARMA(w, q). And an ARMA(w, q) process is written as follows:

\[ p_t = \theta_1 p_{t-1} + \theta_2 p_{t-2} + \ldots + \theta_w p_{t-w} + \epsilon_t + \lambda_1 \epsilon_{t-1} + \ldots + \lambda_q \epsilon_{t-q} \]  

(5.9a)

or in lag operator notation L,

\[ (1 - \theta_1 L - \theta_2 L^2 - \ldots - \theta_w L^w) p_t = (1 - \lambda_1 L - \lambda_2 L^2 - \ldots - \lambda_q L^q) \epsilon_t \]  

(5.9b)

The order of an ARMA can be identified with the same statistical tools that are used for the identification of AR and MA representations. However, in practice it can be difficult to identify adequate orders w and q, and therefore, the developed price model has to be checked. Possibilities for checking are carrying out a residual analysis and doing an overfit of the specified price model. The latter check implies the estimation of the ARMA(w+1, q) and the ARMA(w, q+1) models and then, testing the significance of the extra parameters. The other method, a residual analysis, is to estimate the residual autocorrelations and to check them for example with the portmanteau test statistic 1).

The estimation of an ARMA price model is a non-linear optimization problem. Hence, the unknown parameters can be estimated with the maximum likelihood method, if the \( \epsilon \) are normally distributed. Besides, the unknown parameters can be estimated quite easily with advanced computer programs like SAS and SPSS 2).

So far, it is assumed that the stochastic price process \( p_t \) is stationary. If the price observations do not fluctuate around a constant mean or do not fluctuate with constant variation, then it is reasonable to assume that the price process is non-stationary. The non-stationary price time-series values, which possess no seasonal variation, can be transformed into stationary price time-series values \( z_t \) by taking \( d \) times the differences of the non-stationary price time-series values, where \( z_t = (1 - L)^d p_t \). If \( z_t \) is an ARMA(w, q) transformed price process, then the non-stationary price process, \( p_t \), is called an autoregressive-integrated-moving average price process of integrated order \( d \), which is abbreviated as ARIMA(w, d, q). In the model of the transformed data generating price process, \( z_t \) a constant term, \( \delta \), should be included, when the estimated mean of \( z_t \) is statistically different from zero. The constant term is defined as follows: \( \delta = \mu(1 - \theta_1 - \theta_2 - \ldots - \theta_w) \), where \( \mu \) is the true mean of all possible realizations of the stationary price time-series under consideration 3).

Another cause of non-stationary is the seasonal pattern of price time-series with increasing variability as times advances. The first stage of making stationary price time-series is to stabilize the variability of the price process by using a pre-differencing transformation e.g. taking the natural logarithms of the price time-series values. Let \( x_t \) represent an appropriate pre-differencing transformation of the original price time-series values, then the next stage is to transform the seasonal non-stationary price time-series values \( x_t \) into stationary price time-series values \( z_t \). The seasonal operator is used for this transformation, and it is defined as follows: \( (1 - L^s)^k x_t \), where \( s \) is the number of seasons in a year, and \( k \) is

1) See for diagnostic checking e.g. Bowerman and O'Connell (1987, pp. 147-169) or Judge et al. (1988, pp. 704-5).
2) The procedure of tentative identification, estimation, and diagnostic checking of stochastic process \( z_t \) is known as the Box-Jenkins approach.
3) See e.g. Bowerman and O'Connell (1987, pp. 57-9).
the degree of seasonal differencing used. However, in general, this transformation is not sufficient to transform the non-stationary price time-series values, which possess seasonal variation into stationary price time-series values. In these cases, an additional transformation, the non-seasonal operator \((1 - L)^s\), is required to make stationary price time-series. Bowerman and O'Connell (1987) have combined these two operators in one general stationarity transformer, and their general stationary transformation of non-stationary (non-)seasonal price time-series is defined as follows: 

\[ z_t = (1 - L)^s(1 - L)^d x_t \]

Once the time-series \( p_t \) are transformed into stationary price time-series values, a general model of the price time-series can be formulated. A general Box-Jenkins price model of order \((w, h, q, f)\) is defined as follows:

\[
(1 - \theta_w L^w - \theta_{w-1} L^{w-1} - \ldots - \theta_1 L - \theta_0) (1 - \lambda_h L^h - \lambda_{h-1} L^{h-1} - \ldots - \lambda_1 L - \lambda_0) z_t = \delta + \epsilon_t
\]

where \( \theta_w(L) \) is the non-seasonal autoregressive operator of order \( w \), \( \theta_h(L') \) is the seasonal autoregressive operator of order \( h \), \( \lambda_q(L) \) is the non-seasonal moving average operator of order \( q \), \( \lambda_f(L') \) is the seasonal moving average operator of order \( f \), and \( \delta \) is a constant term. The constant term is defined as follows: 

\[ \delta = \mu \theta_w(L) \theta_h(L') z_t \]

where \( \mu \) is the true mean of the stationary price time-series under consideration.

After the order identification of the general Box-Jenkins price model, the unknown parameters have to be estimated. If the \( \epsilon \) are normally distributed, then the maximum likelihood can be used for the estimation of the unknown parameters, otherwise the least squares method can be used. Besides, the unknown parameters can be estimated quite easily with advanced computer programs like SAS and SPSS.

The developed Box-Jenkins price model can be used to predict the expected values of prices for the next periods. The price forecast structure is mainly based on the autoregressive part and the constant term in a Box-Jenkins price model. As Bowerman and O'Connell (1987) have been noted, 'the constant term \( \delta \) and the autoregressive and differencing operators of the price model determine the 'basic nature' of the forecasts and the moving average operators determine how previous random shocks or errors modify the basic nature of the forecasts'. The significance of a price forecast can be checked with a price forecast interval. If the forecasted price value falls in the price interval, then it is a reliable forecast. However, to obtain an interval for price forecast, a distributional assumption for the price process is required. Assuming that the \( \epsilon_t \) is a Gaussian white-noise process, then the \((1 - \alpha)^*100\%\) price forecast interval for \( p_t \) is defined as follows:

\[
\text{price forecast} = \hat{p}_t \pm t_{(1-\alpha)/2}(\text{estimated standard forecast errors})
\]
where \( t_{(a/2)} \) is the \((1 - (a/2))*100\%\) point of the \( t \)-distribution. If the price sample size is large, then \( t_{(a/2)} \) can be replaced by \((1 - (a/2))*100\%\) point of the standard normal distribution, \( z_{(a/2)} \).

### 5.3 Price time-series regression model

It is also possible to combine regression analysis with the Box-Jenkins approach to forecast price time-series. The price models with this combination are known as the price time-series regression models. These price models are useful when the parameters describing the trend, seasonal, or cyclical components of a price time-series are deterministic, that is, the parameters are not changing over time. The first step of modelling the price time-series \( p_t \) into a price time-series regression model is to distinguish the price regression in trend, seasonal, and error components. It is possible that the price time-series does show a linear trend. This implies that there is a straight line long-run growth or decline over time. Another price trend is the quadratic long-run change over time. This trend can either be growth at an increasing or decreasing rate or decline at an increasing or decreasing rate. According to Bowerman and O'Connell (1987), these two trends are the most common ones.

Seasonal pattern of the price time-series can be modelled by using dummy variables. The purpose of the dummy seasonal variables is to ensure that the appropriate seasonal parameter is included in the price regression model in each time period. If the number of seasons in a year is \( s \), then the number of dummy variables in the model is \( s - 1 \), because one of the seasonal parameter has to be set equal zero. Hence, the other dummy parameters are defined with respect to that season. Intuitively, the parameters are the difference, excluding trend, between the level of the price time series in season that is equal to zero and the levels of the price time-series of the other seasons 2).

Another method for modelling the seasonal effects in time-series price regression models is using trigonometric terms instead of dummy variables. Examples of trigonometric terms are cosine and sine functions. Trigonometric models are useful when the price time-series exhibit trend and seasonal effects that are largely stochastic, that is, the parameters are changing through time 3).

If the error term in the price model is assumed to be a random variable that is normally distributed with mean zero and a variance that is the same for each and every time period \( t \), then the price model may be estimated with the maximum likelihood method. In general, the error terms are not statistically independent, and therefore, a Box-Jenkins model can be used to describe the error terms.

Combining the dependent error terms with the trend and the seasonal components in one model gives the price time-series regression model. The model with dummy seasonal variables can be defined as follows:

\[
p_t = \beta_0 + \beta_1 t + \beta_2 t^2 + \beta_3 x_{1,t} + \beta_4 x_{2,t} + \ldots + \beta_{s-1} x_{s-1,t} + e_t
\]

where the parameters \( \beta_0, \beta_1, \) and \( \beta_2 \) represent the quadratic trend and if \( \beta_0 \) is zero then the trend component represent a linear trend, \( x_{s-1} \) is the dummy variable for season \( s - 1 \) in period \( t \), \( p_t \) is the price time series value for period \( t \), and \( e_t \) is the random error term for period \( t \). The identification of the error by a Box-Jenkins model and the estimation of

1) The computer programs SAS and TSERIES calculate a 95\% prediction interval for \( p_t \) automatically. Other \((1 - a)100\%\) prediction intervals for \( p_t \) can be approximated by the following equation, if the degree of freedom is at least 30, \( [p_t^* \pm (z_{(0.05/2)})(U - L)/2)] \), where \( (U - L) \) is the difference between the upper and the lower limits of a 95\% prediction interval for \( p_t \). See e.g. Bowerman and O'Connell (1987, p. 159).

2) See e.g. Bowerman and O'Connell (1987, p. 208).

3) For applications of the trigonometric models see e.g. Bowerman and O'Connell (1987, pp. 217-252).
the unknown parameters of this price time-series regression model can be done quite easily with advanced computer programs like SAS and SPSS.

If the parameters describing a price time-series are stochastic, then the price time-series regression model and the estimates of the price model parameters need to be updated at the end of each period to account for the most recent price observations. This updating must take into account the fact that the price model parameters may change over time. Therefore, it may not be reasonable to continually give equal weight to each of the previously observed value of the price time-series. The exponential smoothing approach is a possibility to update the parameters of a price time-series regression model. This approach is a forecasting method that weights each of the observed price time-series value unequally, with the recent price observations being weighted more heavily than the more remote price observations. Besides, it updates the estimates of the parameters so that changes in the values of these parameters can be detected and incorporated into the forecasting system. Two applications of this approach will be explained. The first one is the simple exponential smoothing method. It should be used when the price time-series exhibits no trend and seasonal pattern. The first step of this method is to calculate the average of the price time-series at period T-1, \( a_0(T-1) \), then this factor can be updated to \( a_0(T) \), which is an estimate made in time period T of the average level of the price time-series. Updating can be done with the smoothing equation, that is defined as follows:

\[
Pr_t = a_0(T) + \xi p_T \cdot (1 - \xi) a_0(T - 1)
\] (5.13)

where \( \xi \) is a smoothing constant between 0 and 1, and its value is determined with the algorithm that minimizes the sum of squared forecast errors. This equation says that the estimate made in period T of the average level of the price time-series, equals a fraction \( \alpha \) of the newly observed price time-series observation \( p_T \) plus a fraction \( (1 - \xi) \) of the estimate made in time period T-1 of the average level of the process. And the updating value, \( a_0(T) \) is a point forecast in period T for \( p_{T+1} \). It is also possible to construct a 100*(1 - \( \alpha \))% price prediction interval in period T for \( p_{T+1} \).

A more general exponential smoothing method is the Winters' method. It is the basic method for updating all other price time-series regression forecasts. Winters' updating equation says that the estimate of the average level of the price process at time period T contains the updated estimate of the trend component, the updated estimate of the permanent component, and the updated estimate of the seasonal factor. When the updated estimates are obtained, forecasts of future price time-series values can be generated with an equation that is most appropriately for the underlying price time-series regression model. Bowerman and O'Connell (1987) give the appropriate updating equations for the underlying price models in their book Time Series Forecasting in section 6.4.

### 5.4 Multiple price time-series model

The previous price time-series models have considered only one price time-series process, although, in general, the considered price time-series process is related to one or more other time-series processes, like prices of substitutes, energy price etc. Therefore, it may reasonable to include more than one time-series process in the model. A model that considers more than one price time-series process is called a multiple price time-series model. This generated process of the multiple price time-series will be explained by looking at a vector autoregressive process.

Consider a vector autoregressive process of order \( w \), which is abbreviated as VAR(\( w \)) for a system of M time-series variables \( p_t = (p_{1t}, p_{2t}, ..., p_{Mt})' \) and it is defined as follows:

---

1) See e.g. Bowerman and O'Connel (1987, pp. 265-6).
\[ p_t = \nu \cdot \Theta_1 p_{t-1} \cdot \Theta_2 p_{t-2} \cdot \ldots \cdot \Theta_w p_{t-w} + \epsilon_t \]  
(5.14)

where \( \nu = (\nu_1, \nu_2, \ldots, \nu_M)' \) is a M-dimensional intercept vector, \( \Theta_i \) is a \((M \times M)\) coefficient matrix for \( p_{t+i} \), \( i = 1, 2, \ldots, w \), and is defined as follows:

\[
\begin{align*}
\Theta_1 & = \begin{pmatrix} \theta_{11} & \theta_{12} & \ldots & \theta_{1M} \\
\theta_{21} & \theta_{22} & \ldots & \theta_{2M} \\
\vdots & \vdots & \ddots & \vdots \\
\theta_{M1} & \theta_{M2} & \ldots & \theta_{MM} \\
\end{pmatrix} \\
\Theta_2 & = \begin{pmatrix} \theta_{11} & \theta_{12} & \ldots & \theta_{1M} \\
\theta_{21} & \theta_{22} & \ldots & \theta_{2M} \\
\vdots & \vdots & \ddots & \vdots \\
\theta_{M1} & \theta_{M2} & \ldots & \theta_{MM} \\
\end{pmatrix} \\
& \vdots \vdots \vdots \vdots \\
\Theta_w & = \begin{pmatrix} \theta_{11} & \theta_{12} & \ldots & \theta_{1M} \\
\theta_{21} & \theta_{22} & \ldots & \theta_{2M} \\
\vdots & \vdots & \ddots & \vdots \\
\theta_{M1} & \theta_{M2} & \ldots & \theta_{MM} \\
\end{pmatrix}
\end{align*}
\]  
(5.15)

and \( \epsilon_t = (\epsilon_{1t}, \epsilon_{2t}, \ldots, \epsilon_{Mt})' \) is a M-dimensional random error vector. The random error vector is assumed to be a vector white noise, in other words, \( E(\epsilon_t) = 0 \), the variance-covariance matrix is \( \Sigma_\epsilon = E(\epsilon_t \epsilon_t') \) for all \( t \) and \( \text{Cov}(\epsilon_t \epsilon_s) = 0 \) for \( t \neq s \). The order \( w \) of a vector autoregressive process can be identified with statistical tools, although it has to be shown first that the vector stochastic processes are stationary processes. Stationarity for the stochastic vector can be defined in the same way as is done for the univariate stochastic process, only the covariance between two members of an univariate process has to be replaced by the covariance matrices of vectors \( p_t \) and \( p_{t+k} \). If the VAR(\( w \)) has bounded means and covariance matrices and the polynomial defined by the determinant \( \text{det}(I - \Theta_1 L - \Theta_2 L^2 - \ldots - \Theta_w L^w) \) has all its roots outside the complex unit circle, then the vector stochastic processes are stationary. If the multiple time-series are non-stationary then their stationarity can be achieved with the same transformations which are used in the univariate case. But, if the aim is to analyse the relationship between the original variables rather than the transformed variables, it is better to take the original observation, because transformations may distort or eliminate the original relationship.

Assuming that stochastic price vector \( p_t \) is a stationary vector, then the partial autocorrelation matrices can be used to identify the order of a VAR. Of course, these matrices have to be tested for their significance. An alternative approach is to use criteria designed to aid in choosing the VAR order. Akaike's AIC criterion and Schwarz's SC criterion may be used for the model choice 1). The order \( w \) is chosen so that the AIC or SC criterion is minimized.

Since a VAR(\( w \)) may regarded as a reduced form of a simultaneous equation system, the unknown parameter estimation can be done with the simultaneous estimation methods as described in appendix 8. To estimate the unknown parameters equation (5.14) has to be rewritten in the following system:

\[ p_t = (I_w \Theta X)'\theta + \epsilon_t \]  
(5.16)

where \( p \) is \((M \times T)\) vector, \( I_w \) is a \((M \times M)\) identity matrix, \( X \) is a \((T \times M \times w)\) matrix, that contains a \((T \times 1)\) normal vector and lagged time-series variables, \( \theta \) is a \((M \times w \times 1)\) unknown parameter vector, and \( \epsilon \) is a \((M \times T \times 1)\) independent white noise vector. In this system the GLS estimator is identical to the OLS estimator, and therefore the consistent estimate of the \( \theta \) can be written as follows 2):

\[ \hat{\theta}_{\text{GLS}} = (I_w \Theta X'X)^{-1}X'p \]  
(5.17)

1) \( \text{AIC}(n) = \ln \text{det}(\Sigma_n^*) + 2M^2n \ln n - T \), and \( \text{SC}(n) = \ln \text{det}(\Sigma_n^*) + M^2n \ln (T) / T \), where \( M \) is the number of variables in the model, \( T \) is the sample size, \( \Sigma_n^* \) is an estimate of the residual covariance matrix of a VAR(n) model.

2) See e.g. Judge et al. (1988, pp. 755-8).
The estimated system can be used to forecast the future time-series values. A forecast interval with probability \((1 - \alpha)\) for the value of the \(m^\text{th}\) explained variable of explained variable vector in the forecast period \(T+h\), \(p_{T+h}\), is defined as follows:

\[
p_{m,T+h} = t_{T,h} \Phi_m(h)
\]

where \(s_m\) is the square root of the \(m^\text{th}\) diagonal element of the mean square error matrix of an \(h\)-step forecast 1).

Although, the VAR model has proved to be a useful forecasting tool in practice, it may not always provide the most accurate forecasts. Sometimes, it may be preferable to increase the forecast accuracy to incorporate lagged exogenous variables in a VAR model. The new model is a system of dynamic simultaneous equations, which is abbreviated as ARX model.

Another extension of the VAR model is to allow that the errors can be intertemporally correlated, in other words \(e_t\) may be correlated with \(e_{t+s}\), hence, it is possible that the VAR processes have moving-average error processes. These models are called vector autoregressive moving-average models, and are abbreviated as VARMA. In general, these models may involve fewer parameters than the pure VAR model, and therefore, they may provide more efficient forecasts.

5.5 An example

This section presents an example of the price time-series forecasting models. As price time-series is used the monthly prices of mushrooms from the period January 1986 to December 1992. The price data comes from the annual publications 'Veiling Statistiek' published by Produktschap voor Groenten en Fruit (PGF) 2). Figure 5.1 presents the price development of mushrooms in this period 3). It is remarkable to notice that before 1990 the price development of mushrooms had a positive trend, but after this period the price development demonstrates a negative trend. Many factors have caused the turning point. Because nominal prices are used and not real prices it is possible that the inflation has caused this turning point, although in this period significant changes have taken place in the mushroom farming. The most important changes were the rising imports of fresh and preserved mushrooms from East-European countries and Asia to the Netherlands and to other West-European countries. Besides, in this period the developed cultivation method of re-used compost was introduced in the Netherlands. This kind of compost has accelerated the cultivation process of mushrooms. Consequently, the Dutch domestic supply has increased.

---

1) Judge et al. (1988, pp. 764-7) have defined the mean square error matrix of an \(h\)-step forecast, \(\Sigma_h\), as follows:

\[
\Sigma_h = \Sigma + M_1 \Sigma M_1' + \cdots + M_h \Sigma M_h'
\]

with \(M_0 = 1\) and \(M_j = \sum_{j+1}^{\text{max}} \Theta_j M_j\)

where \(\Sigma\) is the variance-covariance matrix of \(e\).

2) Dutch association for vegetables and fruit. They have collected and published the auction prices in the Netherlands from 1984 till now.

3) Nominal prices are used in this example, although probably it is better to take real prices. The decision for nominal prices is a continuation of the usual way to forecast horticultural commodity prices.
In this section two price time-series forecasting models for mushrooms are developed. The estimation of the models and the forecasting is done with the statistical computer program SAS. The univariate price time-series model is the first model that is developed. After examination of the SAS generated autocorrelation and partial autocorrelation figures and several model estimations the price time-series of mushrooms can be represented by a \((1 - \Theta \cdot L(1)) \cdot p_t^* = (1 - \lambda \cdot L(6)) \cdot \varepsilon_t\) model, model 1, with price transformation \(p_t^* = p_t - p_{t-6} - \lambda (1 - 0.86923L(1) - 0.79612L(2) - 0.86923L(3)) p_t\) model, model 2. was also estimated, but the prices of period \(t-2\) and \(t-3\) were insignificant different from zero, therefore the model 1 is preferred to model 2. SAS has also forecasted the prices of mushrooms for 1993, and it generates automatically the 95% price forecast interval. Appendix 7 shows the (partial) autocorrelation figures and also the SAS procedures.

Table 5.1

<table>
<thead>
<tr>
<th>Period of Differencing= 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>(\mu)</td>
</tr>
<tr>
<td>(\lambda)</td>
</tr>
<tr>
<td>(\theta)</td>
</tr>
</tbody>
</table>

Constant Estimate (=\(\delta\)) = -0.0710133  
Std Error Estimate = 17.8786167

MODEL 1: \((1 - 0.86923L(1)) p_t^* = (1 - 0.79612L(6)) \varepsilon_t\), with \(p_t^* = p_t - p_{t-6}\) and \(L(k): p_t^* = p_{t+k}^*\).
Another method to forecast the mushroom prices is to construct a price time-series regression model. For this model the prices from January 1990 till March 1993 are used. This is done because the price development of mushrooms has demonstrated a negative trend after December 1989. Price time-series regression models with different number of seasons were estimated. After comparing these price time-series regression models, the model with 12 months seems to be the best one. This model had the highest adjusted-\(R^2\) measure, besides it has given the best fit 1). Not all estimated parameters of this model are significant different from zero, but in this model it is recommended to use also the insignificant parameters for the price forecasts and the intervals. SAS has also forecasted the prices of mushrooms form March 1993 till December 1993, and their corresponded 95% forecast intervals.

Price time-series regression model for mushrooms with a period of one year is defined as follows:

\[ p_t = \text{constant} + \beta \text{Trend} + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \beta_7 x_7 + \beta_8 x_8 + \beta_9 x_9 + \beta_{10} x_{10} + \beta_{11} x_{11} + \epsilon_t \]

1) For this model it is assumed that the error term did not have an ARIMA representation. The reason for this assumption is to illustrate a relative easy method to forecast prices.
Table 5.4
Parameter Estimates

<table>
<thead>
<tr>
<th>Variable</th>
<th>DF</th>
<th>Parameter Estimate</th>
<th>Error</th>
<th>Parameter=0</th>
<th>Prob &gt;</th>
<th>T</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CONSTANT</td>
<td>1</td>
<td>270.197222</td>
<td>8.37014248</td>
<td>32.281</td>
<td>0.0001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TREND</td>
<td>1</td>
<td>-1.497222</td>
<td>0.22049607</td>
<td>-6.790</td>
<td>0.0001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X1</td>
<td>1</td>
<td>14.997222</td>
<td>10.25010334</td>
<td>1.463</td>
<td>0.1559</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X2</td>
<td>1</td>
<td>18.261111</td>
<td>11.10389855</td>
<td>1.645</td>
<td>0.1126</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X3</td>
<td>1</td>
<td>20.425000</td>
<td>11.08856318</td>
<td>1.842</td>
<td>0.0774</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X4</td>
<td>1</td>
<td>-4.077778</td>
<td>11.07759634</td>
<td>-0.368</td>
<td>0.7159</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X5</td>
<td>1</td>
<td>-13.913889</td>
<td>11.07101103</td>
<td>-1.257</td>
<td>0.2204</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X6</td>
<td>1</td>
<td>-6.750000</td>
<td>11.06881505</td>
<td>-0.610</td>
<td>0.5475</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X7</td>
<td>1</td>
<td>18.747222</td>
<td>11.07101103</td>
<td>1.693</td>
<td>0.1028</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X8</td>
<td>1</td>
<td>30.244444</td>
<td>11.07759634</td>
<td>2.730</td>
<td>0.0114</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X9</td>
<td>1</td>
<td>25.075000</td>
<td>11.08856318</td>
<td>2.261</td>
<td>0.0327</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X10</td>
<td>1</td>
<td>10.572222</td>
<td>11.10389855</td>
<td>0.952</td>
<td>0.3502</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X11</td>
<td>1</td>
<td>16.736111</td>
<td>11.12358439</td>
<td>1.505</td>
<td>0.1450</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.5 Forecasts of mushroom prices for March to December 1993

<table>
<thead>
<tr>
<th>Month</th>
<th>Forecast</th>
<th>Lower 95%</th>
<th>Upper 95%</th>
<th>Price value 1993</th>
</tr>
</thead>
<tbody>
<tr>
<td>March</td>
<td>230.1</td>
<td>193.9</td>
<td>266.2</td>
<td>238</td>
</tr>
<tr>
<td>April</td>
<td>230.7</td>
<td>194.6</td>
<td>266.9</td>
<td>233</td>
</tr>
<tr>
<td>May</td>
<td>204.7</td>
<td>168.6</td>
<td>240.9</td>
<td>215</td>
</tr>
<tr>
<td>June</td>
<td>193.4</td>
<td>157.3</td>
<td>229.5</td>
<td>225</td>
</tr>
<tr>
<td>July</td>
<td>199.1</td>
<td>162.9</td>
<td>235.2</td>
<td>228</td>
</tr>
<tr>
<td>August</td>
<td>223.1</td>
<td>186.9</td>
<td>259.2</td>
<td>251</td>
</tr>
<tr>
<td>September</td>
<td>233.1</td>
<td>196.9</td>
<td>269.2</td>
<td>261</td>
</tr>
<tr>
<td>October</td>
<td>226.4</td>
<td>190.3</td>
<td>262.5</td>
<td>269</td>
</tr>
<tr>
<td>November</td>
<td>210.4</td>
<td>174.3</td>
<td>246.5</td>
<td>269</td>
</tr>
<tr>
<td>December</td>
<td>215.1</td>
<td>178.9</td>
<td>251.2</td>
<td>275</td>
</tr>
</tbody>
</table>

As has been noted in the beginning of this chapter the price data must be measured regular intervals; in this example monthly price data of mushrooms are used. For the mushrooms it is possible to forecast either the short-term prices as the long-term prices, because the supply of mushrooms does not depend on the weather conditions. However, it is not recommended to use the time-series forecasting approach to forecast the long-term prices for commodities which are cultivated outdoor. This can be explained by the fact that the weather plays a crucial role in the price levels of these commodities. But for the forecasting of the short-term prices the price time-series approach is probably an appropriate instrument.
6. CONCLUSIONS

The primary focus of this thesis is the theoretical foundation of various quantitative approaches to forecast both the short-term as well as the long-term prices for horticultural commodities in the Netherlands. The characteristics of horticulture play a crucial role in the possibility to forecast the horticultural commodity prices. Dutch horticulture can be divided into eight sectors: bulb growing, growing of (cut-)flowers under glass, growing of vegetables under glass, growing of pot plants under glass, tree nursery, outdoor growing of vegetables, mushroom farming, and fruit growing. For seven of these sectors it could be said that the assortment range of commodities in each sector is vast, and that the commodities are heterogeneous. The only exception is mushroom farming, because its assortment range of commodities is very small, and its commodities are more or less homogeneous. Another difference between the commodities in the same sector as between sectors is the cultivation season of horticultural commodities. One kind of commodity has a cultivation season of for example three months, whereas, other commodities have a cultivation period of three years. Because of these various horticultural commodity characteristics, it is not possible to develop a standard price-forecasting model for horticultural commodities. It is difficult, perhaps also impossible, to develop a standard price-forecasting model for each sector, except for the mushroom farming. The only possibility is to develop a price-forecasting model for each horticultural commodity separately, and this is already difficult enough.

For all sectors the international horticultural commodity markets are important. Several LEI-DLO publications have demonstrated the importance of Dutch export. In general, it can be concluded that the Netherlands is a net exporter of horticultural commodities. This study did not examine Dutch exports and imports. It has assumed that exports and imports are exogenous. Because the factors which influence Dutch exports and imports differ per commodity and country, it is recommended to devote a study to this subject.

Most of these commodities are traded at auctions in the Netherlands. This means that for these commodities the necessary data are available to forecast the commodity prices. Unfortunately, not all sectors are transparent. Mushroom farming, bulb growing, and tree nursery have an imperfect competitive market structure. In general, the growers of the first two sectors are also exporters of their commodities, and hence each others' rivals. This is the reason that the data needed to obtain price predictions are not available. The other sector, tree nursery, has a monopolistic competitive structure. Each tree nursery experiences some of the elements of a monopoly, because they sell commodities which the consumers are considered to be differentiated. As a consequence, it is difficult to forecast the short-term and the long-term commodity prices for the tree nursery sector.

The first approach to obtain price forecasts is to set up an econometric price model. The framework of an econometric price model relies on the relationships between market structure, exogenous processes, expectations, and behaviour. In general, the price forecasts obtained with an econometric price model are economically justified. For the construction of an econometric price model the demand and supply functions have to be known. However, little or no demand and supply functions are constructed for the Dutch horticultural commodities, and therefore, the demand and supply functions for winter tomatoes in the United States of America which have been developed by Shonkwiler and Emerson in 1982, are used to explain the theoretical foundation of an econometric price model for Dutch horticultural commodities. The econometric price model that is described in chapter 4 is a partial equilibrium-perfect competitive model, and hence, the competitive market clearing prices for five Dutch horticultural markets can be predicted. Of course, this model is a simple one and has to be modified for each single commodity or group of commodities.
The demand functions of the consumers in chapter 4 are derivations of the consumers' Cobb-Douglas utility functions subject to their budget constraints. It is assumed in this study that the derived demand functions are standard and that they have to be modified for each horticultural commodity. However, finding supply functions for horticultural commodities is more difficult than finding demand functions. This can be explained by the fact that the annual yield varies extremely. The yield variations are assumed to be determined primarily by uncontrollable exogenous influences such as weather for commodities which are cultivated outdoor, although changes in economic conditions will have influences on the short-term yield.

For the supply of horticultural commodities the availability of acreage plays a crucial role. The acreage of a commodity is fixed in the short term, but variable in the long term. Growers of horticultural commodities will base their acreage decision on their expected prices for horticultural commodities. This thesis explained three alternatives to determine the grower's price expectation briefly. The first two alternatives, naive and adaptive expectations, are extrapolative methods. Under these assumptions the grower base their acreage decisions on historical prices only. However, the past prices do not necessarily reflect the current information, and therefore, the rational expectations method is explained. This method involves the current information in the grower's price expectations. Probably, the econometric price model with the rational expectations assumption will give the most reliable forecasts. A disadvantage of the rational expectations assumption is its application. It makes the forecasting procedure more complicated. Therefore, it seems better to develop the acreage equations under the adaptive expectations assumption. The adaptive expectations are preferred to the naive expectations, because the naive expectations are too naive and they can cause an explosive price movement.

The development of the aggregate acreage for a commodity is crucial for the long-term price forecasts. On the other hand, for the short-term price forecasts the aggregate acreage is fixed, and only the yield function and the storage possibilities of a commodity are crucial. Since it is difficult and complex to forecast the short-term prices for horticultural commodities with an econometric price model, it is better to use another approach. The price time-series forecasting approach is appropriate to forecast the short-term prices for horticultural commodities. It is even appropriate to forecast the long-term prices for commodities which are cultivated indoors. This method may not be used to forecast the prices of commodities which are cultivated outdoors. It assumes that the identified price data pattern will continue in the future, but the long-term price movements of outdoor commodities do not show a pattern. This can be explained by the fact that there are extreme fluctuations in the annual yield. These fluctuations are mainly caused by the weather.

The price time-series forecasting approach has to satisfy two conditions. The first condition is that the price data must be measured at equally spaced intervals. The other condition is that the price process has to be stationary. If the price process is not stationary, then the user has to transform the price time-series so that it will become a stationary process.

Given the situation in Dutch horticulture it is recommended to develop first the supply and demand models for the Dutch horticultural commodities separately, before the econometric price model for that commodity can be used to forecast its future prices. For this moment it is better to use a qualitative method to forecast the long-term price developments for horticultural commodities, especially for commodities of which the annual productions depend on the weather condition in that particular year. But for the short-term prices it is possible to use the price time-series forecasting approach.

Because of the complexity of the Dutch horticulture the results of a price forecasting method are not reliable enough to give a final opinion about either the short-term or the long-term price developments for horticultural commodities. Therefore, it is always sensible to ask the opinion of experts. Hence, the quantitative price approach has to be combined with the qualitative price approach to forecast both the short as well as the long-term price developments for Dutch horticultural commodities.
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Appendix 1  Axioms on the preference relation 1)

Commodity set definition: - a commodity may not be characterized by strictly negative numbers;
- the commodities can be divided (property of divisibility);
- the commodity set contains the bundle (0, 0, ..., 0), and it is unbounded from above.

BASIC AXIOMS

a) Axiom of comparability
For any pair of commodity bundles in the commodity set the consumer is able to make comparisons between the bundles, and to say which bundle he or she prefers to the other (i.e. the consumer's preference relation is complete).

b) Axiom of transitivity
If the consumer does not prefer bundle $x_1$ to the bundle $x_2$, and the latter is not preferred to $x_3$, then the consumer does not prefer $x_1$ to $x_3$, with $x_1$, $x_2$, and $x_3$ bundles in the commodity set (i.e. the consumer's preferences are consistent).

These two basic axioms give a complete preordering.

c) Axiom of continuity
It is possible that commodity bundle $x_1$ come close to commodity bundle $x_2$ for $x_2$ not to be preferred to $x_1$ (i.e. to be indifferent to $x_1$) with $x_1$ and $x_2$ in commodity set.

The basic axioms are sufficient conditions for the existence of a real-value utility function.

ADDITIONAL AXIOMS

The next three axioms are necessary to maximize a utility function

a) Axiom of dominance
The consumer prefers the bundle in the commodity set that contains more or one of the commodities and not less of the other commodities. Hence, the consumer always prefers more to less.

b) Axiom of strict convexity
If two commodity bundles in commodity set are indifferent, then a linear combination of these two bundles is preferred to these two commodities.

c) Axiom of differentiability
A utility function is twice differentiable.

Appendix 2 Overview section 2.2

\[
\begin{align*}
\text{Max}_x U(x) & \text{ s.t. } p \cdot x \leq Y, x \geq 0 \\
\text{Solve} & \downarrow \\
\text{Marshallian demand function} & \quad \text{Substitution}
\end{align*}
\]

\[
\begin{align*}
D_i(x, p) & \quad \text{Roy's identity} \\
\downarrow \quad \text{Substitution} & \\
\text{Indirect Utility function} & \downarrow \\
V(p, Y) = \text{Max} \{U(x): p \cdot x \leq Y \text{ and } x \geq 0\} & = U(D_1(x, p), D_2(x, p), \ldots, D_n(x, p)) \\
\downarrow \quad \text{Inversion} &
\end{align*}
\]

\[
\begin{align*}
\text{Min}_x p \cdot x & \text{ s.t. } U(x) \geq u, x \geq 0 \\
\text{Solve} & \downarrow \\
\text{Hicksian demand function} & \quad \text{Differentiation}
\end{align*}
\]

\[
\begin{align*}
H_i(u, p) & \quad \text{Substitution} \\
\downarrow & \\
\text{Expenditure function} & \downarrow \\
E(u, p) = \text{Min} \{p \cdot x: U(x) = u \text{ and } x \geq 0\} & = p_1H_1(u, p) + p_2H_2(u, p) + \ldots + p_nH_n
\end{align*}
\]

Note: \(p \cdot x = p_1x_1 + p_2x_2 + \ldots + p_nx_n\).

Appendix 3 Calculation of specialization rate in 1992 1)

<table>
<thead>
<tr>
<th>1) Bulb growing</th>
<th>2) Growing of cutflowers under glass</th>
<th>3) Growing of vegetables under glass</th>
<th>4) Growing of pot plants under glass</th>
<th>5) Tree nursery</th>
<th>6) Outdoor growing of vegetables</th>
<th>7) Mushroom farming</th>
<th>8) Fruit growing</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of outdoor vegetables farms, that are specialized in bulbs</td>
<td>total number of farms, that cultivate bulbs</td>
<td>rate of specialization: 1,919/3,581 = 0.54</td>
<td>total number of specialized farms</td>
<td>total number of farms</td>
<td>rate of specialization: 5,593/6,033 = 0.93</td>
<td>total number of specialized farms</td>
<td>total number of farms</td>
</tr>
</tbody>
</table>

Appendix 4  Derivation of demand functions

The derivation of demand functions is explained for an economy with two commodities, $X_1$ and $X_2$. It is assumed that a household's preferences over these two commodities can be represented by the following Cobb-Douglas utility function: $U(x_1, x_2) = AX_1^\alpha X_2^\beta$ with $0 < \alpha, \beta < 1$, $A > 0$, $U(\cdot)$ is homogeneous of degree $\alpha \cdot \beta$, and the constant elasticity of substitution, $\sigma = d \log(X_1 / X_2) / d \log(-dX_1 / dX_2)$, is one.

As is known, a household will choose the consumption bundle that is best according to its preferences ($U$) subject to its budget constraint, $p_1 X_1 + p_2 X_2 \leq Y$. The maximization problem is given with the Lagrangean function:

$$\text{Max } z(x_1, x_2, \lambda) = AX_1^\alpha X_2^\beta - \lambda(Y - p_1 x_1 - p_2 x_2)$$ \hfill (A4.1)

This function has been differentiated partially with respect to $X_1$, $X_2$, and $\lambda$ to obtain the first order conditions (FOC) for a maximum of utility subject to the budget constraint. The FOC are:

$$\frac{\delta z(x_1, x_2, \lambda)}{\delta x_1} = 0 : \frac{\alpha AX_1^{\alpha-1} X_2^\beta}{p_1} - \lambda$$ \hfill (A4.2)

$$\frac{\delta z(x_1, x_2, \lambda)}{\delta x_2} = 0 : \frac{\beta AX_2^{\alpha} X_1^{\beta-1}}{p_2} - \lambda$$ \hfill (A4.3)

$$\frac{\delta z(x_1, x_2, \lambda)}{\delta \lambda} = 0 : Y - p_1 x_1 - p_2 x_2$$ \hfill (A4.4)

The condition (A4.2) is set equal to (A4.3). They express that at equilibrium all marginal utilities divided by the corresponding prices are equal. After substitution of condition (A4.4) into the equilibrium (A4.2) = (A4.3), the following demand functions are found:

$$x_1 = \frac{\alpha Y}{(\alpha \cdot \beta) p_1}$$ \hfill (A4.5)

$$x_2 = \frac{\beta Y}{(\alpha \cdot \beta) p_2}$$ \hfill (A4.6)

These demand functions can be made linear by taking the logarithm of these demand functions. The loglinear demand functions can be written as follows:

$$D_1(p_1, p_2, Y) = \log x_1 - \log(\alpha/(\alpha + \beta)) \cdot \log Y - \log p_1$$ \hfill (A4.7)

$$D_2(p_1, p_2, Y) = \log x_2 - \log(\beta/(\alpha + \beta)) \cdot \log Y - \log p_2$$ \hfill (A4.8)
The derived demand functions are general functions. In reality, the demand for a commodity also depends on other factors, like advertising, temperature etc. It is possible to incorporate these factors in demand functions. This can be done by dividing the constant term into variables, that influence the demand significantly and in a resulting constant term. Of course, an error term has to be included in the demand equations. See section 4.2.1 for three reasons to include an error term.
Appendix 5  Derivation of yield function

Focusing on area planted allows only a partial description of the determination of supply. Therefore, a more complete analysis of supply has to be found. A possibility is to specify equations to explain both area planted and yield per unit area. It is important to specify the right yield equation, although this is not easy. In practice, yield fluctuates extremely. This can be explained by the fact that the yield fluctuations are assumed to be determined primarily by uncontrollable exogenous influences such as weather, but can also be a deliberate short-term response to changes in economic conditions. This implies that it is difficult to derive the yield function, because the exogenous influences cannot be determined. Although the yield fluctuates, it does not violence the primary aim of horticultural entrepreneurs. This aim is that they are still profit maximizers. This implies that efforts of harvesting depend on the profit maximization problem of the entrepreneurs. If the harvest effort is less then the yield will also decrease. The harvest function can be for example a Cobb-Douglas function, with as factors labour, capital, price of commodity. The yield depends also on the inputs such as fertilizers. Hence, to derive the yield function is a big and difficult problem, therefore the yield function that is used in chapter 4 is based on the yield function defined by Shonkwiler and Emerson (1982).
Appendix 6 Three grower's alternatives for determining his expected price for commodity I

6.1 Naive expectations hypothesis

Naive expectations is the first hypothesis that will be explained in this part. This method is generally known as the simple cobweb model and is defined as follows:

\[ P_t' - P_{t-1} \] (A6.1)

The key in this model is that the supply decisions that are made in period t-1 are based on the price prevailed at that time. More precisely, the growers set their expected price equal to the prevailed price at the time to make decisions about the total acreage they would like to use for the cultivation of commodity i. Under the naive expectations, the general long-term price equation appears as:

\[ P_t = X_t + \gamma_1 P_{t-1} + \epsilon_t \] (A6.2)

The advantage of this hypothesis is that it is easy to apply. Unfortunately, this hypothesis has significant disadvantages. The first one is the explosive movement. This movement can be caused if the supply side reacts stronger on a price change than the demand side, and that the long-term price movement will become more unstable. And as the name of this hypothesis implicates the formation of the expectations would often seem to be too naive, since it implies that the farmers take no account of additional price experience (Cowling et al., 1970, pp. 29-30).

6.2 Adaptive expectations hypothesis

As Sheffrin (1983) has been noted, ‘Nerlove (1958) recognized that empirical work based on the simple cobweb model was likely to give misleading results. He introduced the concept of adaptive expectations to the modelling of agricultural markets’. The adaptive expectations hypothesis is a more sophisticated one. It assumes that grower’s price expectations for commodity i are revised each period with the revision, \( \zeta \), proportional to the error in the previous expectations. This hypothesis can be defined as follows:

\[ P_t' = P_{t-1}' + \zeta(P_{t-1}' - P_{t-2}'), \quad 0 \leq \zeta \leq 1 \] (A6.3)

The closer the revision parameter, \( \zeta \), is to one, the greater the weight given to the most recent observations in determining the current expectation. And if the parameter is equal to one, then the adaptive expectations hypothesis is the same as the naive expectations. Furthermore, the grower’s price expectations in the previous periods could be written in a same way, and the resulting expression can be substituted into that for the current expectation. By continued substitution the grower’s expected price for commodity i can then be defined as follows:

\[ P_t' = \sum_{s=0}^{\infty} \zeta(1 - \zeta)^s P_{t-s} \quad 0 \leq \zeta \leq 1 \] (A6.4)

This formula is called a geometric distributed lag model. It illustrates that the growers are assumed to base their price expectations only upon an extrapolation of past prices. Substituting this geometric distributed lag model in the general acreage equation, then applying the Koyck

1) In a World Bank study, an acreage equation for tea depended on the price of seven years back. This model is mentioned in Hallam (1990, pp. 52-3).
2) An X-year weighted average of past prices, with more weight being given to more recent prices, is a simple application of the adaptive expectations hypothesis.
transformation 3) and this results in a new general acreage equation. The new general acreage equation of commodity i restricted under the adaptive expectations hypothesis can then be defined as follows:

\[
A_{it} = \xi y_0 \cdot (y_{1} - (1 - \Omega)A_{it-1} + y_fK - \Omega) + Y y_{2} + P_{it-1} + Y \beta \cdot \eta_t - (\xi - 1)\eta_{it-1}
\]

Using the new general acreage equation for the determination of the long-term market clearing price development, then the long-term clearing market price equation can be defined as follows:

\[
P_{it} = (\alpha - \beta) \cdot (\xi - \beta) + \xi y_0 - \xi y_{1} + \xi y_{2} + \xi y_{4} + M_{it} + E_{it} - \alpha_1 y_{it-1} - \alpha_2 y_{it-1} - \alpha_3 y_{it-1} - \alpha_4 y_{it-1} - \alpha_5 y_{it-1} - \alpha_6 y_{it-1} \cdot \eta_t - (\xi - 1)\eta_{it-1}
\]

or alternatively,

\[
P_{it} = X_{it}^T \cdot \theta + X_{it}^T \cdot \delta + \xi y_{2} + P_{it-1} + \eta_t
\]

where \(X_t\) is the same vector as in equation (4.8b), \(\theta\) is a corresponding \((16+N)\times1\) vector of parameters, \(X_{it}\) is the \((4\times1)\) vector of exogenous variables which are lagged one period, \(\delta\) is a corresponding \((4\times1)\) vector of parameters, and \(\eta_t\) is the aggregate error of the general price equation for period \(t\).

Unfortunately, this equation is a statistical complex model, because the equation has serially correlated errors and this means that the successive values are not independent. Besides, the explanatory variables includes stochastic lagged dependent variable, \(P_{it}\). According to Hallam (1990), 'most applications of the Nerlove model have ignored these statistical problems'. An alternative way is to predict first the grower's expected price with the geometric distributed lag model and use the estimate as an exogenous variable in the original acreage equation.

6.3 Rational expectations hypothesis

The extrapolative expectations approach, naive and adaptive hypotheses, is inadequate. According to Fisher (1982), 'not because it implies that the forecast of a particular variable is a distributed lag of its own past values, but because it implies that the distributed lag parameters are restricted in an ad hoc way, because the parameter restrictions in the distributed lag are not the result of an optimization process'. Another disadvantage of the extrapolative approach is that the growers can and do make decisions only on historic price information. Finally, the current information is not necessarily reflected in the past prices. Muth (1961) developed the rational expectations theory to overcome these problems. And Huntzinger (1979) estimated a rational expectation model of the broiler industry in the United States of America in what appears to be the first attempt to apply the rational expectations hypothesis to agricultural supply. His rational expectations model of the US broiler market has provided evidence to support the applicability of the rational expectations hypothesis to agricultural markets. In the rational expectations theory, 1)

---

1) The Koyck transformation is defined as follows: first lag the equation for one period and than multiply it with the factor (1 - \(\Omega\). Finally, substrakt the transformed equation from the original equation.
the available information set plays a very important role in the prediction of the prices. As Muth has been noted, 'what kind of information is used and how it is put together to frame an estimate of future conditions is important to understand, because the character of dynamic process is typically very sensitive to the way expectations are influenced by the actual course of events'. The concept of rational expectations provides a method of interpreting grower's use of available information in making decisions or in other words, rational expectations for a particular variable are mathematical expectations conditional on available information or written in a formula,

\[ P_t^e = E[P_t|\Omega_{t-1}] \quad \text{with } \Omega_{t-1} \text{ available information set at } t-1 \]  

(A6.7)

As a consequence, a rational expectations framework provides a systematic way to incorporate the effects of uncertainty about the future prices.

Under the assumption of the rational expectations hypothesis, the structural model can be solved for the expected price as a function of the expected values of the exogenous variables. This price function can then be substituted into the structural model leading to a specification which contains the original endogenous and exogenous variables and the expected values of the exogenous variables. The rational expectations of the endogenous variables of the structural model are consistent with the model's view of how the values of those endogenous variables are determined. On average, rational expectations of the value of a variable will be equal to the realised value, differing only as a result of purely random factors (Hallam, 1990, pp. 54-51). 1) The horticultural commodity growers are acting now in accordance with the information that is available to them at planting time and in a way represented by the interaction in the supply and demand model. Hence, the solution illustrates the relationships between market structure, exogenous processes, expectations, and behaviour.

Under the rational expectations hypothesis the equation for the grower's expected price can be determined easily. First, setting the total supply equal to the demand, then taking the conditional expectation of both sides and rearranging the equilibrium. The equation for the grower's expected price of commodity \( i \) for period \( t \) is then as follows:

\[
R_t^e = (\alpha_1 - \beta_1 - \gamma_t)^{-1} (\alpha_0 - B_0 - Y_0) - \alpha_e P_t^e - \alpha_e Y_t^e - M_t^e - X_t^e - \alpha_e E_t^e
- \alpha_e \text{Temp}_t^e - \alpha_e T - \sum_{j=1}^{N} W_j^e C_j^e - \beta_1 Y_t^e - \beta_2 W_t^e - \beta_3 Y_t^e - \beta_4 E_t^e
+ Y_t^e A_{t+1} - Y_t^e R_t^e - Y_t^e O_t^e - Y_t^e C_t^e - (V_t^e - U_t^e - n_t^e)]
\]

(A6.8a)

or alternatively,

\[
R_t^e = X_t^e \lambda_t + \tau_t
\]

(A6.8b)

where \( X_t^e \) is the vector of the expected values for the exogenous variables for period \( t \), \( \lambda \) is the corresponding vector of parameters, and \( \tau \) is the error term of the equation.

This equation explicitly illustrates that the grower's expected price depends upon the predetermined variables and the expected exogenous variables in the system, therefore, the implementation of the rational expectations hypothesis requires that the expected values of the exogenous variables have to be defined in terms of observable data. Time-series models and specific equations with the particular variable as endogenous can be used to define the expected values of these exogenous variables 2). As a consequence, the dynamic stochastic processes of these exogenous vari-

1) Conditional expectation is the same as a forecast. And associated with any forecast is a forecast error, \( e_t \). The forecast error is defined as: \( e_t = x_t - E(x_t|\Omega_{t-1}) \). The error term is on average zero, \( E(e_t) = 0 \), if on average the forecast of variable \( x_t \) is equal to the realized value of \( x_t \).

2) Shonkwiler and Emerson (1982) have forecasted the values of the exogenous variables in the expected price equation under rational expectations by the following relation:

\[
Z_t = \delta_0 + \delta_1 z_{t-1} + e_t
\]

since there was no other structural information concerning their generation.
ables then determine the dynamic stochastic properties of the rational expectations model. Under the rational expectations hypothesis the general acreage equation for commodity \( i \) is then defined as follows:

\[
A_t = \nu_0 + \nu_1 A_{t-1} + \nu_2 (\alpha_1 - \beta_1 - \nu_3)^T \alpha_0 + \beta_0 + \nu_4 (\alpha_2 P_t^* - \alpha_3 Y_t^* + (1 - \alpha_3) M_t^*) - \alpha_5 E_t^* - \alpha_6 Temp_t^* - \alpha_7 T - \sum_{j=1}^{N} w_j M_{j,t}^* - \beta_1 L_t^* - \beta_2 W_t^* - \beta_3 V_{i,t}^* - \beta_4 R_{i,t}^* - \nu_5 C_{i,t}^* - \nu_6 C_{i,t}^* - (\nu_7^* + \mu_t^* + \omega_t^*) = Y_t R_t
\]

or alternatively,

\[
A_t = M_t \zeta - P_t^*_\zeta \cdot \omega_t
\]

where \( M \) is the vector of exogenous variables from the original general acreage equation excluded the expected price variable for period \( t \), \( P_t^* \) is the expected price variable for commodity \( i \) in period \( t \), and \( \omega_t \) is the error term.

Since the expected acreage for commodity \( i \) can be predicted, the market clearing price development for the medium and the long term can be predicted. The prediction of the market clearing price has to be done in the same way as in the extrapolative approach, that is described in the previous two subsections.

The rational expectations hypothesis seems to be an improvement on the extrapolative expectations approach in attempting to broaden the information set upon which the expectations are assumed to be based. However, there are objections to the rational expectations hypothesis. As Fisher (1982) has been noted, 'according to McCallum (1980, p. 38), there are two common criticisms of the hypothesis. First, it may be unrealistic to assume that agents use all information that is available. Second, it may be realistic to assume that agents use information as intelligently as the hypothesis claims'. He has said further, that the rational expectations hypothesis is consistent with the common notion that economic agents are optimizers, and it generates readily testable propositions. As a consequence, it is important to test the rational expectations hypothesis assumption. The rational expectation model has to be tested for four properties: first, for the unbiasedness (expectation on average is equal to the realised value), secondly, for efficiency (expectation should use the information of the past), thirdly, for forecast error unpredictability (difference between expectation and actual realization should be uncorrelated with any information available at time of forecast), and finally, for consistency (forecasts for a variable in different time periods must be consistent with one another). Two possible methods for testing these hypotheses are the log likelihood test and the predictive test.
Appendix 7  Huntzinger's price conditions 1)

 Behavioural equations

 Demand equation:

\[ D_t = \alpha_0 \cdot \alpha_1 P_{it} + \alpha_2 X_{it} + v_t \]  \hspace{1cm} (A7.1)

The demand, \( D_{it} \), is linear in price, \( P_{it} \), a vector of exogenous and predetermined variables, \( X_{it} \), and a stochastic disturbance term, \( v_t \), with expected value zero.

 Supply equation:

\[ S_t = \beta_0 \cdot \beta_1 P_{it+1} + \beta_2 X_{it} + \eta_t \]  \hspace{1cm} (A7.2)

The supply, \( S_{it} \), is linear in expected price of commodity \( i \) for period \( t+1 \), \( P_{it+1} \), a vector of exogenous and predetermined variables, \( X_{it} \), and a stochastic term \( \eta_t \) with expected value zero.

 Inventory demand:

\[ Q_t = \delta_0 \cdot \delta_1 P_{it+1} + \delta_2 P_{it} + \delta_3 X_{it} + \eta_t \]  \hspace{1cm} (A7.3)

The inventory demand, \( Q_{it} \), is linear in expected price of commodity \( i \) for period \( t+1 \), \( P_{it+1} \), the current price of commodity \( i \), \( P_{it} \), a vector of exogenous and predetermined variables, \( X_{it} \), and a stochastic term \( \eta_t \) with expected value zero.

 Equilibrium condition

Every period prices adjust so that demand, \( D_{it} + Q_{it} \), is equal to supply, \( S_{it} + Q_{it} \). Substitution of the behavioural equations into the market clearing conditions for the current and future periods provides conditions which can be solved for the prices. The conditions are

for the current period:

\[ (\alpha_1 - \delta_2)P_{it} - \delta_1 P^e_{it+1} - \alpha_0 - \delta_0 \cdot \alpha_2 X^d_{it} - \delta_3 X^d_{it} - v_i - \eta_t - Q_{it+1} - S_{it} \]  \hspace{1cm} (A7.4)

for the next \( h-1 \) periods, \( 0 < j < h \),

\[ -\delta_4 P^e_{it+j} - (\alpha_1 - \delta_1 - \delta_3)P^e_{it+j} - \delta_1 P^e_{it+j+1} - \alpha_0 - \alpha_2 X^d_{it+j} - \delta_3 X^d_{it+j} - \delta_4 (X^d_{it+j+1} - X^d_{it+j}) - S_{it+j} \]  \hspace{1cm} (A7.5)

and for periods after \( h \), \( j \geq h \),

\[ -\delta_2 P^e_{it+j} + (\alpha_1 - \beta_1 - \delta_1 - \delta_2)P^e_{it+j} - \delta_1 P^e_{it+j+1} - \beta_0 - \beta_2 X^d_{it+j} - \alpha_2 X^d_{it+j} - \delta_3 X^d_{it+j} - \delta_4 (X^d_{it+j+1} - X^d_{it+j}) \]  \hspace{1cm} (A7.6)

Appendix 8  Other estimation methods

8.1 Instrumental variable estimation

The estimation procedures in section 4.3 are based on the assumption that the explanatory variables of a linear price regression model are non-stochastic, although, in general, these variables are stochastic in nature 1). If the stochastic explanatory variables are independent of the error terms, then the least squares estimators are still consistent 2). Unfortunately, this assumption of independent stochastic explanatory variables is not always justifiable and then the previous estimation procedures will give inconsistent estimators. The instrumental variable (IV) estimation is a possible solution to the problem of dependent stochastic explanatory variables. The first step of the IV procedure is to construct a stochastic matrix \( Z (T \times k) \), that contains instrumental variables. These instrumental variables have to be correlated with the stochastic matrix \( X \) of the linear price regression model but uncorrelated with the random error vector \( e \). This requirement is a crucial one for the construction of the IV estimators for the unknown variables \( \beta \) and \( \sigma^2 \). The second step is to premultiply the linear price regression by the transposed matrix \( Z \), and, then, to apply the OLS procedure to the transformed price regression. This results in the following IV estimator of \( \beta \):

\[
\hat{\beta}_IV = (Z'X)^{-1}Z'y
\]

(A8.1)

with the variance-covariance matrix for large size samples given by:

\[
\Sigma_{\hat{\beta}_IV} = \frac{s^2}{T-k} (Z'Z)^{-1}
\]

(A8.2)

where

\[
s^2 = \frac{(p - X\hat{\beta}_0)(p - X\hat{\beta}_0)}{T-k}
\]

(A8.3)

The developed IV procedure provides a consistent estimate for the linear price regression model, although, the IV estimate is not necessarily efficient. This can be explained by the fact that many variables can be used as instrumental variables. According to Judge et al. (1988, p. 592), 'among the instrumental variable estimators, the one that makes use of the linear combination of all possible instrumental variables is believed to be more efficient than other instrumental variable estimators, since more information is incorporated'. Besides, it is not always possible to identify all possible instrumental variables.

8.2 Seemingly unrelated regressions estimation

This subsection deals with a situation where there is more than one price equation to estimate. It is likely to assume that the elements of the random error vector in the different price equations at a given time are reflecting some common unmeasurable or omitted factors, and hence, the error terms can be correlated. The correlation between the elements of the random error vectors from the different price equations at a given time is called the contemporaneous correlation. This kind of correlation is different than the described autocorrelation in subsection 4.3.4. The latter reflects the correlation over time for the elements of the random error vector in a single price equation. When the contemporaneous correlation exists, it may be more efficient to estimate all price equations jointly, rather than to estimate each price equation separately using one of the estimation procedures from chapter 4. The estimation procedure to estimate all price equations jointly is known as the seemingly unrelated regressions estimation (SUR) method 3). The first step

---

1) Explanatory variables are also stochastic when some of them cannot be measured accurately or simply cannot be directly observed or measured at all.
2) See e.g. Judge et al. (1988, pp. 574-5).
3) The seemingly unrelated regressions problem appears in particular in a set of equations using time-series data.
of this procedure is to combine all $M$ price equations into a framework of a big single price equation model with special definitions for $p$, $X$, $\beta$, and $e$. This special single price equation is called a super price model. In vector notation, the $M$ separate linear price equations are defined as follows:

$$p_i = X_i \beta_i + e_i, \quad i = 1, 2, \ldots, M$$

(A8.4)

where $p_i$ is a $(T \times 1)$ vector of price observations of commodity $i$, $X_i$ is a $(T \times k)$ matrix of $k$, known values of explanatory variables, where the first column is a vector with ones, $\beta_i$ is a $(k \times 1)$ vector of unknown parameters, and $e_i$ is a $(T \times 1)$ unobserved random error vector. Combining the $M$ price equations into the super price model yields

$$p_i = X_i \beta + e$$

(A8.5a)

or alternatively,

$$p = X \beta + e$$

(A8.5b)

where the dimensions of $p$, $X$, $\beta$, and $e$ are respectively, $(M \times T \times 1)$, $(M \times T \times K)$, $(K \times 1)$, and $(M \times T \times 1)$, with $K = \sum_{m=1}^{M} k_m$. Under the assumption of contemporaneous correlation and no autocorrelation, the variance covariance matrix for the random error vector of the super price model is defined as follows 1):

$$\Sigma = \begin{pmatrix} \Sigma_{11} & \cdots & \Sigma_{1M} \\ \vdots & \ddots & \vdots \\ \Sigma_{M1} & \cdots & \Sigma_{MM} \end{pmatrix}$$

where the symmetric matrix $\Sigma$ $(M \times M)$ contains the elements $E(e_t e_s) = \sigma_{ts}$ with $t = s$, and the matrix $I_T$ is the identity matrix of dimension $(T \times T)$.

Since the super price model has the same form as the simple linear price regression in section 4.3, its unknown parameter $\beta$ can be estimated with the GLS method under the assumption that the variance-covariance matrix $\Sigma$ is known. The applied GLS procedure gives the following estimator of $\beta$ for the super price model:

$$b_{GLS} = (X'X)^{-1}X'p$$

(A8.7)

with the variance-covariance matrix given by:

$$\Sigma_{b_{GLS}} = (X'X)^{-1}$$

(A8.8)

The GLS estimator of $\beta$ is defined with the Kronecker product when all $M$ price equations have the same number of observations ($T$).

In two special cases, the super price model can be estimated with the OLS method. The first case is when the $\Sigma$ is a diagonal matrix, hence $\sigma_{ij} = 0$ for all $i \neq j$. This implies that there does not exist correlation between the random errors of the $M$ price equations. The second case is when the explanatory variables are identical for all $M$ price equations, hence, $X_1 = X_2 = \cdots = X_M$.

1) The symbol $\otimes$ is the Kronecker product of matrices, see e.g. Judge et al. (1988, appendix A.15).
In practice, the variance-covariance matrix $\Sigma$ is often unknown, and therefore the EGLS procedure has to be used. The unknown variances and covariances can be obtained by estimating each price equation separately. The estimates can be used to estimate the least squares residuals of each price equation, and the variances and covariances are then defined as follows:

$$s^2_i = \frac{e_i'e_i}{T} \quad (A8.9)$$

An alternative estimation of $s_i$ is to use $T - K/M$ as divisor, where $K/M$ is the average number of explanatory variables per price equation, because the different $M$ price equations can have different numbers of explanatory variables. This divisor has the advantage of being constant for the super price model, and it leads to unbiased variance estimates when each price equation has the same number of explanatory variables 1).

If contemporaneous correlation does not exist, the OLS procedure for each separate price equation is fully efficient, and hence there is no need to use the SUR method. Therefore, it is useful to test if the assumption of contemporaneous correlation is valid. The Lagrange multiplier statistic is a useful test for doing this 2).

### 8.3 Two-stage least squares estimation

In practice, the economic price data are generated by a system of relations that are in general stochastic, and simultaneous. Therefore, it is useful to construct a statistical model that is consistent with the simultaneous-instantaneous feedback nature of the economic system. In general, these models have to contain behavioural, technical, institutional, definition, and equilibrium equations. The simultaneous linear statistical model can do this. A general simultaneous linear statistical model reflecting $M$ equations that represent the relationships among the jointly determined $M$ endogenous variables of $T$ observations, the $k$ exogenous and predetermined variables by the $(T\times 1)$ vectors, and the $M$ random error vectors $(T\times 1)$ is defined as follows:

$$
egin{align*}
Y &= X\beta + \varepsilon \\
X'\varepsilon &= 0
\end{align*}
$$

or alternatively,

$$
Y'\Gamma = X'B + E = 0 \quad (A8.10b)
$$

where the dimensions of $Y$, $X$, $B$, $\Gamma$, $E$, and 0 are respectively, $(T\times M)$, $(T\times k)$, $(k\times M)$, $(M\times M)$, $(T\times M)$, and $(T\times M)$. This system is called the structural form, and its unknown parameters, $\beta$ and $\gamma$, and equations are known as the structural parameters and equations.

Assuming that the structural errors have the same properties as the errors in the SUR model, then their properties can be defined as follows: $E(e_i) = 0$ for $i = 1, 2, ..., M$, or $E(e'e') = \Sigma + I$, with $e = (e_1', e_2', ..., e_M')$. And the unknown contemporaneous variance-covariance matrix $\Sigma$ is a $(M\times M)$ symmetric and positive semi-definite matrix. This matrix is semi-definite because some of the equations may appear in the form of identities, and hence, they do not contain error terms. Therefore, they will have the null vector of errors in the structural model.

Since the least squares procedures applied directly to a structural equation containing two or more endogenous variables will be inconsistent, its unknown parameters have to be estimated with another procedure. The procedures which will obtain consistent estimates are special instrumental variable methods.

The first stage of these estimation procedures is the same, namely to transform the structural model so that it is possible to express each endogenous variable as a linear function of all exoge-

1) See e.g. Judge et al. (1988, p. 452).
2) For the explanation of this test and other tests for contemporaneous correlation see e.g. Judge et al. (1988, pp. 456-9).
nous and predetermined variables in the model. Premultiplying the structural model with the inverse of structural parameter matrix $\Gamma$ gives the following reduced form 1):

$$ Y = X\pi + V $$  \hspace{1cm} (A8.11)

where $Y$ is a $(T \times M)$ matrix, $X$ is a $(T \times k)$ matrix, $\pi = \beta \Gamma^{-1}$ is a $(k \times M)$ matrix of reduced form unknown parameters, and $V = -\Delta \Gamma^{-1}$ is a $(T \times M)$ matrix of reduced form unknown random errors. The reduced unknown parameters of the reduced form can be estimated with the least squares procedure, and gives the following estimator of $\Pi$:

$$ \Pi_{stl} = (X'X)^{-1}X'Y $$  \hspace{1cm} (A8.12)

These estimates of the reduced form are used to predict the sample value of $Y$, $Y_{stl} = X'\Pi_{stl} = X'(X'X)^{-1}X'Y$. The second stage is to estimate the structural parameters. First, the structural model has to be written in the seemingly unrelated regression form. The rewritten structural model is defined as follows:

$$ y_i = y_{stl} + X'\delta_i + e_i = Z'e_i $$  \hspace{1cm} (A8.13)

After the substitution of the prediction $Y_{stl}$ for $Y_i$ in the matrix $Z$, the structural unknown parameter $\delta_i$ can be obtained to apply the OLS method to equation (A8.13). Estimates of all structural unknown parameters may be obtained by repeating this procedure for each structural equation. This estimation procedure is known as the two-stage least squares estimation (2SLS) method.

The 2SLS estimate of $\delta_i$ is consistent and exact the same as the indirect least squares estimation 2) if and only if the $i^{th}$ equation is identified 3). Another advantage of the 2SLS is that its estimate is still unique when the $i^{th}$ equation is overidentified.

### 8.4 Three-stage least squares estimation

Although the 2SLS estimation for each equation makes use of the information from the exogenous and predetermined variables in the super model, it ignores the information concerning the endogenous variables that do not appear in the $i^{th}$ equation. Besides, it ignores the possible available contemporaneous correlation. The three-stage least squares (3SLS) method incorporates this information in the estimation of the structural parameters. This method is a combination of the 2SLS and the SUR estimation, and hence, the variance-covariance matrix $\Sigma$ is important. Therefore, the first stage of the 3SLS procedure is to obtain the estimates of the elements of the unknown $\Sigma$. The estimates of these unknown elements can be computed with the standard method for the covariances 4):

$$ s_{ij} = \frac{(y_i - Z_i\delta_{stl})y_j - Z_i\delta_{stl})}{T} $$  \hspace{1cm} (A8.14)

where $\delta_{stl}$ is the 2SLS estimation of the structural parameters for the $i^{th}$ equation. Using the estimated variance-covariance matrix $\Sigma_{stls}$ all unknown structural parameters of the super model can be estimated simultaneity. The 3SLS estimator of $\delta$ is defined as follows 5):

---

1) Of course, $\Gamma$ has to be non-singular.
2) For explanation of this method see e.g. Judge et al. (1988, pp. 637-639).
3) An equation is (over-)identified, when $M + k - 1 - m > 0$, $M > 1$, where $M$ is number of endogenous variables, $k$ is number of exogenous variables, $m$ is number of variables in $Y$, and $k$ is number of variables in $X$. Judge et al. (1988, pp. 625-6) gives some useful practical rules to examine the model.
1. An equation that contains only an endogenous variable is just identified.
2. An equation that contains all variables in the system is not identified.
3. If none of the excluded variables of the $i^{th}$ equation appears in the $j^{th}$ equation, the $i^{th}$ equation is not identified.
4. If two equations contain the same set of variables, both equations are not identified.
5) For derivation of the estimator see e.g. Judge et al. (1988, pp. 646-8), or Johnston (1984, pp. 486-490).
\[ B_{3SLS} = \left( Z^T \left( \Sigma_{Y_i}^{-1} \otimes X_i X_i' \right)^{-1} Z \right)^T \left( \Sigma_{Y_i}^{-1} \otimes X_i X_i' \right) \left( Z^T \right)^T \]

where \( y = [y_1, y_2, \ldots, y_m]' \) is a \((M\times 1)\) vector, and \( Z \) is a \((M\times \sum_{i=1}^{M} (m_i - 1 + k_i))\) diagonal matrix with \( Z_i (= [Y_i, X_i]) \) on its diagonal. A statistical property of the 3SLS estimator is that it is asymptotic efficient. However, the 3SLS gains no efficiency over the 2SLS estimator if the variance-covariance matrix \( \Sigma \) is diagonal or all structural equations are just identified. In these cases the 3SLS estimator is the same as the 2SLS estimate, that is equal to the indirect least squares estimate. Finally, the 3SLS estimator is consistent if and only if the equations are identified.
Appendix 9  Autocorrelation and partial autocorrelation figures

ARIMA Procedure

Name of variable = Price Mushroom  
Period(s) of Differencing = 6  
Mean of working series = 0.717949  
Standard deviation = 33.05749  
Number of observations = 78

NOTE: The first 6 observations were eliminated by differencing.

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".*" marks two standard errors.
The autocorrelation figure is obtained by calculating the sample autocorrelation at lag k for lags k = 1, 2, 3, ..., 84. In this figure sample autocorrelation values are listed under the heading 'Correlation', besides the values are represented by spikes. A spike at lag k exists in the figure, if the sample autocorrelation at lag k is statistically large. This means that the spike is larger than the dotter line. The sample autocorrelations cut off after lag k if there are no spikes at lags greater than k in the figure. As Bowerman and O'Connell (1987) have been noted 'The sample autocorrelation of a model at lag k measures the linear relationship between time-series values (determined by the model) separated by a lag of k time units. If the sample partial autocorrelation value is close to 1 (-1) then the time-series values separated by a lag of k time units have a strong tendency to move together in a linear fashion with a positive (negative) slope'.

The partial autocorrelation may intuitively be thought of as the autocorrelation of time-series values separated by a lag of k time units with the effects of the intervening time-series values eliminated.

The autocorrelation function for the original mushroom price values has died down extremely slowly, besides the values did not seem to fluctuate around a constant, see figure 5.1. Consequently, it could be concluded that the original price values were non-stationary. Looking at the two figures generated by SAS, the original price data had to be transformed in \( p_t^* = p_t - \alpha e_t \). The transformed price data gave the above figures. It can be concluded that the transformed price values are stationary, since both figures have died down quite fast. After trying and estimating several models, the \( (1 - \Theta L(1))p_t^* = (1 - \lambda L(6))e_t \) model has generated the lowest standard error estimate.
SAS-procedures:

data champ;
input jr p;
cards;
  1  197
  2  235
  3  251
  4  231
  5  193
  .  
  .  
  79 196
  80 223
  81 240
  82 241
  83 228
  84 231
run;
proc ARIMA data = champ;
identify var = p(6);
estimate w = (1) q = (6);
forecast lead = 12;
run;

data champ;
input prijs trend x1 x2 x3 x4 x5 x6 x7 x8 x9 x10 x11;
cards;
  269 1 0 0 0 0 0 0 0 0 0 0 0 0 0
  273 2 1 0 0 0 0 0 0 0 0 0 0 0 0
  275 3 0 1 0 0 0 0 0 0 0 0 0 0 0
  281 4 0 0 1 0 0 0 0 0 0 0 0 0 0
  244 5 0 0 0 1 0 0 0 0 0 0 0 0 0
  278 6 0 0 0 0 1 0 0 0 0 0 0 0 0
  .  
  .  
  .  
  .  
  241 34 0 0 0 0 0 0 0 0 0 0 1 0 0
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  225 37 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  230 38 1 0 0 0 0 0 0 0 0 0 0 0 0 0
  .  39 0 1 0 0 0 0 0 0 0 0 0 0 0 0
  .  40 0 0 1 0 0 0 0 0 0 0 0 0 0 0
  .  41 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0
  .  42 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0
  .  43 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0
  .  44 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0
  .  45 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0
  .  46 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0
  .  47 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0
  .  48 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0
run;
proc reg data = champ;
model prijs = trend x1 x2 x3 x4 x5 x6 x7 x8 x9 x10 x11 / p cli clm;
run;
Appendix 10  Nominal prices of horticultural commodities which are used in chapter 3

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