INFORMATION TO USERS

This reproduction was made from a copy of a document sent to us for microfilming. While the most advanced technology has been used to photograph and reproduce this document, the quality of the reproduction is heavily dependent upon the quality of the material submitted.

The following explanation of techniques is provided to help clarify markings or notations which may appear on this reproduction.

1. The sign or "target" for pages apparently lacking from the document photographed is "Missing Page(s)". If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting through an image and duplicating adjacent pages to assure complete continuity.

2. When an image on the film is obliterated with a round black mark, it is an indication of either blurred copy because of movement during exposure, duplicate copy, or copyrighted materials that should not have been filmed. For blurred pages, a good image of the page can be found in the adjacent frame. If copyrighted materials were deleted, a target note will appear listing the pages in the adjacent frame.

3. When a map, drawing or chart, etc., is part of the material being photographed, a definite method of "sectioning" the material has been followed. It is customary to begin filming at the upper left hand corner of a large sheet and to continue from left to right in equal sections with small overlaps. If necessary, sectioning is continued again—beginning below the first row and continuing on until complete.

4. For illustrations that cannot be satisfactorily reproduced by xerographic means, photographic prints can be purchased at additional cost and inserted into your xerographic copy. These prints are available upon request from the Dissertations Customer Services Department.

5. Some pages in any document may have indistinct print. In all cases the best available copy has been filmed.
Salazar, Mario

A MULTICOMMODITY EQUILIBRIUM APPROACH TO WELFARE ANALYSIS OF MARKET INTERVENTIONS IN THE COSTA RICAN AGRICULTURAL SECTOR

Iowa State University

University Microfilms International

300 N. Zeeb Road, Ann Arbor, MI 48106

Ph.D. 1984
PLEASE NOTE:

In all cases this material has been filmed in the best possible way from the available copy. Problems encountered with this document have been identified here with a check mark ✓.

1. Glossy photographs or pages ✓
2. Colored illustrations, paper or print ✓
3. Photographs with dark background ✓
4. Illustrations are poor copy ✓
5. Pages with black marks, not original copy ✓
6. Print shows through as there is text on both sides of page ✓
7. Indistinct, broken or small print on several pages ✓
8. Print exceeds margin requirements ✓
9. Tightly bound copy with print lost in spine ✓
10. Computer printout pages with indistinct print ✓
11. Page(s) ✓ lacking when material received, and not available from school or author.
12. Page(s) ✓ seem to be missing in numbering only as text follows.
13. Two pages numbered ✓. Text follows.
14. Curling and wrinkled pages ✓
15. Other

University Microfilms International
A multicommodity equilibrium approach to welfare analysis of market interventions in the Costa Rican agricultural sector

by

Mario Salazar

A Dissertation Submitted to the Graduate Faculty in Partial Fulfillment of the Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Department: Economics
Major: Agricultural Economics

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

For the Major Department

Signature was redacted for privacy.

For the Graduate College

Iowa State University
Ames, Iowa
1984
# TABLE OF CONTENTS

## CHAPTER I. INTRODUCTION

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

## CHAPTER II. DEVELOPMENT STRATEGIES AND ITS RELATED POLICY VARIABLES

| Agricultural Sector: Its Importance in the Costa Rican Economy | 4 |
| Price Determination | 14 |
| Basic Grains | 15 |
| Sugarcane | 35 |
| Coffee | 52 |
| Beef Cattle | 64 |
| The Tax Framework | 77 |

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
</tr>
<tr>
<td>14</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>35</td>
</tr>
<tr>
<td>52</td>
</tr>
<tr>
<td>64</td>
</tr>
<tr>
<td>77</td>
</tr>
</tbody>
</table>

## CHAPTER III. A MULTICOMMODITY EQUILIBRIUM MODEL

| The Supply System | 88 |
| The Demand System | 104 |
| The Multicommodity Equilibrium System | 114 |

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>85</td>
</tr>
<tr>
<td>88</td>
</tr>
<tr>
<td>104</td>
</tr>
<tr>
<td>114</td>
</tr>
</tbody>
</table>

## CHAPTER IV. THE THEORETICAL FRAMEWORK FOR APPLIED WELFARE ANALYSIS

| The Consumer Surplus | 122 |
| The Producer's Surplus | 126 |
| Multicommodity Equilibrium and Welfare Measurements | 129 |
| The Welfare Analysis of the Producer Side | 130 |
| The Welfare Analysis on the Consumer Side | 144 |
| Welfare Measures of Single Policy Interventions | 155 |
| Price Control | 156 |
| Ad Valorem Tax and Quotas | 165 |

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>122</td>
</tr>
<tr>
<td>126</td>
</tr>
<tr>
<td>129</td>
</tr>
<tr>
<td>130</td>
</tr>
<tr>
<td>144</td>
</tr>
<tr>
<td>155</td>
</tr>
<tr>
<td>156</td>
</tr>
<tr>
<td>165</td>
</tr>
</tbody>
</table>

## CHAPTER V. THE ESTIMATION PROCEDURE

| The Demand System | 177 |
| The Supply System | 188 |

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>177</td>
</tr>
<tr>
<td>188</td>
</tr>
</tbody>
</table>

## CHAPTER VI. STATISTICAL RESULTS

| The Demand System | 197 |
| The Supply System | 206 |
| The Multicommodity Model | 210 |
| The Partial Equilibrium Results | 213 |

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>197</td>
</tr>
<tr>
<td>206</td>
</tr>
<tr>
<td>210</td>
</tr>
<tr>
<td>213</td>
</tr>
</tbody>
</table>

## CHAPTER VII. WELFARE MEASURES OF COSTA RICA MARKET INTERVENTIONS

| Basic Grains | 224 |
| Sugarcane | 233 |
| Coffee | 237 |
| Beef | 239 |

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>220</td>
</tr>
<tr>
<td>224</td>
</tr>
<tr>
<td>233</td>
</tr>
<tr>
<td>237</td>
</tr>
<tr>
<td>239</td>
</tr>
<tr>
<td>Chapter/Section</td>
</tr>
<tr>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>CHAPTER VIII. SUMMARY AND CONCLUSIONS</td>
</tr>
<tr>
<td>LITERATURE CITED</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
</tr>
<tr>
<td>APPENDIX</td>
</tr>
</tbody>
</table>
In most less developed countries, the agricultural sector's economic situation compared to other sectors of the economy, particularly the industrial sector, has been unfavorable. Its relative situation has been lowered in those countries as a result of a variety of government interventions. Some of these interventions are the instruments for applying a specific theory of development. Other interventions stem from a series of concerns and considerations, such as the simplicity of raising revenues from export taxes on agricultural products; the necessity to placate interest groups, particularly politically powerful urban ones which induces the government to keep the price of food and other agricultural products low; the economic-social importance of assuring a stable supply of agricultural products; the argument that the infant industry has to be protected strongly; and the lack of consideration on the part of policymakers on the long-run effects of policy interventions.

In simple terms, the development theory that has promoted the market intervention is the belief that productivity and its rate of growth are much higher in the industrial sector than in agriculture. Therefore, the development of the former sector would give more benefits to society, and, by doing so, resources like agricultural surplus and foreign exchange are used to finance the growth of the industrial sector. Two assumptions implicit in the theory are of importance: the assumption that the agricultural supply is price inelastic, that is, the farmers do
not respond to changes in output prices, which constitutes the perfect environment for taxing the agricultural output without altering the amount supplied. Second, the substitution of the market mechanism for the government bureaucrats in solving quantity and price determination.

This theory, together with the concerns and considerations previously expressed, has really spread market interventions such as price controls, quantity controls, taxes, and subsidies, which, with the passage of time, tend to increase, maybe by the failure of the partial interventions to achieve the desired goals. However, there is hope. In recent years, a rethinking of these policies appears to have occurred, not a complete liberalization of the market price as a resource allocation device, but at least as a guide to the policy decision-makers.

It is curious that so little attention has been paid to, or research undertaken, into the effects of agricultural price control, taxes, subsidies on the patterns of production, consumption, income distribution, and development in general, especially when the agricultural sector's relations with the social, economic and political structures are so interrelated. Little or no attempt has been made by the Costa Rican government to monitor and evaluate the effects of government intervention. At the very heart of this issue are the economic questions: Who gains and who loses from government involvement in the agricultural sector? What is the net benefit to society of that intervention? What are the appropriate measures of economic gains and losses?

The major purpose of the study is to estimate the welfare effects of agricultural market intervention applied by the Costa Rican government.
However, some subsidiary objectives can be more specifically stated.
The following objectives will unify the study and serve as a basis for organizing the contents.

A) To provide a historical overview of the country's major development strategies and its effects on the development of the agricultural sector. Focusing primarily on the use of market prices and quantities as the major policy variables, it also will review the tax legislation relevant to the agricultural sector.

B) To develop a simple and normative model which permits us to estimate a system of demand and supply equations. For each side of the market, a theoretical model will be developed from which tractable and applicable results implied by the theory will be obtained. A general equilibrium model based on those results will be generated.

C) To develop the theoretical backgrounds required for welfare analysis. Focus will be placed on the economic meaning of the areas enclosed between the general equilibrium demand and supply curves. Welfare measures of single policy interventions will be developed under this framework.
CHAPTER II.
DEVELOPMENT STRATEGIES AND
ITS RELATED POLICY VARIABLES

This chapter presents the relevant characteristics and trends shown by the Costa Rican agricultural sector in the period 1960-1980. Mainly the evolution of factors such as the agricultural output, prices, development policies, and government market interventions are reviewed.

Agricultural Sector:
Its Importance in the Costa Rican Economy

The agricultural sector was the most important sector in the evolution of the country's economic development during 1960-1980, although the industrial sector increased its share of the domestic national product (DNP) by the end of the period. About 56 percent of the population is located in the rural areas and approximately 60 percent of them depend directly on the income earned in agricultural activities (AID, 71). This situation indicates that whatever happens in agriculture has relevance to a very large segment of the country population.

The composition of the domestic national product is presented in Table 2.1 for the key years of 1960, 1970, and 1980. The relative participation of the agricultural sector on the DNP has changed significantly since 1960, this sector held a relative share of 30.5 percent, which put it in first place as the most important sector on the productive structure of the country. Agriculture's relevance has decreased since then. In 1970, its share fell to 22.5 percent, a trend
Table 2.1. Structure of the Domestic National Product in percentage terms and rate of growth for 1971-80\(^a\)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture and Livestock</td>
<td>30.5</td>
<td>22.5</td>
<td>17.4</td>
<td>2.6</td>
</tr>
<tr>
<td>Manufacture Industries</td>
<td>13.1</td>
<td>18.3</td>
<td>19.6</td>
<td>7.6</td>
</tr>
<tr>
<td>Utilities</td>
<td>.96</td>
<td>1.7</td>
<td>1.8</td>
<td>7.8</td>
</tr>
<tr>
<td>Construction</td>
<td>4.5</td>
<td>4.3</td>
<td>6.4</td>
<td>10.5</td>
</tr>
<tr>
<td>Commerce</td>
<td>21.4</td>
<td>21</td>
<td>20</td>
<td>4.8</td>
</tr>
<tr>
<td>Transportation and Communications</td>
<td>3.7</td>
<td>4.2</td>
<td>4.3</td>
<td>10.6</td>
</tr>
<tr>
<td>Financial and Insurance Services</td>
<td>3.5</td>
<td>4.6</td>
<td>4.8</td>
<td>9</td>
</tr>
<tr>
<td>Real Estate</td>
<td>9.9</td>
<td>7.6</td>
<td>5.9</td>
<td>4.1</td>
</tr>
<tr>
<td>General Government</td>
<td>7.6</td>
<td>10.6</td>
<td>15.2</td>
<td>5.8</td>
</tr>
<tr>
<td>Other Personal Services</td>
<td>5</td>
<td>5.2</td>
<td>4.6</td>
<td>4.6</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>5.7</td>
</tr>
</tbody>
</table>

\(^a\)Source: BCCE (4, 7).
that continued during the 1970s. In 1980, its share was just 17.4 percent of the DNP, and first place was surrendered to the commerce and industrial sector. The industrial sector has shown a rising trend during the same period. The industrial sector's relative participation increased from 13 percent in 1960 to 20 percent in 1980. Looking at the annual average rate of growth (in constant monetary units) for the period 1971-80, the primary sector presented the lowest rate of 2.6 percent, at the same time the industrial sector showed a 7.6 percent rate of growth. The highest rates belong to the construction and transport sectors with 10.5 percent and 10.6 percent, respectively. The domestic national product increased at a 6 percent rate during the same 10 years.

The structure of the agricultural sector in percentage terms is presented in Table 2.2. In 1960, the participation of coffee, bananas, and beef cattle on the total agricultural value\(^1\) is about 58 percent, which also corresponds to 83 percent of the total exports of the country (Table 2.3). This high degree of specialization on the productive structure of the country makes its economic development highly dependent on the international market.

During this 20-year period, the agricultural sector's annual rate of growth has been 4 percent, which is lower than the 6 percent rate of growth for the DNP. This characteristic reflects the economic development policy. First the policy was aimed at promoting the production of agricultural exports at high international prices. The policies became

\(^1\) Evaluated at constant colones (base 1966).
Table 2.2. Structure of the agricultural sector in percentage terms and rates of growth

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60-70</td>
</tr>
<tr>
<td>Coffee</td>
<td>28.3</td>
<td>22.9</td>
<td>23.8</td>
<td>4.3</td>
</tr>
<tr>
<td>Bananas</td>
<td>15.7</td>
<td>27.3</td>
<td>23.5</td>
<td>14.3</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>4</td>
<td>5.6</td>
<td>5.1</td>
<td>8.6</td>
</tr>
<tr>
<td>Cocoa</td>
<td>3.4</td>
<td>.6</td>
<td>.6</td>
<td>-4.5</td>
</tr>
<tr>
<td>Rice</td>
<td>6</td>
<td>4</td>
<td>8</td>
<td>5.4</td>
</tr>
<tr>
<td>Corn</td>
<td>2.2</td>
<td>1.8</td>
<td>1.4</td>
<td>4</td>
</tr>
<tr>
<td>Beans</td>
<td>1.9</td>
<td>.7</td>
<td>.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Others</td>
<td>9.4</td>
<td>7.9</td>
<td>8.9</td>
<td>4.7</td>
</tr>
<tr>
<td>Beef</td>
<td>13.6</td>
<td>13</td>
<td>9.7</td>
<td>5.4</td>
</tr>
<tr>
<td>Milk</td>
<td>10</td>
<td>10.3</td>
<td>12.3</td>
<td>6.4</td>
</tr>
<tr>
<td>Pork</td>
<td>2</td>
<td>1.1</td>
<td>2.3</td>
<td>4.5</td>
</tr>
<tr>
<td>Lumber</td>
<td>4</td>
<td>4.7</td>
<td>3.9</td>
<td>6.2</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>6.4</td>
</tr>
</tbody>
</table>

^Source: BCCR (5, 6).
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Coffee</td>
<td>53.86</td>
<td>31.32</td>
<td>24.21</td>
</tr>
<tr>
<td>Bananas</td>
<td>24.03</td>
<td>28.88</td>
<td>19.77</td>
</tr>
<tr>
<td>Cocoa</td>
<td>6.94</td>
<td>.83</td>
<td>1.10</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>2.15</td>
<td>4.39</td>
<td>3.99</td>
</tr>
<tr>
<td>Livestock Beef</td>
<td>5.07</td>
<td>7.78</td>
<td>6.22</td>
</tr>
<tr>
<td>Industrial</td>
<td>4.1</td>
<td>25</td>
<td>34.7</td>
</tr>
<tr>
<td>Other</td>
<td>3.9</td>
<td>1.8</td>
<td>10</td>
</tr>
</tbody>
</table>

Source: BCCR (5, 6).

more industrial oriented during the early 1960s. This variation in the development policy is also reflected in the different rates of growth shown by the agricultural sector, 6.4 percent for the decade 1960-70 and 2.7 percent for the rest of the period (Table 2.2). About this rapid deterioration of the agricultural production, particularly since 1972, Lizano (49) has pointed out that there are two main causes; the decrease in the absolute as well as in the relative profitability of agricultural activities. No conclusive data exist in absolute terms but it is reasonable to expect that this factor has played an important role (Salas, 62). The relative profitability indicates the economic situation between economic sectors, particularly between the agricultural and industrial sectors. An important trend has been the decrease in the rate
of investment in agriculture which has fallen by 50 percent between 1968-1977 (Lizano, 49). This trend would indicate that the entrepreneurs have found it more convenient, due to the more profitability and lower risk, to invest in the other sectors, which have been growing at a faster rate.

As is the case in most of the developing countries, the agricultural sector is the primary source of foreign exchange. Total agricultural exports constituted 95.9 percent of the total exports of Costa Rica in 1960 (Table 2.3) when coffee and bananas reported a share of 78 percent. By 1980, the export share of the agricultural sector had fallen to 55 percent and at the same time the exports from the industrial sector had increased from 4 percent to 35 percent. Coffee and bananas remain the predominant export products. These figures reflect the still important place of agriculture as well as the increasing role of the industrial sector in the Costa Rican economy.

As previously stated, the economic development of the different sectors was not a balanced process in which all the productive activities grew at a similar rate, but rather the development programs have significantly changed priorities during these 20 years. There have been two distinctive periods. The first one, where the industrialization objective had priority, covers most of the 1960s and mid-1970s. The second period includes the current period when a more balanced development is the major objective.

The high priority that the agricultural sector enjoyed in the late 1950s was no longer granted. Industrialization came to the forefront
particularly with the introduction of Costa Rica into the Central American Common Market (CCM) in 1962. This event considerably influenced the industrial development because it opened the Central American markets to the manufactured products and made attracted investment in industry because of the heavily protective policies.

The CCM did not present direct and relevant changes for the agricultural sector because it did not include the free trade of agricultural products, except during the period 1966-1968 when the Costa Rican government was forced to reduce basic grain support prices to be more in accordance with other CCM countries. After that, the regional trade of basic grain has been loaded with protectionist barriers that have eliminated any possibility of free trade between the countries. The country's participation in the CCM did have an indirect effect on the performance of the agricultural sector as a whole. That effect stems from the given relevance to the industrial development, which changed in an unfavorable way the relative importance of the primary sector. Even though this situation does not reduce significantly the support to the export activities such as coffee, bananas and beef cattle because they still constituted the primary source of foreign exchange. The same cannot be said with respect to those activities directly related with the domestic consumption, which was reduced significantly. The relevant elements of the development strategy proposed by the government programs in the period 1962-1975 for the agricultural sector, are the diversification of export products to reduce the dependency on coffee and bananas exports, the self-sufficiency in some agricultural products to release
the balance of payment problems, and the promotion of the production of raw materials required by the industry (fiber, vegetable oil, tobacco). That strategy did not give the results expected. The diversification of exports did not show any significant changes in 1972 the value of exports from coffee and bananas represented 80 percent of the total value of exports from the sector. The self-sufficiency targets were not accomplished because grain imports have increased since 1965. The production of raw materials also did not show a significant improvement; in fact, the wool production suffered a sharp decrease (Salas, 62).

Despite some variation in the annual production rate of the agricultural sector, the average rate of growth was a satisfactory 6 percent (Table 2.2). Export activities, however moved in opposite directions with respect to those directed to domestic consumption. The amount of exports did not increase in the years 1962-1965 basically because of the sharp decrease in coffee production, but at the same time the production of commodities for the domestic market increased at an annual rate of 5.5 percent. From 1965 to 1972, the quantity of exports increased at a rate of 12 percent primarily because of the expansion of the banana plantations. The production directed to the domestic market only increased at a rate of 2 percent annually, which is lower than the population rate of growth, forcing increased amounts of imports to satisfy the domestic demand. The agricultural policy variables relevant to this period were the subsidized credit and to some extent price supports. Even though the share of the agricultural credit, as a percentage of the total credit given by the National Bank System, declined from 60 percent at the
beginning of the period to a 40 percent in 1972. The credit policy was oriented mainly toward the export crops with beef cattle and banana activities benefitting the most, a departure from the traditional leader of coffee production. By the end of this period, there was a significant improvement in the amount of credit available to small farmers mainly because of the existence of very favorable foreign credit.

The price support policies were not utilized significantly during 1960-1972, because for the most part the support price for basic grains held constant except for corn and beans, whose support levels were increased in the early 1970s when the production deficit was notorious. The efforts for a liberalization of the basic grain trade between the members of the CCM also affected the support level during a short period of time as previously explained.

The decrease in the value of traditional agricultural exports, as well as the notorious decrease on the dynamic of the CCM which has reduced significantly the rate of growth of the industrial sector, has enhanced the necessity to restate the development strategy. Thus, in the past few years it has been necessary again to promote a strong diversification of agricultural exports, to redirect the industrial sector toward more agriculture oriented (Agro-Industry), and to increase the efforts on the production for the domestic markets. The credit system of maximum quantity for activity (topes) was applied, even though the share of the agricultural sector decreased from 41 percent to 37 percent (1972-1978) of the total credit. Also, the percentage of credit directed to the small farmers recorded a sharp decrease in the same period, from 21
percent to 13 percent. Finally, in 1978 the credit policy was significantly changed. Traditionally, the interest rate for agricultural activities has been subsidized but in that year that policy was reviewed and instead an interest rate was implemented based on the international money markets, which, of course, produced a significant decrease in the production of most agricultural commodities in the subsequent years.

The difficulties caused by the deficits in basic grains hastened the use of price supports as a mechanism to increase domestic production. The level of support was double for rice and corn and triple for beans from 1973 to 1980. This new support price increased the production of those grains, particularly rice which has been exported.

The inflation rate increased in the last half of the 1970s making more urgent the control of the maximum retail price of a series of essential food commodities (rice, beans, corn, popular cuts of beef, eggs, sugar, etc.). These price ceiling measurements have been applied since the early 1950s but not strictly enforced. Some institutions were created with the idea of reducing the marketing costs basically by reducing the number of intermediaries, a series of farmers' fairs were established at different market locations.

In the agri-industrial subsector, the production and participation of the private sector has been promoted through credit lines. The export of products of this subsector as well as the exports of nontraditional raw agricultural products has been supported by the mechanisms established in the Export Promotion Law of 1972.
Another type of policy has been the establishment of agricultural industries by the central government, especially in those cases where the initial costs are high enough to discourage private initiative.

Price Determination

This section will deal with the different characteristics that determine the relations between buyers and sellers in each of the commodity markets relevant in this study. We will analyze the institutional and legal arrangements that promote or interfere with the consumer's preferences and the producers comparative advantages as they are reflected in a free market. We will focus our attention on the historical pattern, particularly the last decade, of producer and consumer prices and the government policies which have in some way or another determined that historical pattern. Lastly, we will also examine the major events occurring at the international markets and their effect on the domestic markets.

Five agricultural commodities have been chosen in this study, they are rice, corn, sugar, coffee, and beef. Two (rice and corn) are produced mainly for domestic consumption and the rest are primarily export crops. These five agricultural products well-represent Costa Rican agricultural sector. The basic grains have been of major concern for the central government because they constitute the major source of foodstuffs for low-income families. The three agricultural export crops included in this analysis also are a good representation of the export
subsector. Those three products jointly with the banana exports will represent almost all of the Costa Rica agricultural exports.

Basic Grains

The institutions with greater influence on the price policy of agricultural products are the Ministry of Economics, Industry, and Commerce (MEIC) and the Consejo Nacional de Produccion (CNP). The role of the MEIC on the price policies is based on its Organic Law No. 6054 of June 14, 1977 and also the Consumer Protection Law No. 5665 of February 28, 1975, which states in its article No. 1 that it is attribution of the MEIC to set the official prices for those goods and services necessary for the domestic production and consumption. This institution will have the faculty to a) set, modify, and control the maximum retail prices of the goods and services and b) set, modify, and control the marketing margins of the goods and services.

The CNP's Organic Law No. 2035 of May 1965 authorizes intervention in the marketing of all commodities important in the average diet and all those raw materials used as inputs for domestic industries. The objectives of this law are the price stabilization of a group of commodities included in the law as well as to promote the production of them. The latter indicates that the CNP is responsible for setting the level of price support not just for the basic grains as it has been traditionally but also for those commodities needing production increases.
The principal objectives of the government policies in the last decade has been almost the same, in general terms they have been oriented to a) obtain the price stabilization at the producer and consumer level, b) foster the agricultural production, and c) increase the farmers income.

These objectives have been guiding the government policies primarily with respect to those commodities of importance in the national diet as the basic grains are. For the rest of the commodities, the major objective of the government policies have been to set and monitor the marketing margins.

Grain is marketed through both private and government channels. The government buys grains at the support price established before planting and sells grain back into the market through wholesalers, retailers, and its own retail outlets. Domestic producers sell to private merchants when farm prices are above support price levels but deliver quantities of grain to the government when the free-market prices fall below support levels. When domestic production falls short or is in excess, the government can import or export grains to maintain domestic prices. Most of the government efforts have been devoted to the direct intervention in the grain market. Regulatory and service functions such as grain inspection and grading, research, and education, market news are less developed or nonexistent (BID, 9).

At the consumer level, the price of rice and corn has been fixed by law during the whole period covered. Even though it is important to note that the price set by the MEIC has been traditionally subsidized by
the government, particularly by not charging the storage cost with the objective of not increasing the cost of the basic food basket. Another important point is that the fixed maximum price correspond to a grain grade which is difficult to find at the private retail market. For example, the fixed retail price for rice corresponds to a quality of rice with 25 percent of grain broken, quality which is only found at the CNP outlets. The private market mainly offers a better quality whose price is not controlled. This situation is similar for corn (SEPSA, 66).

The variability of the basic grain prices can be seen in Table 2.4, which presents the different groups of commodities and their annual change in the consumer price index. The basic grain group is the one that presents the greater activity through the whole period, also the index of growth shown by this group was higher throughout the period than the index of growth of the consumer price index.

The rice and corn price trends for the period 1960-1980 are shown in Figure 2.1. We have to mention that the price series used is the one gathered by the "Oficina de Estadística y Censo," data used in the estimation of the CPI and correspond to the nominal price paid by the consumers in the metropolitan area. Thus, they can be considered as the uncontrolled prices. From the same Figure 2.1, we see that the consumer price for both products was fairly stable during the decade of the 1960s, when a good supply reinforced by government imports helped to maintain normal increases in the price. In the early 1970s the country suffered a shortage of basic grain and its dependency on imports increased. Under this situation, the central government implemented the National Program
Table 2.4. Index of growth of the consumer price index and the agricultural prices at consumer level 1973-80

<table>
<thead>
<tr>
<th>ANO</th>
<th>CPI 1964=100</th>
<th>CPI 1973=100</th>
<th>Basic grain</th>
<th>Export crop</th>
<th>Livestock</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973</td>
<td>139.9</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>1974</td>
<td>182.0</td>
<td>130</td>
<td>153</td>
<td>120</td>
<td>118</td>
</tr>
<tr>
<td>1975</td>
<td>213.6</td>
<td>153</td>
<td>183</td>
<td>122</td>
<td>132</td>
</tr>
<tr>
<td>1976</td>
<td>221.0</td>
<td>158</td>
<td>189</td>
<td>142</td>
<td>136</td>
</tr>
<tr>
<td>1977</td>
<td>230.3</td>
<td>165</td>
<td>188</td>
<td>157</td>
<td>141</td>
</tr>
<tr>
<td>1978</td>
<td>244.1</td>
<td>174</td>
<td>204</td>
<td>174</td>
<td>149</td>
</tr>
<tr>
<td>1979</td>
<td>272.4</td>
<td>195</td>
<td>222</td>
<td>198</td>
<td>205</td>
</tr>
<tr>
<td>1980</td>
<td>314.8</td>
<td>225</td>
<td>267</td>
<td>245</td>
<td>219</td>
</tr>
</tbody>
</table>

*aSource: SEPSA (66).*

of Basic Grain with the major objective of increasing the domestic production of this group of staple products with the goal of becoming self-sufficient. The principal policy instrument utilized was a substantial increase in the price support level, which also was reflected at the consumer level, when the price of rice paid by the consumers increased by 43 percent and 25 percent for corn relative to the 1974 level. The basic grain program was satisfactory considering that the country attained self-sufficiency in rice and decreased substantially its imports of corn (see Table 2.7). Because of this success, the central government decided to reduce the price support level for rice in 1976, a
Figure 2.1. Historical consumer price trends for rice and corn 1960-80, DGEC (28)

RCP = Rice consumer price
CCP = Corn consumer price
change that resulted in a consumer price of 9.3 percent. During 1976-1979, the price of rice was stable showing a moderate average increase of 4 percent. By the end of 1979, the effects of a new policy of liberalization of prices is reflected at the consumer level by the drastic increase of about 50 percent. This increase may reflect a speculative purpose as well as adjustment to the international market price because rice is the only grain that has been exported since 1976. The response of corn to the National Basic Grain Program has not been that successful because the level of production has not been sustained. After a dramatic increase in the quantity produced (118 percent) in the crop year 1975-1976, the same level has been decreasing then after with the largest drop of 13 percent during the crop year 1977-1978. This variability in supply was also reflected by the consumer price, thus the decrease in price in 1976 of about 21 percent can be explained by the excess of supply, particularly in yellow corn. By the next year (1977), however, the retail price suddenly increased 34.4 percent reflecting the fall in supply. Since then the price of corn at the retail level has been increasing at the moderate rate of 8.7 percent.

The price control at the producer level has been through price support policies, which assure the producer a minimum price for the product. This price support level varies for different qualities of grain at the farm gate and these differences are also reflected at the wholesale and retail level. The price support levels are adjusted for quality and for the cost of transporting the product to San Jose (the
capital). To assure reliability on the policy, the CNP does not reduce the support level during the crop year.

The historical levels of domestic price support, producer price and the international price for rice and corn are presented in Figures 2.2 and 2.3.

The average producer prices are always below the support prices, because of the quality and transport cost adjustments. The simple correlation between the support price and the producer price is .96 for corn and .92 for rice. The average ratio of producer price to support price is .80 for corn and .81 for rice.

Another general characteristic of both products, has been that the price support level has been established historically higher than the international price with minor exceptions for rice, particularly for the years 1973 and 1974. The price support level for corn during 1960-1971 was on average U.S. $3.74 per hundredweight and for rice the average was U.S. $9.64 per hundredweight. During the same period, the average international price was $2.53 and $7.12, respectively.

Because of the shortage of supply in both rice and corn and with the implementation of the National Basic Grain Program, the support level for corn was increased to $8.93/cwt (1974-1977), which represented an increase of 139 percent compared to the average level of the 1960s. For rice, the situation similar, the support level for 1975 was $16.27/cwt meaning an increase of 69 percent compared to the average support level during the previous decade. Due to the success obtained under this policy, the rice support level was reduced to an average of $15.13/cwt.
Figure 2.2. Historical trends of the domestic support and world price\textsuperscript{a}
of corn 1960-80, BCCR (3), FAO (29)

CPP = Corn average producer price  
CSP = Corn support price  
CWP = Corn world price

\textsuperscript{a}Number 2 yellow corn, FOB, Gulf.
Figure 2.3. World price\textsuperscript{a}, support price, and producer price of rice\textsuperscript{b}, historical trend 1960-80, BCCR (3), FAO (29)

\begin{align*}
\text{RPP} &= \text{Rice average producer rice} \\
\text{RSP} &= \text{Rice support price} \\
\text{RWP} &= \text{Rice world price}
\end{align*}

\textsuperscript{a}White 5 percent broken, FOB, Bangkok.

\textsuperscript{b}Paddy rice.
for the short period 1976-1978, while the corn support level remains the same. Both commodity support levels started to show a claiming tendency from 1979 reflecting the decline in corn production since 1976, the higher cost of production (inflation), and the government policy to encourage the production of basic grain, especially corn, beans, and sorghum. Thus, the rate of increase of the support levels for those two years (1979-1980) has been 31.5 percent for corn and 30 percent for rice.

As mentioned previously, the CNP had the two basic objectives of stabilizing prices and stimulating production. Both objectives are stated quite broadly, a situation which has made program implementation difficult. The CNP has shown traditionally a preference for increasing production, as it is reflected by the higher support level than the international market. This emphasis on production has become stronger over the last decade. National self-sufficiency is the primary objective of the basic grain program implemented in 1975. As pointed out by Lizano (49), the central government in pursuing this type of policy has forgotten the comparative advantages of the country especially because Costa Rica is an active member of the CCM where the production of basic grain in the rest of the Central American countries appears to be more productive.

A related and important point is the way that the support price is established. The principle that it should be possible to calculate the cost of producing a commodity and ensure producers that their costs will be covered by minimum price has served as a base for price support
levels. However, systematic information about the cost of production on different areas of the country, on different size farms, and with different levels of technology is not available. Without this information, it is difficult to determine if a price support level will encourage inefficient farmers or if the small or larger farmers are the most benefited. A good price support for stabilization purposes should be set along the free market trend so there is no discouraging the interest of buyers and suppliers.

The CNP should be a marginal buyer. If farmers can get a better price, they will sell elsewhere. Government purchases are made through a network of purchasing agencies located in different producing areas and nearby cities where farmers come to sell their products. Buying stations are generally located in the Pacific coast area, where the majority of grains, rice in particular, is produced. The CNP purchase program probably has a limited impact on small farmers, because the CNP purchases mostly rice. The grain is produced primarily by larger farmers, and the CNP has located the majority of its buying agencies in those regions.

Table 2.5 presents the quantity of rice and corn purchased by the CNP and how much those purchases mean in terms of total production.

The quantity purchased by the CNP of rice varies but is far from being a marginal buyer. In the last half of the 1960s, the quantity of rice bought ranges from 18 to 48 percent with an average of 34 percent, decreasing to an average of 29 percent in the early 1970s. With the implementation of the basic grain policy and its high support levels, the participation of the CNP or the quantity marketed increased dramatically.
Table 2.5. CNP’s purchase of rice and corn in metric tons 1965-80\(^a\)

<table>
<thead>
<tr>
<th>Year</th>
<th>Rice(^b)</th>
<th>%</th>
<th>Corn</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965/66</td>
<td>10,376</td>
<td>34.5</td>
<td>3,946</td>
<td>6.3</td>
</tr>
<tr>
<td>1966/67</td>
<td>7,809</td>
<td>25.3</td>
<td>2,964</td>
<td>4.4</td>
</tr>
<tr>
<td>1967/68</td>
<td>19,007</td>
<td>48</td>
<td>1,525</td>
<td>2.1</td>
</tr>
<tr>
<td>1968/69</td>
<td>30,632</td>
<td>45.6</td>
<td>1,901</td>
<td>3.1</td>
</tr>
<tr>
<td>1969/70</td>
<td>11,699</td>
<td>18.4</td>
<td>803</td>
<td>1.3</td>
</tr>
<tr>
<td>1970/71</td>
<td>8,500</td>
<td>11.9</td>
<td>1,520</td>
<td>2.47</td>
</tr>
<tr>
<td>1971/72</td>
<td>38,614</td>
<td>41.6</td>
<td>2,562</td>
<td>4.0</td>
</tr>
<tr>
<td>1972/73</td>
<td>20,277</td>
<td>20.8</td>
<td>1,834</td>
<td>2.8</td>
</tr>
<tr>
<td>1973/74</td>
<td>32,653</td>
<td>27.9</td>
<td>1,279</td>
<td>1.5</td>
</tr>
<tr>
<td>1974/75</td>
<td>17,624</td>
<td>13.9</td>
<td>8,206</td>
<td>19.5</td>
</tr>
<tr>
<td>1975/76</td>
<td>97,740</td>
<td>50</td>
<td>14,024</td>
<td>15.3</td>
</tr>
<tr>
<td>1976/77</td>
<td>139,791</td>
<td>93</td>
<td>27,340</td>
<td>30.8</td>
</tr>
<tr>
<td>1979/80</td>
<td>22,357</td>
<td>9.5</td>
<td>13,446</td>
<td>19.0</td>
</tr>
</tbody>
</table>

\(^a\)Source: CNP (20, 21, 22, 23).

\(^b\)Paddy rice.
to nearly the entire domestic productions (93 percent) in the crop year 1976-1977. Since then, the purchase quantity has been decreasing. The CNP's participation in the corn market as a buyer can be considered a marginal one, particularly in the 1960s and early 1970s with an average of 3.1 percent of the total domestic production. This trend has changed since 1974 when the average quantity purchased constituted 21 percent of total production reaching its maximum in 1976 with 30 percent. This change can also be attributed to the high support levels induced by the grain program.

A major problem with high support price for corn is their effect on the poultry industry. According to the information from the Food Balance Sheet the proportion of yellow corn relative to total domestic production of corn has increased since 1976 (Table 2.6). Before that year, the average was 16.7 percent and the country relied heavily on imports to satisfy the domestic demand of yellow corn. After 1976, the proportion of yellow corn domestically produced increased to an average of 42.6 percent with a maximum of 63 percent for the year 1978.

Government regulation of grain imports is another crucial component of the Costa Rican price support system. The CNP makes or authorizes all imports from outside Central America, which require approval by the MEIC. In fact, the CNP maintains its influence over intrazonal trade, closing the borders to rice imports from other Central American countries. Grain imports have been used as buffer stocks to influence wholesale and retail prices. The ability of the CNP to stabilize grain prices has probably depended more on its power to regulate grain imports than to buy and sell
Table 2.6. Production and imports trend for yellow corn and their relevant prices 1971-80

<table>
<thead>
<tr>
<th>Year</th>
<th>Percent yellow corn</th>
<th>Percent imports</th>
<th>Price support $/cwt</th>
<th>World price $/cwt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>23.7</td>
<td>202.5</td>
<td>4.41</td>
<td>2.4</td>
</tr>
<tr>
<td>1972</td>
<td>15.5</td>
<td>179.2</td>
<td>4.41</td>
<td>7.89</td>
</tr>
<tr>
<td>1973</td>
<td>15.8</td>
<td>467.5</td>
<td>4.70</td>
<td>5.58</td>
</tr>
<tr>
<td>1974</td>
<td>11.6</td>
<td>495</td>
<td>4.52</td>
<td>5.81</td>
</tr>
<tr>
<td>1975</td>
<td>17</td>
<td>124</td>
<td>6.55</td>
<td>5.22</td>
</tr>
<tr>
<td>1976</td>
<td>31</td>
<td>14</td>
<td>8.93</td>
<td>5.13</td>
</tr>
<tr>
<td>1977</td>
<td>52.8</td>
<td>0</td>
<td>8.93</td>
<td>4.31</td>
</tr>
<tr>
<td>1978</td>
<td>63</td>
<td>0</td>
<td>8.93</td>
<td>4.59</td>
</tr>
<tr>
<td>1979</td>
<td>33</td>
<td>0</td>
<td>9.76</td>
<td>5.22</td>
</tr>
<tr>
<td>1980</td>
<td>33</td>
<td>268</td>
<td>11.7</td>
<td>5.72</td>
</tr>
</tbody>
</table>

aSource: CP (15).

bThe proportion of domestic produced yellow corn on the total quantity of produced corn.

cThe proportion of imports of yellow corn to the quantity produced domestically.
domestic grain. Table 2.7 shows that Costa Rica was a net importer of both rice and corn in the 1960s and early 1970s. The imported quantity of rice has declined significantly since 1972 and the country became a rice exporter with the basic grain program. For corn, Costa Rica always has depended on imports to satisfy its internal demand, especially of yellow corn. With the basic grain program, the percentage of imports have shown a significant drop from 67 percent in 1973 to 3.7 percent in 1977. This situation changed in 1980 when it was necessary to import 73 percent of the total domestic production.

The description of the basic grain market interventions above indicate that the key government policy has been the support price. By putting this policy in an analytical framework and recognizing the different results obtained for corn and rice, particularly in the last half of the seventies, we would be able to have a better understanding of the effects of such a policy. For corn, the tradition has been to set the support level higher than the world price even though the country needs to resort to imports to satisfy its domestic demand. These characteristics of the corn market are represented in Figure 2.4.

Under free trade, the domestic quantity supply at the world price (WP) is given by \( Q_1 \) and the quantity demand will be \( Q_2 \). At this price, the country's imports will be represented by the distance \( Q_1 - Q_2 \). Once the support level (SP) is established the quantity supply will increase to \( Q_3 \) and the amount demanded will decrease to \( Q_4 \). Therefore, the corn imports will be reduced and they are given by the distance \( Q_3 - Q_4 \). The effect of the corn price support policy can be explained by the areas
Table 2.7. Export and import as a percentage of the domestic production of rice and corn 1966-80\(^a\)

<table>
<thead>
<tr>
<th>Year</th>
<th>Rice Exp</th>
<th>Rice Imp</th>
<th>Corn Exp</th>
<th>Corn Imp</th>
</tr>
</thead>
<tbody>
<tr>
<td>1966</td>
<td>.071</td>
<td>44.5</td>
<td>.14</td>
<td>4.8</td>
</tr>
<tr>
<td>1967</td>
<td>4</td>
<td>28.4</td>
<td>1.1</td>
<td>4.7</td>
</tr>
<tr>
<td>1968</td>
<td>5.3</td>
<td>21.6</td>
<td>2.6</td>
<td>15.4</td>
</tr>
<tr>
<td>1969</td>
<td>11.8</td>
<td>.5</td>
<td>.08</td>
<td>26.6</td>
</tr>
<tr>
<td>1970</td>
<td>.08</td>
<td>13.2</td>
<td>.7</td>
<td>51.8</td>
</tr>
<tr>
<td>1971</td>
<td>0</td>
<td>34</td>
<td>.7</td>
<td>42.6</td>
</tr>
<tr>
<td>1972</td>
<td>.01</td>
<td>2.3</td>
<td>.3</td>
<td>30.7</td>
</tr>
<tr>
<td>1973</td>
<td>.2</td>
<td>.6</td>
<td>2.4</td>
<td>67</td>
</tr>
<tr>
<td>1974</td>
<td>16.3</td>
<td>.4</td>
<td>0</td>
<td>40</td>
</tr>
<tr>
<td>1975</td>
<td>4.8</td>
<td>.5</td>
<td>6.9</td>
<td>31</td>
</tr>
<tr>
<td>1976</td>
<td>2.3</td>
<td>.06</td>
<td>0</td>
<td>4.31</td>
</tr>
<tr>
<td>1977</td>
<td>35.5</td>
<td>.04</td>
<td>5.2</td>
<td>3.7</td>
</tr>
<tr>
<td>1978</td>
<td>29.5</td>
<td>0.7</td>
<td>1.6</td>
<td>7.4</td>
</tr>
<tr>
<td>1979</td>
<td>45.2</td>
<td>.11</td>
<td>0</td>
<td>5.3</td>
</tr>
<tr>
<td>1980</td>
<td>25.8</td>
<td>.04</td>
<td>0</td>
<td>73.0</td>
</tr>
</tbody>
</table>

\(^a\)Source: BCCR (3, 8).
between the price lines. Thus, the consumer group would suffer a loss given by the sum of areas a, b, c, d. The producer, on the other hand, will gain a benefit described by area a. The government, by importing the required quantity and selling it at the domestic support level, will accrue an income benefit represented by c. Finally, the country as a whole will suffer a loss given by the areas b and d.

For rice, the analytical framework is a little bit different because by implementing the same policy the country has become a rice exporter. Such a framework is given by Figure 2.5.

The rice support price policy is biased in favor of the producers because they will accrue a benefit represented by areas a, b, c, d. At the same time, the domestic consumers will have a loss of a and b. The
Figure 2.5. Support price or rice

government by following this type of policy will suffer a loss (foreign consumers subsidy) represented by b, c, d. The areas b and d also represent a loss to the country because no domestic group accounts for

Sugarcane

The institutional framework within the sugarcane industry has been developing is dominated by two major institutions. One private, the "Liga Agricola e Industrial de la Cana de Azucar" (LAICA) and one public institution, the "Ministerio de Economia Industria y Comercio" (MEIC). LAICA took over the "Junta de Proteccion de la Agricultura de la Cana" in 1965 through the Law 3579 of November 1965. This private institution gathers all interested parties on the production and industrialization of the sugarcane. The Board of Directors consists of two representatives of
the central government, three members from the sugar mill group, and three members from the producers group. Among the several responsibilities given to LAICA by this law and its modification in 1971 by the Law 4856 of September of that year, the most important attributions are:

a) To maintain a system of relations between producers and processors of sugarcane that guarantees a fair economic participation to both groups.

b) To set and allocate the quota for domestic consumption and exports among the sugar mills.

c) To set the final price that the sugar mills have to pay to the producers of sugarcane according with the yield obtained, geographic regions, and sell prices.

d) To control all the sale of sugar in both the domestic market and the foreign market, for it can participate in selling and buying in both markets.

LAICA represents the producers and processors of sugarcane and the MEIC represents the domestic consumers by fixing the wholesale price and the marketing margin at the retail level.

The producer price has been regulated throughout the whole period (1960-1980). The way that the producer price is set considers both prices, the domestic wholesale price is set by the MEIC and the international price.

The economic participation of the producers on the final price has been increasing throughout the period covered. Thus, by the Executive Decree No. 2 of 1951 the sugarcane producer had a participation of 54
percent of the net value of sugar, which was also increased to 56 percent by agreement between producers and processors, this percentage lasted from 1951 to 1965. With the creation of LAICA in 1965, the percentage of the net value of sugar received by the producer increased to 57 percent. In 1971, the Law No. 4856 raised again the economic participation to 59 percent, and finally in September of 1976 this participation was set at 62.5 percent of the net value of sugar.

The way that the net value of sugar and subproducts is estimated has been fixed and controlled by LAICA. The formula applied is the following (LAICA, 48).

<table>
<thead>
<tr>
<th>White Sugar</th>
<th>Total Earnings</th>
<th>Total Cost</th>
<th>Net Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row Sugar</td>
<td>Total Earnings</td>
<td>Total Cost</td>
<td>Net Income</td>
</tr>
<tr>
<td>Total Net income</td>
<td>total net income</td>
<td>tonnage of sugar cane processed</td>
<td></td>
</tr>
<tr>
<td>Income per ton of sugarcane = Plus Earnings from subproducts/ton</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equal Final price of sugarcane/ton</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distribution Producers: Final price x .625</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Processors: Final price x .375</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The total earnings from white sugar is the gross value of the quantity sold in the domestic market. The earnings from raw sugar is the total value (FOB) of the quantity exported. The total cost for both white and raw sugar represents the marketing costs, taxes, cost of quality control, administrative cost, and others which the LAICA incurs as an intermediary. If the sugar mill markets its own sugar, these costs are controlled by LAICA.

The price at the domestic market (wholesale level) is fixed by the MEIC and since the quantity destined to the internal market is between 50 to 60 percent of the total sugar produced (see Table 2.8), then this price has a great influence in the estimation of the final price. Figure 2.6 presents the historical patterns for the average price received by producers, the wholesale price, and the international price (U.S. Sugar Price).

The wholesale price level was pretty much the same through the 1960s and early 1970s. For most of the 1960s, the wholesale price was higher than the U.S. market price reflecting the policy of promoting this activity to obtain self-sufficiency and some exports. By Executive Decree No. 2 of 1951, the wholesale price was fixed at $7.65 per cwt, price that remained until 1963. This domestic price level was economically attractive since 15,000 new hectares were planted with sugarcane (Barboza et al., 10). In the same year, 1963, the price of sugar was reduced to $7.35 per cwt. (48.60 colones) a decrease of 4 percent. This happened with the inclusion of Costa Rica into the preferential U.S. sugar market, which expanded the export possibilities through the quota
Figure 2.6. World, wholesale and producer prices of sugar, period 1960-80, LAICA (47), BCCR (5, 6), FAO (29).

SCWP = Sugarcane world price
SCWhP = Sugarcane wholesale price
SCPP = Sugarcane producer price

---

aRaw sugar 96, New York, Spot, c.i.f.

bProducer price in terms of white sugar
of about 27,000 short tons (LAICA, 46) at a higher price than the international spot market. This wholesale price ($7.35) remained effective until April 1974. Its relation with the U.S. price started to change in the late 1960s when the U.S. price was for the first time higher than the domestic price in that decade, a trend that has been increasing to the dramatic difference between both prices in 1974 and 1975. The increasing gap between the domestic and export prices discouraged the domestic production that became critical in the crop year 1973-1974. The central government then decided to increase the domestic price up to $7.88 per cwt, this increment represents a 36.4 percent in domestic currency, but considering the devaluation of the colon in 1974 (1:8.4) the increment in terms of dollars just represent 7.2 percent. Interesting is the fact that 1975 is the only year that the average price received by producers was higher than the wholesale price and this is because the alltime high record price occurring in the international market.\textsuperscript{1} With the sharp decrease of the world price beginning in 1976, the higher cost of inputs and the low price level of the domestic market, Costa Rica needed to import sugar at the end of 1975 to satisfy its domestic demand (LAICA, p. 47). Because of this the government agreed to increase the domestic price to $10.14 in October of 1975 and again in 1976 at $13.14/cwt, which was a 66.8 percent increase relative to the price of the early 1970s.

For reasons of increasing costs, the domestic price was raised again in 1978 at $15.52/cwt, which represented a 18.1 percent increase. Because

\textsuperscript{1}The U.S. preferential market and its quota assignment has been eliminated since 1974.
of these successive and substantial increases, the wholesale price shows a higher level than the international market in two years (1977-1978) before being caught again by the latter, which began an increasing trend in 1977. Finally, in February of 1980 the domestic price increased to $18.81/cwt. mainly induced by the new high world price which reached that level in 1975. In general and since the elimination of the preferential U.S. market, the Costa Rican wholesale price has shown a continuous increase with an average rate per year of 15.2 percent. Comparing the average wholesale price for the periods 1960-73 and 1974-80, the level of the latter period represents an increase of 74 percent over the price of the earlier one.

Because of the high variability shown by the international price, especially in the last decade, and since for the most part the domestic policy was to fix the domestic price below the world price, then it is advisable to split the decade of the 1970s into short-term periods for comparison purposes. The first period covers the years 1967-1973 when the domestic wholesale price was set at a constant level of $7.13/cwt. The world price average was $8.36/cwt, which implies that the domestic price was 15 percent below the U.S. sugar market price. In the next period (1974-1976), the average wholesale price of sugar was fixed at $8.63/cwt, while the world price recorded its highest level with an average of $21.8/cwt, therefore the domestic sugar price was 60.4 percent below the world price. The next two years (1977-78) stand out from the rest of the periods because the wholesale price was set above the world price, a policy that was disregarded in the late 1960s. The average
percentage that the domestic price was fixed above the reference price was 15.2 percent. The last period (1979-1980) reflects the reimplementation of the old policy, that is the domestic price below the world price, with an average percentage of 11.7 percent.

Before leaving the producer side of the sugar industry, we have to mention that unlike the basic grains there is not a price support for sugarcane but instead, the Sugar League (LAICA) determines the advance payment that the sugar mills have to advance to the producers at the beginning of the season. That price serves as a reference point for the final price that they will receive at the end of the crop year.

At the consumer level, two policy variables are relevant, the retail price fixed through the marketing margins and the domestic consumption quota. The consumer price is governed by the controlled wholesale price to which the marketing margin for the wholesaler (4 percent) and the marketing margin for the retailer (12 percent) are added (LAICA, 45). Therefore, the consumer price should present the same pattern as the wholesale price and this can be seen in Figure 2.7 which plots the historical trends of the retail price and the export price (FOB). Comparing this figure with Figure 2.6, we see that the behavior of both the wholesale and retail prices are almost the same, relative to the foreign market prices. Again, we can distinguish four periods which are different just in the extent from those obtained in the last section, but the effect of the government policies in those periods is the same.

The main objective of the domestic sugar policy since the creation of the "Junta de Proteccion de la Agricultura de la Cana" in 1940 and
Figure 2.7. Consumers and export\textsuperscript{a} prices of sugar, period 1960-80, LAICA (47), BCCR (3)

SCEP = Sugarcane export price
SCCP = Sugarcane consumer price

\textsuperscript{a}Costa Rica FOB prices.
later by the LAICA in 1965 is to ensure the domestic requirements of sugar before allowing exports. The instrument used by these institutions, particularly the LAICA, is a quota system. The Sugar League assigns a determined quota of production to each sugar mill in such a way that satisfies both domestic consumption as well as foreign demand. The domestic consumption quota is obtained by forecasting both the human consumption and the industrial requirements according to their past tendencies.

A time series data corresponding to the industrial demand are not available but from some studies made by LAICA and the high per capita consumption of sugar (64.8 kgs.) since the early 1970s it is reasonable to suppose that the industrial requirement has been increasing. LAICA (47) has estimated that the industrial consumption is about 25 percent of the domestic consumption in 1981. But in any case, the industrial sector buys the sugar at the price established by the MEIC, thus, enjoying an input factor subsidy.

The proportions of the quantity consumed and the quantity exported in relation to total domestic production are presented in Table 2.8. From the same tables we can see that the proportion of sugar that is consumed at the domestic market has ranged between 40 to 67 percent of the total production. We can distinguish three periods, the beginning of the 1960s when Costa Rica had just entered into the U.S. preferential market, when the annual average percentage allocated to the domestic market was 57 percent and the average export was 40 percent (1961-1965). The second period is characterized by the growth in the sugar industry
Table 2.8. Proportion of domestic production of sugar designated for consumption and exports 1961-80

<table>
<thead>
<tr>
<th>Year</th>
<th>Consumption</th>
<th>Exports</th>
</tr>
</thead>
<tbody>
<tr>
<td>61/62</td>
<td>64</td>
<td>36</td>
</tr>
<tr>
<td>62/63</td>
<td>54</td>
<td>41</td>
</tr>
<tr>
<td>63/64</td>
<td>56</td>
<td>47</td>
</tr>
<tr>
<td>64/65</td>
<td>55</td>
<td>35</td>
</tr>
<tr>
<td>65/66</td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>66/67</td>
<td>46</td>
<td>53</td>
</tr>
<tr>
<td>67/68</td>
<td>48</td>
<td>52</td>
</tr>
<tr>
<td>68/69</td>
<td>50</td>
<td>41</td>
</tr>
<tr>
<td>69/70</td>
<td>46</td>
<td>49</td>
</tr>
<tr>
<td>70/71</td>
<td>48</td>
<td>57</td>
</tr>
<tr>
<td>71/72</td>
<td>46</td>
<td>39</td>
</tr>
<tr>
<td>72/73</td>
<td>52</td>
<td>55</td>
</tr>
<tr>
<td>73/74</td>
<td>59</td>
<td>53</td>
</tr>
<tr>
<td>74/75</td>
<td>59</td>
<td>38</td>
</tr>
<tr>
<td>75/76</td>
<td>62</td>
<td>31</td>
</tr>
<tr>
<td>76/77</td>
<td>59</td>
<td>47</td>
</tr>
<tr>
<td>77/78</td>
<td>63</td>
<td>36</td>
</tr>
<tr>
<td>78/79</td>
<td>63</td>
<td>35</td>
</tr>
<tr>
<td>79/80</td>
<td>67</td>
<td>42</td>
</tr>
</tbody>
</table>

\(^a\)Source: LAICA (46), BCCR (3).
promoted by the U.S. sugar price and the domestic price, both of which were higher than the international spot price. The annual average proportion allocated to domestic consumption (1965-1972) was 47 percent and for exports (1965-1974) was 50 percent. The third period is dominated by two events; the elimination of the U.S. preferential market in 1974 and the establishment of a new industry which uses sugar as an input factor in the early 1970s encouraged by the CCM. Thus, the annual average domestic demand rose to 61 percent and exports declined to 38 percent.

The characteristics of the international market relevant to Costa Rica have been its introduction to the U.S. preferential market (1963-1974) and becomes a member of the International Sugar Agreement in 1975. In the early 1960s and particularly with the broken relations between U.S. and Cuba, the U.S. allocated the Cuban quota to a series of countries, including Costa Rica. This new situation gave these selected countries the opportunity to take advantage of the U.S. domestic price support. The U.S. price was $3/cwt higher on average than the world price during the period 1964-1972 (Table 2.9); a period that was dominated by the assignment of quotas to the exported countries. From then on, the U.S. price has been pretty close to the world price and even in some years has been lower. Thus, by the end of 1973 the quota system was disregarded and substituted by the Generalized System of Tariff Preference (GNTP) under the Trade Act of 1974. This new system established preferential trade practices particularly with less developed countries. In general terms, the GNTP has four major characteristics
Table 2.9. Relation between the U.S. domestic price and the world price of sugar, 1960-80

<table>
<thead>
<tr>
<th>Year</th>
<th>World price $/cwt(^b)</th>
<th>U.S. price $/cwt(^c)</th>
<th>Quota premium or discount/$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>4.09</td>
<td>6.30</td>
<td>2.21</td>
</tr>
<tr>
<td>1961</td>
<td>3.85</td>
<td>6.30</td>
<td>2.45</td>
</tr>
<tr>
<td>1962</td>
<td>3.87</td>
<td>6.45</td>
<td>2.58</td>
</tr>
<tr>
<td>1963</td>
<td>9.41</td>
<td>8.18</td>
<td>-1.23</td>
</tr>
<tr>
<td>1964</td>
<td>6.79</td>
<td>6.90</td>
<td>0.11</td>
</tr>
<tr>
<td>1965</td>
<td>3.07</td>
<td>6.75</td>
<td>3.68</td>
</tr>
<tr>
<td>1966</td>
<td>2.82</td>
<td>6.99</td>
<td>4.17</td>
</tr>
<tr>
<td>1967</td>
<td>2.95</td>
<td>7.28</td>
<td>4.33</td>
</tr>
<tr>
<td>1968</td>
<td>2.96</td>
<td>7.52</td>
<td>4.56</td>
</tr>
<tr>
<td>1969</td>
<td>4.32</td>
<td>7.75</td>
<td>3.38</td>
</tr>
<tr>
<td>1970</td>
<td>4.88</td>
<td>8.07</td>
<td>3.19</td>
</tr>
<tr>
<td>1971</td>
<td>5.65</td>
<td>8.52</td>
<td>2.82</td>
</tr>
<tr>
<td>1972</td>
<td>8.54</td>
<td>9.09</td>
<td>0.55</td>
</tr>
<tr>
<td>1973</td>
<td>10.99</td>
<td>10.29</td>
<td>-0.70</td>
</tr>
<tr>
<td>1974</td>
<td>31.62</td>
<td>29.50</td>
<td>-2.12</td>
</tr>
<tr>
<td>1975</td>
<td>21.92</td>
<td>22.47</td>
<td>0.55</td>
</tr>
<tr>
<td>1976</td>
<td>13.14</td>
<td>13.31</td>
<td>-0.03</td>
</tr>
<tr>
<td>1977</td>
<td>9.68</td>
<td>10.99</td>
<td>1.31</td>
</tr>
<tr>
<td>1978</td>
<td>13.86</td>
<td>13.93</td>
<td>0.07</td>
</tr>
<tr>
<td>1979</td>
<td>15.72</td>
<td>15.73</td>
<td>0.02</td>
</tr>
<tr>
<td>1980</td>
<td>30.42</td>
<td>23.13</td>
<td>-7.29</td>
</tr>
</tbody>
</table>

\(^a\)Source: USDA (73).

\(^b\)The Caribbean Port Price at New York port. Includes transport, insurance and import fee.

\(^c\)New York spot price, C.I.F.
(USDA, 73). The total U.S. quota of sugar imports was set at the nonrestricted level of 7 million tons of short tons, since the average annual imports are about 5 million tons of raw sugar. An import fee, which has to be paid by all the sugar imported, was initially set at .625 cents/pound and raised in 1978 to 2.7 cents. Since then, it decreased until it was eliminated in 1980. An import duty that has to be paid by the sugar imported from countries that are not current members of the GNTP system. This import duty was set at 1.875 cents/pound of raw sugar, but after 1977 was raised to 2.81 cents/pound, and finally in February of 1980 was reduced to .625 cents/pound. The objective of these two import taxes is to protect the U.S. sugar price support program from the international market. For a country to be selected as a member of the GNTP system and therefore pay no import duty is not to export to the U.S. market over a certain monetary limit which is set and annually revised by the U.S. government. For example, the limit was set at $26.6 millions worth of sugar imports in 1975; in 1978, it was $33.4 million; and in 1980, the level was $41.9 million. Costa Rica has never exported to the U.S. more than the limited value. Thus, for the period covered in this analysis, Costa Rica always has been a member of the GNTP list of countries.

We have mentioned that Costa Rica has been a member of the International Sugar Agreement since 1975. The main purpose of this international organization is to stabilize the international price of sugar particularly for the type of variation that the sugar price presented in the early 1970s. The mechanisms used to stabilize the world
sugar price takes as a reference a free market price range which was set between 11 and 21 cents/pound. If the world sugar price hits the 21 cents level or higher, a contingency stock of 2.5 million tons is released by the ISA. On the other hand, if the price of sugar reaches 15 cents/pound a quota system of about 85 percent of the Basic Tonnage Export (BTE) assigned to each member enters into effect. Further, if the price of sugar reaches the 11 cents level, the quota restriction is increased to 75 percent of the BTE. Costa Rica has been assigned a BTE of 105,000 metric tons. With the 85 percent quota limit, the level is 89,000 MT and at 75 percent the quota level is 86 MT (USDA, 73). In general, we can say the international quota system has not been restrictive to the Costa Rican sugar exports since according to the figures released by LAICA (46), Costa Rica has never exported its BTE, the maximum quantity exported took place in the crop year 1976/77 with 91,384 MT. During the remaining years, the quantity exported has been even lower than the level of the quota at 75 percent or 86,000 MT.

The wholesale ceiling price has been the traditional policy on the domestic sugar market, which in the last decade has been set below the world price, except for a couple of years. This characteristic of the sugar market is represented as in Figure 2.8.

The implementation of the ceiling price on the sugar market can be analyzed with respect to the free trade price level. Under this circumstance, this policy will benefit the domestic consumers by the areas a and b. On the other hand, the sugarcane producers will suffer a
Figure 2.8. Wholesale ceiling price on the sugar market

loss represented by the areas a, b, and c. The efficiency loss caused by this policy is then given by the triangle c.

Coffee

The coffee industry is the single most important activity in the Costa Rican economy. The production of coffee generates the most important source of rural employment. Because the production structure is dominated by small- and medium-size farmers, the distribution of income generated by this activity is one of the most efficient (in terms of the scope and economic participation) within the country's economic system. In the foreign trade sector, the coffee exports represent the first if not the second activity of importance on the total value of the
country exports, thus being a key source of foreign exchange and a key figure in the country's balance of payment situation.

Because of its relevance on the domestic economy, this agricultural activity was the first to be organized under the guidance of the central government. In 1933, by the Law No. 17, the "Instituto de Defensa del Cafe" (IDC) was created with two main objectives. To regulate the economic relations between producers, processors, and exporters and to implement and encourage the adaptation of new technology. In 1948 by Law No. 74, the IDC was transformed into the "Oficina del Cafe" (OFICAFE), which took control of the economic relations between the different groups and the agricultural-related activities were transferred to the Ministry of Agriculture. In 1961, a legal framework was given to the economic relations through the Law No. 2762. With these two laws all the economic transactions are controlled by OFICAFE. This institution is managed by a board of directors composed of representatives from producers, processors, exporters, and the central government.

The most relevant characteristic established by the legal framework is that the OFICAFE should maintain a policy such that the economic relations between the relevant groups ensures to them a fair economic participation on the total value of coffee. The task is accomplished by setting the price that the processors and exporters must pay to the producers. Price that is obtained under specific rules that consider the domestic and international price, processing and marketing costs as well as some taxes from this activity. This system was designed to protect
smaller farmers in their dealings with the few large buyers and the price set by OFICAFE must be paid to all farmers, large or small, for the same quality product. Further, the processors are required by law to purchase a certain proportion of their raw materials from independent producers, who in many cases are small farmers. The OFICAFE influences the marketing of this product, not by buying or selling it directly, but by setting producer price and administering production and export quotas. It requires that millers register all purchases and exporters all export contracts. The same law also fixes margins for the millers and exporters to ensure that all participants share equitably in the distribution of income generated by this activity. Finally, the law also requires that OFICAFE satisfy the domestic demand by administering the supply to the domestic market, for this office manages the coffee exchange where by law all the coffee for internal consumption is auctioned. Finally, the MEIC sets the maximum price that coffee can be sold at the retail level.

The price received by the coffee producers is strongly tied to the export price. Figure 2.9 shows the historical trend of both the export price (FOB) and the final price or liquidation price received by the producers. From that figure, one can see how close the price received by coffee farmers follows the export price. The latter has shown a

\[^1\text{The liquidation price is recorded in colones for double hectolitter of cherry coffee, thus to convert it to dollars per cwt. of green coffee use this formula.}
\]

\[
\frac{\text{Final price}}{\text{Yield at coffee mill}} \times \frac{45.4}{\text{Exchange rate}} = \frac{\text{$/cwt.}}{\text{Final price}}
\]
Figure 2.9. Producers\textsuperscript{a} and export\textsuperscript{b} prices for green coffee, 1965-80, OFICAPE (55)

CFEP = Coffee export price
CFPP = Coffee producer price

\textsuperscript{a}Export price refers to FOB.

\textsuperscript{b}Liquidation price.
pattern more or less stable in the decade of the 1960s with a decreasing tendency in the last years of the same decade. By the early 1970s, the export price started to recuperate except for the crop year 1974-75 when it decreased from an excess supply. By the next crop year, the export price began to increase promoted by the cold temperatures occurring in Brazil in 1975 and their effect on the following two or three crop years. It is during this period that the export price as well as the producer price reached a record level. The former reached the $198.85/cwt. level.

The final price that the producers received for their product is determined by the following method (Aguilar et al., 1).

I. Total value of green coffee

II. Less the cost of processing

III. Net value

IV. Less the Ad-Valorem tax

V. Net value after tax

VI. Less processor margin

VII. Total value to be distributed

VIII. Liquidation price = \frac{\text{VII}}{\text{quantity received}}

The total value of the quantity processed involves the export sales as well as the sales to the domestic market, including also what the coffee mill has in stock. A tax of $.004/cwt of cherry coffee received by the processor is deducted from the total value. The processor costs are specified by law and they refer mainly to handling and transport.
costs as well as some insurance costs, these costs cannot be greater than a specified value ($1.79/cwt). The processor's margin is set also by the law which is 9 percent over the gross total value less the allowed processing cost. The application of the above method ensures the producers that the price received will reflect the price variation presented by the world market. Historically, the producers have received around 75 percent of the export price.

The domestic market for coffee is regulated by two institutions, the OFICAFE at the wholesale level and the MEIC at the retail level. According to Law No. 2762, a function of OFICAFE is to establish a quota level that satisfies the domestic demand; this quota is then distributed among all coffee processors. All the coffee designated to the domestic market has to be auctioned at the coffee exchange, which is administered by OFICAFE. It is in this market that the objective of a lower domestic price is obtained by regulating the quantity supply, because OFICAFE has the power to call upon the assigned quotas to increase the supply. Table 2.10 shows the relation between both the export price and the wholesale domestic market. The latter has shown a level that is about 66 percent of the export market price during the decade of the 1960s and early 1970s. However, this proportion has been decreasing since the crop year 1972-73 with the lowest figure in 1976-77 of 17 percent and the average is 34 percent of the export price. It is important to realize that the coffee for domestic consumption is of a lower quality and domestic consumers have been enjoying a price for this product is lower than its opportunity cost at the international market.
Table 2.10. Relationship between the export price and the wholesale domestic price for green coffee in $/cwt\(^a\)

<table>
<thead>
<tr>
<th>Crop year</th>
<th>Export price</th>
<th>Domestic price</th>
<th>Relation percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-70</td>
<td>39.6</td>
<td>26</td>
<td>66</td>
</tr>
<tr>
<td>1970-71</td>
<td>41.31</td>
<td>29.3</td>
<td>71</td>
</tr>
<tr>
<td>1971-72</td>
<td>39.95</td>
<td>26.52</td>
<td>66</td>
</tr>
<tr>
<td>1972-73</td>
<td>57.66</td>
<td>26.50</td>
<td>46</td>
</tr>
<tr>
<td>1973-74</td>
<td>63.56</td>
<td>29.30</td>
<td>46</td>
</tr>
<tr>
<td>1974-75</td>
<td>52.21</td>
<td>26.56</td>
<td>51</td>
</tr>
<tr>
<td>1975-76</td>
<td>92.16</td>
<td>27</td>
<td>29</td>
</tr>
<tr>
<td>1976-77</td>
<td>198.85</td>
<td>33.51</td>
<td>17</td>
</tr>
<tr>
<td>1977-78</td>
<td>159.81</td>
<td>37</td>
<td>23</td>
</tr>
<tr>
<td>1978-79</td>
<td>122.13</td>
<td>38.3</td>
<td>31</td>
</tr>
<tr>
<td>1979-80</td>
<td>152.54</td>
<td>47</td>
<td>31</td>
</tr>
</tbody>
</table>

\(^a\)Source: OFICAFE (57).
The other institution that intervenes in the domestic coffee market (MEIC) accomplishes its objective of maintaining a low level for the retail price of ground coffee by setting the maximum price that ground coffee with 12 percent sugar can be sold to the consumers. Figure 2.10 shows that both the wholesale price and the consumer price were more or less stable during the 1960s and middle 1970s, but since 1975 both prices have increased, promoted by the sharp increase experienced by the export price as well as the domestic inflation that became severe in the last half of the 1970s. These two factors forced the MEIC to critically increase the maximum retail price of ground coffee.

As previously mentioned, the coffee industry is one of the most important sources of foreign exchange for the country's economy, and this importance has been obtained by exporting a high percentage of the domestic production. The quantity exported during the 1960s represents a 92 percent of the total production (Table 2.11), proportion that is decreased to 88.7 percent in the Seventies due to the increase in domestic consumption (11.3 percent).

Since the beginning of the 1960s (1962), the international market has been controlled by the International Coffee Organization and its respective International Coffee Agreement to which Costa Rica has been a member. The main objective of this institution is to stabilize the international price of coffee at a level no lower than the level reached in the crop year 1961-62 ($38/60 kgs). The mechanism used to accomplish this objective is the control of the world supply by assigning quotas to the country members and encouraging them to control the domestic
Figure 2.10. Wholesale and retail domestic prices of coffee, 1960-80, OFICAFe (56), DGEC (28)

CFCP = Coffee consumer price
CFWhP = Coffee wholesale price
Table 2.11. Percentage of the domestic production that is domestic consumed and exported

<table>
<thead>
<tr>
<th>Crop year</th>
<th>Domestic consumption</th>
<th>Exported</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-70</td>
<td>8</td>
<td>92</td>
</tr>
<tr>
<td>1970-71</td>
<td>8.88</td>
<td>91.12</td>
</tr>
<tr>
<td>1971-72</td>
<td>6.43</td>
<td>93.57</td>
</tr>
<tr>
<td>1972-73</td>
<td>10.15</td>
<td>89.85</td>
</tr>
<tr>
<td>1973-74</td>
<td>10.05</td>
<td>89.95</td>
</tr>
<tr>
<td>1974-75</td>
<td>11.04</td>
<td>80.96</td>
</tr>
<tr>
<td>1975-76</td>
<td>13.02</td>
<td>86.98</td>
</tr>
<tr>
<td>1976-77</td>
<td>13.95</td>
<td>86.05</td>
</tr>
<tr>
<td>1977-78</td>
<td>14.05</td>
<td>85.95</td>
</tr>
<tr>
<td>1978-79</td>
<td>12.58</td>
<td>87.42</td>
</tr>
<tr>
<td>1979-80</td>
<td>13.05</td>
<td>86.95</td>
</tr>
</tbody>
</table>

*aSource: BCCR (3).*
the decade of the 1960s. Once the 1975 frost happened in Brazil, this latter policy has been somewhat disregarded. The 1962 agreement assigned to Costa Rica a basic quota of 57,000 m.t. of green coffee which corresponds to a 2 percent of the world supply; in 1968 a new agreement based on the 1962 one was signed by Costa Rica which was reassigned a basic quota of 66,0 m.t. (Aguilar, et al.). Finally, in 1976 was signed the last and current international coffee agreement which set a quota of 78,840 m.t. These basic levels are modified annually according with the situation of the world market as well as redistribution of quotas not satisfied by other country members. The effect of this quota system on the export capacity of the country has been somewhat moderate since significant levels of surplus have occurred only in the middle 1960s (Aguilar et al., 1) which were sold to nonmember countries at the spot prices which historically has been lower than the price accepted by the international organization.

**Beef Cattle**

The beef cattle industry, because of importance to both the domestic consumers as the primary source of animal protein and the foreign exchange earnings produced, also has been regulated by the central government.

Unlike the other two export activities (coffee and sugarcane) the beef cattle industry does not have a semi-public institution that controls the relations between the different participant groups. The central government directs participation in this industry, started in
1954, by imposing an export quota system (Law No. 1754 of Beef Cattle Exports). The government worried that insufficient quantities of beef would remain for domestic consumption. Under this law, representatives of the private sector, particularly producer associations, are called to advise on setting the export quota. The CNP implements this program, by setting officially the export quota and controlling the flow of cattle between the domestic and export market. The last modification made to the 1954 law was issued in 1978 (Law No. 6247 Beef Cattle Law and Regulations). This law created the "Comision Asesora del Mercadeo de la Carne", which is formed by representatives of both private groups as well as public institutions. The major function of this commission is to advise the CNP in the applications of the norms relative to the setting of the domestic and export quota. In the same year, the "Comision Reguladora de la Carne" was created, which is a private agreement between public institutions, export plants, and cattle producers. The principal functions assigned to this private association are to approve the final liquidation price for exported cattle, to set and monitor the quality of export beef, and to set the minimum acceptable export price. The law makes export plants also responsible for filling the domestic quota. Estimates of slaughter for domestic consumption (primarily slaughter of females) in nonexport plants are subtracted from estimates of domestic consumption (a per capita consumption of 18 kgs is used) to determine how many animals have to be diverted from the export market to meet domestic consumption needs. Finally, the MEIC has been setting the ceiling price for beef at the retail level.
The beef cattle producer faces two markets for his product with a significant price differential—the export market, basically the U.S. market, and the domestic market. The beef cattle law explicitly states that the primary objective is to satisfy the domestic consumption, for a system of domestic quotas is established to ensure adequate supplies for the domestic market. This market is not as well-organized as the market for exports. A great deal of intermediaries, wholesalers, and distributors participate in the handling and process of beef from the farm to the retail level, which implies unnecessary marketing costs (SEPSA, 65). The price at the producer level as well as the price at the wholesale level are not explicitly intervened by any type of policy, they may reflect though the ceiling price policy at the retail level. The market for exports is much more well-organized where the transactions between producers, slaughters, and packing plants are controlled by a private agreement (Comision Reguladora de la Carne). The U.S. constitutes its principal market by buying 95 percent of the total exported by the country (SEPSA, 65). The producers are reassured that the price they received for their product will reflect the fluctuations of the U.S. market price, through a system of liquidation prices, similar to those applied for coffee and sugarcane, and which is controlled and approved by the "Comision Reguladora de la Carne."

The average price (liveweight) received by the beef producers during 1960-1980 is depicted in Figure 2.11 where it shows the same general fluctuations as the U.S. market price but with less dynamism. As previously mentioned, there is a price differential between both markets
Figure 2.11. World\textsuperscript{a} and producers\textsuperscript{b} prices of beef cattle, BCCR (3, 8)

\[ BWP = \text{Beef world price} \]
\[ BPP = \text{Beef producer price} \]

\textsuperscript{a}World price: frozen boneless cow beef, Chicago, The National Provisioner.

\textsuperscript{b}Producer price: average live weight price.
where the price for export cattle is higher than the domestic market.

This situation reflects two things, first the quality of the cattle for exports is better since just young steers are designated to this market unlike the domestic market which is satisfied by slaughtering cows, bulls, and oxes and in some instances where the domestic quota has not been fulfilled a proportion of the steers for export are diverted to the domestic market at the cow beef price. The second factor that could be reflected in this price differential is the policy of price ceiling at the retail level that to some degree could prevent the cattle for the domestic market from reaching comparable levels with those destined to the foreign market. The historical trend for both sets of prices is shown in Figure 2.12 from which shows generally that both prices have followed the fluctuations presented by the international price (see Figure 2.11). The export price (liveweight) paid to the beef cattle producers is on average 22 percent higher than the one received from the domestic market for the period 1960-1974. The next period, 1975-1978, the price differential was increased to 30 percent reflecting the enforcement of the Consumer Protection Law No. 5665 of 1975 and the decline of the export price. For the last two years (1979-1980), a liberalization of prices at the retail level was allowed reducing the price differential to 18 percent.

We have mentioned that the price at the consumer level has been controlled by the government—first, by the Economic Defense Law No. 1208 during the period 1950-1974 and, since then, by the Consumer Protection Law No. 5665 of 1975. These laws entitle the MEIC to set the maximum
Figure 2.12. Average producer prices at the export and domestic markets of beef cattle, live weight, 1961-80, BCCR (5, 6).

- **EBPP** = Beef export market producer price
- **DBPP** = Beef domestic market producer price

---

aFOB prices.
prices for the different beef cuts at the retail level. The effectiveness of these laws as a price stabilization device is questionable. Comparing the domestic retail price of beef (inside round)\(^1\) with the export price (FOB), the former has been historically higher. Even more, the domestic price has followed pretty well all the price fluctuations showing foreign demand (Figure 2.13). For the period 1961-1972, the internal price was 14.5 percent higher, margin that increased to 31.3 percent for the period 1973-1979 even with the implementation of the consumer protection law and for 1980 this difference reached its all-time record of 67 percent. Figure 2.13 indicates that the effectiveness of this policy is far from expected. Maybe its enforcement is more evident on the popular cuts (bone soup, liver) whose price trends have been much less dynamic. Another point worth noting is the absence of quality standards for the different beef cuts which makes the control and enforcement of the law very difficult (SEPSA, 66). Comparing the retail price and the wholesale price (carcass weight), the retail price has been historically higher by a substantial margin. For the period 1961-1979, that margin was on average 73 percent increasing to 90 percent in 1980. This significant difference between both prices could be explained in part by the deficient marketing channels that characterized the domestic market for beef.

---

\(^1\)The specific beef cut chosen is more comparable with the export beef beside it represents the second in importance on domestic consumption (DGEC, 27).
Figure 2.13. Historical trends of the consumer, wholesale\(^a\) and export\(^b\) prices of beef cattle, 1961-80, DGECC (28), BCCR (3), SEPSA (65).

BCP = Beef consumer price
BEP = Beef export price
BWhP = Beef wholesale price

\(^a\)Carcass weight.
\(^b\)Boneless beef.
The export market has been increasing its share of the total beef quantity supplied. During 1960-1965, this market represented 27 percent of the total supply increasing to an average of 54 percent in the last decade (Table 2.12). The U.S. constitutes the principal buyer of the Costa Rica export beef, thus any import policy applied by that country will have an important impact on the performance of the beef cattle industry of Costa Rica. The U.S. import market has been controlled by the Meat Import Act of 1964 (PL88-482), which stated that a quota system will be put into effect if total imports of fresh, chilled, frozen beef would exceed a certain specified limit. But for the most part of the 1960s and early 1970s, the procedure followed was a voluntary agreement with the major exporters to restrain their quantities shipped to the U.S. (USDA, 72). The restraint level has changed over time, for example in 1971 it was 1.160 million pounds, in 1975 it was 1.180 million pounds and in 1979, 1.570 million pounds. Because of the quantity imported and the internal economic situation of the beef cattle producers in the U.S., this country implemented the quota system for the year 1975-1976, corresponding to Costa Rica's share of 53.7 million pounds. This caused some problems since in those two years the quantity exported was greater than the quota, forcing to hold the excess quantity in bond. As a result of the surplus, it was necessary to export 10,000 m.t. to Venezuela in 1977 (SEPSA, 65). The voluntary restriction system was retained until 1979 when the new Anticyclical Law (PL96-117) came into effect. This new legislation, like its predecessor, established a limit, which now is set according to the U.S. cow beef supply. That limit was increased for
Table 2.12. Percentage of beef cattle destined for the domestic market and to the export market\textsuperscript{a}

<table>
<thead>
<tr>
<th>Year</th>
<th>Domestic market</th>
<th>Export market</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-65</td>
<td>73.2</td>
<td>26.8</td>
</tr>
<tr>
<td>1966</td>
<td>66.5</td>
<td>33.5</td>
</tr>
<tr>
<td>1967</td>
<td>63.9</td>
<td>36.1</td>
</tr>
<tr>
<td>1968</td>
<td>61.8</td>
<td>38.2</td>
</tr>
<tr>
<td>1969</td>
<td>52.7</td>
<td>47.3</td>
</tr>
<tr>
<td>1970</td>
<td>54.2</td>
<td>45.8</td>
</tr>
<tr>
<td>1971</td>
<td>52.8</td>
<td>47.2</td>
</tr>
<tr>
<td>1972</td>
<td>46.6</td>
<td>53.4</td>
</tr>
<tr>
<td>1973</td>
<td>49.4</td>
<td>50.6</td>
</tr>
<tr>
<td>1974</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td>1975</td>
<td>44.2</td>
<td>55.8</td>
</tr>
<tr>
<td>1976</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td>1977</td>
<td>46</td>
<td>54</td>
</tr>
<tr>
<td>1978</td>
<td>46</td>
<td>54</td>
</tr>
<tr>
<td>1979</td>
<td>48</td>
<td>52</td>
</tr>
<tr>
<td>1980</td>
<td>53.5</td>
<td>46.5</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Source: BCCR (5, 6).
1979-1980 and Costa Rica could not satisfy its share (SEPSA, 65). In addition to those years (1975-1977), the U.S. import quantity restriction does not seem to have had a limiting effect on the development of the beef cattle industry.

The Tax Framework

The most stable and permanent source that a government has to finance its activities is the revenue obtained from the imposition of taxes, particularly in those products which are mainly exported. As in any other market price intervention, the imposition of a tax will divert the market price from accomplishing its primary role and negative effects are possible on the expectations of those who look upon the market price as a guide for their investment decisions.

It is of major importance to have a historical perspective of the tax structure that has been affecting the five products chosen, so that we will understand why they were created, their rate level, and in doing so completing all the information that we need to analyze the welfare effects of agricultural market intervention policies. To begin with, let us see what has been the participation of the agricultural sector in total tax revenue received by the central government (Table 2.13). During the whole period (1962-1979), the total tax revenue grew at an average rate of 5.1 percent annually, while the tax rate for agriculture was 6.5 percent, industry was 5.4 percent, and the commerce sector shows the lower rate 3 percent. The agricultural sector's share of the total
Table 2.13. Participation of the three major economic sectors on the composition of the total tax revenue of central government

<table>
<thead>
<tr>
<th>Year</th>
<th>Total $</th>
<th>Agriculture $</th>
<th>%</th>
<th>Industry $</th>
<th>%</th>
<th>Commerce $</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1962-69</td>
<td>102</td>
<td>10</td>
<td>10</td>
<td>25</td>
<td>25</td>
<td>37</td>
<td>36</td>
</tr>
<tr>
<td>1970</td>
<td>143</td>
<td>15</td>
<td>11</td>
<td>37</td>
<td>26</td>
<td>51</td>
<td>36</td>
</tr>
<tr>
<td>1971</td>
<td>147</td>
<td>11</td>
<td>8</td>
<td>38</td>
<td>26</td>
<td>51</td>
<td>35</td>
</tr>
<tr>
<td>1972</td>
<td>157</td>
<td>11</td>
<td>7</td>
<td>41</td>
<td>26</td>
<td>49</td>
<td>31</td>
</tr>
<tr>
<td>1973</td>
<td>180</td>
<td>15</td>
<td>8.9</td>
<td>46</td>
<td>26</td>
<td>57</td>
<td>32</td>
</tr>
<tr>
<td>1974</td>
<td>210</td>
<td>29</td>
<td>14</td>
<td>45</td>
<td>22</td>
<td>62</td>
<td>31</td>
</tr>
<tr>
<td>1975</td>
<td>198</td>
<td>31</td>
<td>16</td>
<td>46</td>
<td>23</td>
<td>55</td>
<td>28</td>
</tr>
<tr>
<td>1976</td>
<td>204</td>
<td>29</td>
<td>14</td>
<td>51</td>
<td>25</td>
<td>55</td>
<td>27</td>
</tr>
<tr>
<td>1977</td>
<td>216</td>
<td>35</td>
<td>16</td>
<td>51</td>
<td>24</td>
<td>58</td>
<td>27</td>
</tr>
<tr>
<td>1978</td>
<td>216</td>
<td>30</td>
<td>14</td>
<td>50</td>
<td>23</td>
<td>61</td>
<td>28</td>
</tr>
<tr>
<td>1979</td>
<td>209</td>
<td>29</td>
<td>14</td>
<td>50</td>
<td>24</td>
<td>58</td>
<td>28</td>
</tr>
</tbody>
</table>

\(^a\)Source: SEPSA (66).

\(^b\)In millions of dollars (exchange rate 1:6.4).
central government tax revenue was 12 percent, the industry share, 25 percent, and commerce, 31 percent.

Since 1974, new taxes were imposed and substantial changes were made in the old ones which altered the composition of total revenue accrued by the government. For the period before 1974 (1962-1973), the total tax revenue grew at an annual rate of 6.5 percent; for agriculture, the tax rate was 3.9 percent; for the industry, 8.4 percent and for commerce, the annual rate was 4.3 percent. The shares of each of these sectors were 9 percent, 26 percent, and 34 percent, respectively. After major changes on tax policy (1974-1979), those shares have changed to 15 percent for agriculture and 23 and 28 percent for the industry and commerce, respectively. The major effect has been on the growth rate, while the tax rate for the commerce sector just barely presents an increase (.5 percent) and the industry sector enjoyed a reduction of .4 percent, the agricultural sector, particularly the export crops, registered an annual rate of growth of 12 percent in its taxes paid to the government.

The agricultural activities that generate most of the tax paid are coffee and bananas. Both activities represent 67 percent of the total (SEPSA, 66). The coffee industry is the most heavily taxed and the taxes are imposed on all stages—production, processing, and export. The ad valorem tax on production implemented originally by the Law No. 1411 of January 19, 1952, which states that a tax of 5 percent on the liquidation price received by the producer will be charged. In 1961, the percentage was raised to 10 percent by Law No. 2802. After this, several changes have been made to the law, where the last one was made in 1974 by
Executive Decree D.E. 4093-MEIC. These modifications were mainly concerned with the tax base as well as with the tax rate which was tied to the export price (E.P.) Thus, the law ended up with four tax rate levels

1. 10 percent if $E.P. \geq 42.5$/cwt.
2. 7.5 percent if $40 \leq E.P. < 42.5$
3. 5 percent if $37.5 \leq E.P. < 40$
4. 2.5 percent if $E.P. < 37.5$

Another tax that affects directly the coffee producer is the tax on each double hectoliter of cherry coffee sold to the coffee processors. This is a fixed tax of $.03 cents and it was established by Law No. 200 in 1948. The purpose of it was to finance the inspection services and later (1964) it was designated as a crop improvement program.

The Law No. 3064 of 1962 established a fixed tax of $.45 cents per cwt. of coffee exported which is used to finance the administrative cost of OFICAFE and to pay the international obligations under the Coffee Agreement. The tax level was modified in 1979 where it was expressed that the level would not be inferior than one half of the 1 percent of the FOB price.

Another tax on coffee that affects the quantity exported is the Ad Valorem Right on coffee exports, which was established by Law No. 5519 of 1974 indicating that 13 percent of the FOB price will be charged in favor of the central government. This law has been changed several times, the original level just lasted eight months followed by a period of one year at 5 percent. Then the level was increased again to 8 percent for almost
three years and finally in 1980 it was increased to its original level, 13 percent.

The coffee, which is consumed at the domestic market, is also taxed by the Law No. 74 of 1948, which set a fixed tax of $0.083 cents/cwt. of coffee auctioned at the Exchange Coffee. In 1962, the level was raised to $24 cents/cwt (2). This tax is in favor of OFICAPE to finance the administrative cost of the Exchange Coffee.

The exports of raw sugar are also taxed, basically with two export taxes. The first is what is called export rights tax, which was established by Law No. 2802 of 1961 and modified in 1979. The tax rate for each cwt. of sugar exported depends on the level of FOB price, thus we have:

1. 9 percent if FOB Price $26.5/cwt.
2. 7 percent if $21.5 \leq FOB P. < 26.5
3. 5 percent if $16.5 \leq FOB P. < 21.5
4. 3 percent if $11.5 \leq FOB P. < 16.5
5. 1 percent if FOB P. < $11.5

This export rights tax was issued in favor of the central government to finance its operations.

The second tax on exports is an ad valorem export right which was set by Law No. 5519 of 1974 in favor of the central government. After some modifications, the final version states that:

1. 18 percent if FOB Price $35/cwt.
2. 13 percent if $28 \leq FOB P. < 35
3. 8 percent if $23 \leq FOB P. < 28
4. 5 percent if $18 \leq \text{FOB P.} < 23$

5. 1 percent if FOB P. $< 18$

There are also several specific taxes on the sugar exported, where the most relevant, in terms of quantity, are a fixed tax on the raw sugar exported of $1.43/\text{Mt}$ whose beneficiary is a local government (Puntarenas) where the relevant ports are located. Another fixed tax of $2/\text{Mt}$ is imposed to finance the institution in charge of the port facilities (INCOP). The first tax is given by Law No. 5582 of 1974 and the second one is given by Law No. 3652 of 1974.

The domestic consumption of sugar is taxed by Law No. 2719 of 1961. After several modifications, the final version establishes a total fixed tax of $.30 \text{ cents/cwt}$. The beneficiaries of this tax are the central government (.12 cents), the local governments (.13 cents) for improvements on rural roads, and the difference goes to two other institutions.

The beef cattle industry is the one with the less taxes out of the three export activities. The quantity of beef exported has to pay the ad valorem right to export, which was set by Law No. 3719-H of 1974 when the tax rate was specified at 13 percent. This rate only lasted eight months, because by Executive Decree No. 4431-H of 1974 the tax rate was lowered to 1 percent. The tax revenue goes to the central government without any specific purpose. Also, the exports of beef have a specific tax of $2.98/\text{Mt}$ that goes to the CNP to finance the refrigeration system as well as to improve the equipment of the CNP retail outlets. This specific tax was established by Law No. 5426 of 1973.
Each cattle head that is slaughtered also brings a tax of $1.19, of which 50 percent of the revenue goes to local governments to improve rural roads, 30 percent of the Education Board of the respective region, and the remaining 20 percent is counted as ordinary income by the local governments. This tax was set by Law No. 5259 of 1973. Finally, those steers that are designated to the export market, support another tax of $.004 cents/kg of liveweight. The revenue is distributed among several institutions related to the beef cattle activity. This was established by Law No. 5426 of 1973.

The effects of an export crop tax on the domestic economy can be represented as in Figure 2.14.

An export tax is bias against producers who will suffer a loss in income given by the sum of areas a, b, c, d. The domestic consumer, on the other hand, will receive a benefit represented by area a. The country's exports will be sold at the world price, therefore, the government will accrue a tax revenue which is measured by the rectangle c. The tax on export products will also leave the country with an efficiency loss which is equal to the sum of the triangles b and d.
Figure 2.14. A tax on export products.
The literature on applied demand theory is very rich, as is exemplified by the surveys in this field made by Brown and Deaton (14), Barten (12), and Theil (69), among others.

Johnson and Hasson (43) has classified the development of applied demand theory based mainly on the way that the parameters have been estimated, which reflects the development on the integration of applied work and the behavioral assumptions derived from economic theory. He has postulated four components: the "Statistical Approaches" is the first group, followed by "Statistical Approaches with Restrictions," "Statistical Approaches with Restriction on Estimation," and "Tractable Static Demand Systems."

In the first category, the most notable work was done by Moore (53), who made a major attempt to combine economic theory and statistical techniques in the estimation of several agricultural demand parameters. Later, he also introduced the concept of flexibility of price defined as the reciprocal of the elasticity of demand. The distinctions of these early works were that they reflected a great step forward on the statistical estimation, but with little guidance from the economic theory, no more than the price, quantity, and income are the relevant variables for estimating the demand function.

The second category represents the first attempt to introduce some of the derived restrictions on the estimation procedure. The major work opening the way to these advances in demand analysis can be attributed to
Schultz (64), who presented an effort on the application of adjustments in the least-squares single-equation fitting of market models based as far as possible on the theoretical results of Slusky.

The works of Wold and Jureen (79) on Paretian demand theory and of Stone (68) on the measurement of consumer expenditures consolidated the theoretical and empirical work on static demand models (Brown and Deaton, 14). These two publications mark the beginning of the third generation on applied demand works, that is, the "statistical approach with restriction on estimation." Some of the studies in this group start showing the idea of directly estimating demand systems, but the estimation methods and the restriction imposed to obtain the set of demands were limited. With the arrival of more sophisticated statistical techniques, particularly those referring to simultaneous estimation of a set of equations, plus further development in economic theory, such as the specification of specialized utility functions, and the development and use of the separability concept, it was possible to formulate and estimate theoretically sound demand systems. Hence, we arrive at the fourth generation, namely "Tractable Static Demand Systems," where the idea is to estimate a system that will obey the restrictions on the consumer allocation problem and incorporate specialized behavioral assumptions. Some of the early studies on the applications of complete demand systems can be enumerated by beginning with the linear expenditure system, which satisfies various theoretical restrictions (Stone, 68); then, Frisch (30) developed a scheme for computing all price elasticities in a system context, Houthakker (40) studied the theoretical and empirical implications of
direct and indirect additivity; and Brandow (13) used Frisch's assumption
of want independence to construct a matrix of price and income
elasticities for 25 products at retail level. More recently, Caves and
Christensen (16) and Christensen et al. (18) have proposed the flexible
functional form which by using the indirect translog function the model
expands the empirical capabilities of the theory, because it can be
useful in testing the assumption, such as the additivity of preferences.
Another type of development that has taken place in the last decade or so
is the specification of demand systems where the functional forms of the
set of demand equations is explicitly specified. An example of this
latter development is the Rotterdam Demand System (Barten, 11), which
defines the demand system as a set of logarithmic differential equations
and whose arguments are the set of prices and a measure of real income.
Finally, the System of Additive Preferences proposed by Powell (59),
which specifies the system as a set of $n$ linear relations, where the per-
capita expenditure on one commodity is defined as a function of prices,
total expenditure per-capita, and a variable that counts for changes in
consumer tastes. These models satisfy some, if not all, of the modern
behavioral restriction on demand.

Most of the development found in the theory of applied demand
systems have also been applied to the theory of production, where much of
the effort has been aimed to the specification of the production function
and its implications on the system of derived factor demands. Mundlak
(54), with the transcendental multiple-output production function, and
Powell and Gruen (60) with the constant elasticity transformation
multiple output production function, are examples of the former. Griliches (32), Welch (78), and Thirsk (70) are examples of applied system of derived factor demands. The theory and applications of derived supply systems, particularly for the multiple product production function, are found in Christensen, Jorgenson, and Lau (17), and Hasenkamp (34). More recently, Clements (19) has made an attempt to apply the Rotterdam Model to the estimation of a supply system.

General equilibrium models, which include demand and supply system of equations, can be found in the work of Johnson (41), who analyzed the effect of a tariff under self-sufficient policy objective; also, Hotelling (39) studies the effect of a tariff, but under different assumptions. DeMelo (26) estimated the cost of protection by applying the linear expenditure model to the Colombian economy.

The Supply System

The purpose of this section is to develop the theoretical framework from which a set of aggregate supplies can be derived. This will be accomplished by applying the theory of the multiple-output production function. Clements (19) has pointed out four major characteristics of this type of approach. First, the model allows for joint production, a characteristic of technology that cannot be captured by a single-output production function. The supply side of the market is represented as a system of equations, which will be a more flexible mean for testing and applying the different types of market interventions; third, the basic structure of the model is symmetric to the system of demand on the
consumer side of the market. Then, both systems can be put together, leading to a general equilibrium model.

The model is based on the behavioral characteristics of a single firm, where these characteristics are assumed to be common for all the firms in the industry. If that industry is the agricultural sector where it is common to find farmers producing more than one type of crop, for reasons of cash flow, resource conservation, reduction of risk, and some others, then, it is not far from reality to assume a single farm producing \( n \) products and, in the production process, it hires \( m \) variable inputs, and has an endowment of \( z \) fixed or exogenous factor of production. The outputs and factor of production linkages can be represented by

\[
(3.1)\quad h(Q_i, X_j, K_k) = 0 \quad i = 1 \ldots, n \quad j = 1 \ldots, m \\
\quad k = 1 \ldots, z
\]

which is the implicit form that any type of smooth production technology can be represented.

If one is willing to take no explicit difference between variable and fixed factors of production, then, by pooling all together as one composite factor of production, the technology representation can be rewritten as

\[
(3.2)\quad g(x) = f(Q_i).
\]
The functions of \( g() \) and \( f() \) are scalar valued and are assumed to be differentiable of the required order. The function \( g() \) serves to aggregate the variable and fixed factors into a scalar index. Then, to simplify the notation, we denote the value of this index by \( X \); then

\[
(3.3) \quad X = f(Q_i).
\]

This relationship is a multiple-output production function, which gives the maximum feasible output combinations \( Q_i \) associated with the composite factor \( X \). In the output space, given the level of the aggregate factor, the relationship (3.3) denotes a transformation surface, where, holding all outputs constant except one, this transformation surface gives the maximum amount that can be produced of the remaining output. The negative of the slope of this curve is called the marginal rate of transformation between a pair of products, which describes the ease that the resources used in the production of one can be transferred to the production of the other. This coefficient is given by

\[
(3.4) \quad \frac{\partial Q_i}{\partial Q_k} = \frac{\partial f}{\partial Q_k} > 0, \quad i \neq k = 1, \ldots, n.
\]

Writing equation (3.1) in the form of (3.3) implies a strong separability assumption on the technology; that is, \( f(Q_i) \) is strongly separable from \( X \), which means that all marginal rate of transformations \( \{\text{MRT}_{i,k}\} \) are
independent of the level of X. Although the restrictions involved in this transformation do not represent the most general case, we will work with them mainly because it yields tractable results and the data requirements on quantities and prices of the factors of production are not generally available.

The system of supply equations will be derived under the assumption that a competitive firm maximizes revenue given its transformation technology constraint. The microeconomic theory indicates that, in such a system, the price of outputs are given to the individual firm under the competitive market assumption, which implies that the firms know with certainty the set of prices that they will receive for their products, and also the theory implicitly indicates that firms react in a simultaneous way to the contemporary set of prices. But, in the real world, that is not always the case, especially in agricultural production, where prices are not so stable and the production process itself is constrained by biological factors. In view of this, we will assume that farmers react to expected prices instead of actual current prices, where the firm forms its expectations through an adaptive process.

Keeping this in mind, the maximization problem can be formulated by using the Lagrangian technique

\[(3.5)\quad L = P_1Q_1 + P_2Q_2 + \ldots + P_nQ_n + \lambda[X - f(Q_i)]\]

where

- \(P_i\) = expected price of the ith output,
- \(Q_i\) = ith output,
\[ \lambda = \text{Lagrangian coefficient, and} \]

\[ X = \text{composite factor.} \]

Solving the Lagrangian equation with respect to the exogenous variables \((P_i, X)\), one obtains the first order conditions (F.O.C.) for a maximization problem

\[
\begin{align*}
\frac{P_1}{\lambda f_1} &= 0 \\
\frac{P_2}{\lambda f_2} &= 0 \\
& \quad \ldots \\
\frac{P_n}{\lambda f_n} &= 0 \\
X - f(Q_i) &= 0
\end{align*}
\]

where \(f_i\) denotes the first derivative of \(f(\cdot)\) with respect to the \(i\)th argument.

The F.O.C. imply that in equilibrium, the marginal resource requirement \((f_i)\) must be proportional to the expected prices where the proportionality factor is \(\lambda\). Also, from the F.O.C. we can obtain the condition that at equilibrium the MRT \(\frac{MRT_i}{MRT_k}\) is equal to the price ratio

\[
\begin{align*}
(3.7) \quad \frac{MRT_i}{MRT_k} &= -\frac{\partial Q_i}{\partial Q_k} = \frac{\frac{f_i}{f_k}}{\frac{P_i}{P_k}} = \frac{P_i}{P_k}
\end{align*}
\]
The Lagrangian multiplier in this case represents the marginal revenue product of $X$, since, at equilibrium,

\begin{equation}
\frac{\partial R}{\partial X} = \lambda,
\end{equation}

where $R$ denotes the revenue function.

The same marginal revenue product of $X$ can be interpreted also as the shadow price of the composite factor, for we have from the F.O.C.

\begin{equation}
\lambda = \frac{p_1}{\frac{1}{x_1}} = \frac{p_2}{\frac{1}{x_2}} = \ldots = \frac{p_n}{\frac{1}{x_n}}.
\end{equation}

By applying the inverse function rule, we know

\begin{equation}
\frac{\partial Q_i}{\partial x_i} = \frac{1}{\frac{1}{f_i}}, \quad i = 1 \ldots n.
\end{equation}

Substituting

\begin{equation}
\lambda = p_1 \frac{\partial Q_1}{\partial X} = p_2 \frac{\partial Q_2}{\partial X} = \ldots = p_n \frac{\partial Q_n}{\partial X},
\end{equation}

which says that the value of the marginal product of the composite factor ($VMP_X$) must be equal to $\lambda$. At the same time, we know from profit maximization that the firm will use the input factor up to the point where the $VMP_X$ is equal to the factor price, thus leading to the
conclusion that $\lambda$ reflects the shadow price of that factor. Another interesting interpretation of $\lambda$ under the assumption of linear homogeneous production function, and for that matter, a long-run characteristic, it is that $\lambda$ is also the average revenue product of the aggregate factor

$$ (3.12) \quad \lambda X' = \frac{\sum_{i=1}^{n} P_i Q_i}{X} = \frac{P_1 Q_1 + P_2 Q_2 + \ldots + P_n Q_n}{X} $$

By applying the F.O.C. and the Euler theorem,

$$ (3.13) \quad \lambda \left( \frac{Q_1}{P_1} + \frac{Q_2}{P_2} + \ldots + \frac{Q_n}{P_n} \right) = \lambda. $$

Also, from the F.O.C. we can obtain the system of derived supplies and factor demand by applying the implicit function theorem; then,

$$ (3.14) \quad Q_1 = Q_1(P_1, P_2, \ldots P_n, X) \\
Q_2 = Q_2(P_1, P_2, \ldots P_n, X) \\
Q_n = Q_n(P_1, P_2, \ldots P_n, X) \\
P_{X} = P_{X}(P_1, P_2, \ldots P_n, X). $$

These derived functions are homogeneous of zero degree in output prices (Silberberg, 67).

Up to this point, the theory presented refers to a single firm supply; but for all practical purposes what we need is the market supply
for the different commodities. Following the lines of Just et al. (44), such a market supply is obtained by the horizontal summation of the individual firm supplies. By assuming perfect competition and the same technology for all firms, the change in producer surplus associated with a market supply curve has a willingness to pay interpretation.

Following Thirsk (70) and Van de Wetering (74) in looking for a more explicit form of the system (3.14), we differentiate each of the implicit functions with respect to the parameters

\[
\begin{align*}
\frac{dQ_1}{Q_1} &= e_{11} \frac{dP_1}{P_1} + e_{12} \frac{dP_2}{P_2} + \ldots + e_{1n} \frac{dP_n}{P_n} + e_{1X} \frac{dX}{X} \\
\frac{dQ_2}{Q_2} &= e_{21} \frac{dP_1}{P_1} + e_{22} \frac{dP_2}{P_2} + \ldots + e_{2n} \frac{dP_n}{P_n} + e_{2X} \frac{dX}{X} \\
&\ldots \\
\frac{dQ_n}{Q_n} &= e_{n1} \frac{dP_1}{P_1} + e_{n2} \frac{dP_2}{P_2} + \ldots + e_{nn} \frac{dP_n}{P_n} + e_{nX} \frac{dX}{X} \\
\frac{dP_X}{P_X} &= e_{PX1} \frac{dP_1}{P_1} + e_{PX2} \frac{dP_2}{P_2} + \ldots + e_{PXn} \frac{dP_n}{P_n} + e_{PXX} \frac{dX}{X}
\end{align*}
\]

where

- \( e_{ij} \) = supply elasticity with respect to \( j \)th price (i, \( i,j = 1 \ldots n \)),
- \( e_{iX} \) = output factor elasticity (\( i = 1 \ldots n \)),
- \( e_{PXj} \) = factor demand elasticity with respect to output prices (\( j = 1 \ldots n \)), and
- \( e_{PXX} \) = factor demand flexibility.
Letting the prices vary in turn and since the F.O.C. holds for any set of prices, then the effects on supply from these changes are obtained by total differentiation of the FOC.

\[
\begin{bmatrix}
0 & f_1 & f_2 & \cdots & f_n \\
f_1 & f_{11} & f_{12} & \cdots & f_{1n} \\
f_2 & f_{21} & f_{22} & \cdots & f_{2n} \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
f_n & f_{n1} & f_{n2} & \cdots & f_{nn}
\end{bmatrix}
\]

\[
\begin{bmatrix}
\frac{dP_X}{P_X} & \frac{1}{P_X} & \frac{dQ_1}{dP_1} & \frac{dQ_1}{dP_2} & \cdots & \frac{dQ_1}{dP_n} & \frac{dQ_1}{dX} \\
\frac{1}{P_X} & \frac{dP_X}{P_X} & \frac{dQ_1}{dP_1} & \frac{dQ_1}{dP_2} & \cdots & \frac{dQ_1}{dP_n} & \frac{dQ_1}{dX} \\
\frac{dQ_2}{dP_1} & \frac{dQ_2}{dP_2} & \frac{dQ_2}{dP_1} & \frac{dQ_2}{dP_2} & \cdots & \frac{dQ_2}{dP_n} & \frac{dQ_2}{dX} \\
\frac{dQ_n}{dP_1} & \frac{dQ_n}{dP_2} & \frac{dQ_n}{dP_n} & \frac{dQ_n}{dP_n} & \cdots & \frac{dQ_n}{dP_n} & \frac{dQ_n}{dX}
\end{bmatrix}
\]

\[
\begin{bmatrix}
0 & 0 & \cdots & 0 & 0 \\
1/P_X & 0 & \cdots & 0 & 0 \\
0 & 1/P_X & \cdots & 0 & 0 \\
\vdots & \vdots & \ddots & \vdots & \vdots \\
0 & 0 & \cdots & 1/P_X & 0
\end{bmatrix}
\]

If the second order conditions (SOC) are satisfied, then the principal minors of the bordered Hessian (BH) matrix alternate in signs (Henderson and Quandt, 36).
Following Allen (2), we define

\[ F = \text{determinant of the BH matrix,} \]
\[ F_0 = \text{cofactor of the element } 0 \text{ in } F, \]
\[ F_{ij} = \text{cofactor of the element } f_{ij} \text{ in } F, \text{ and} \]
\[ F_{Oj} = \text{cofactor of the element } j. \]

Then, the partial elasticity of substitution

\[ (3.17) \quad \sigma_{ij} = \frac{\sum_{i=1}^{n} Q_i f_i}{Q_i Q_j} \cdot \frac{F_{ij}}{F} = \sigma_{ji} \quad i, k=1 \ldots n. \]

equation (3.17) can be interpreted in the following way (Thirsk, 70). If \( \sigma_{ij} > 1 \), then a one percent increase in the output price ratio \( (p_i/p_j) \) will cause a larger than one percent increase in the ratio of output \( j \) to output \( i \), and the share of output \( j \) on total income will rise.

Holding the level of prices and the composite factor constant, except for one price, then the system (3.16) can be solved by applying Cramer's rule

\[ (3.18) \quad e_{ij} = \frac{\partial Q_i}{\partial P_i} \cdot \frac{p_j}{Q_i} = k_j \sigma_{ij} \quad (i \neq j = 1 \ldots n). \]

In the case of own price elasticity, the (3.18) becomes

\[ (3.19) \quad e_{ii} = -k_i \sigma_{ii}, \]

since, by SOC, the term \( \sigma_{ii} \) is negative (Allen, 2).
In the last two equations, the term \( k_i \) stands for the share of the \( i \)th output in total income; that is

\[
(3.20) \quad k_i = \frac{p_i q_i}{R}, \quad i = 1 \ldots n,
\]

such as

\[
(3.21) \quad \sum_{i=1}^{n} k_i = 1,
\]

which is true in the long-run scenario or under the assumption of linear homogeneity (Vazquez and Pau, 77; Allen, 2). We already know that \( P_X = P/X = \lambda \) which also implies

\[
(3.22) \quad R = P_X = P_1 Q_1 + P_2 Q_2 + \ldots + P_n Q_n.
\]

Therefore, we can rewrite (2.20) as

\[
(3.23) \quad k_i = \frac{f_i q_i}{X} \quad (i = 1 \ldots n).
\]

Equation (3.18) indicates that the partial price elasticity of the derived supply is proportional to the partial elasticity of substitution, where the proportionality factor is the share of the \( i \)th output on total income. Therefore, the product whose price increased it becomes more profitable than the others and it pays to substitute it for the others in
production \((-k_i \sigma_{ij}\)). The effect on the supply of the other outputs will depend on the sign of the cross partial elasticity of substitution \(\sigma_{ij}\); hence, we have two possibilities. First, if \(\sigma_{ij} > 0\), then the supply of the \(i\)th product will increase, which implies that the pair of products are complementary in production. On the other hand, if \(\sigma_{ij} < 0\), the supply of the \(i\)th output will decrease; thus, the \(j\)th commodity is a substitute for the \(i\)th product on production.

The partial elasticities of substitution are not independent from each other, in fact, there is a series of interesting relationships that set a series of constraints or restrictions on them. Allen (2) has demonstrated that

\[
(3.24) \quad k \sigma_{ij} = \frac{f_i}{Q_i} \frac{F_{ij}}{F}.
\]

But, also note that \(\sum_{j=1}^{n} f_j F_{ij} = 0\), since it is the product of \(f_j\) by an Allen cofactor. Thus, by adding (3.24) throughout the set of commodities, we have

\[
(3.25) \quad \sum_{j=1}^{n} k \sigma_{ij} = 0,
\]

which indicates that the weighted sum of the partial elasticities of substitution for the \(i\)th quantity supply is equal to zero, in other words the homogeneity assumption. By applying (3.18) and (3.19) we can express (3.25) in terms of elasticities
\[
\sum_{j=1}^{n} e_{ij} = 0 \quad i,j=1 \ldots n.
\]

Since \( e_{ii} < 0 \), then we have

\[
\sum_{j=1}^{n} e_{ij} > 0 \quad i\neq j=1 \ldots n,
\]

which implies that the cross price elasticities of supply could be positive or negative, but not all can be negative. In other words, not all products can be substituted on production.

Another interesting restriction comes from the symmetric condition of the partial elasticities of substitution. From (3.17), we know that \( \sigma_{ij} = \sigma_{ji} \), by using (3.18) and multiplying by the shares of the products in question then

\[
k_{i}e_{ij} = k_{j}e_{ji} \quad i\neq j=1 \ldots n,
\]

which is known as the symmetric condition. Substituting equality (3.28) into equality (3.26) and multiplying by \( k_{j} \), we get another set of restrictions:

\[
\sum_{j=1}^{n} k_{j}e_{ji} = 0 \quad j=1 \ldots n.
\]
So, for a given commodity, the weighted sum of the own effect and the effects caused on the other commodities by a change in its price should be equal to zero.

The output-factor elasticity, or the percentage change in the supply of the ith commodity resulting from one percentage change in the composite factor, holding the set of output prices constant is given by

\[ (3.30) \quad e_{ix} = \frac{\partial Q_i}{\partial X} \cdot \frac{X}{Q_i} = \frac{X}{Q_i} \cdot \frac{F_{oi}}{F} < 0. \]

The SOC does not determine the sign of this elasticity. But, if we apply the same definition that Hicks (38) used to classify the factor of production, then we may say that an output is inferior if its output supply decreases when factor usage increases at constant output prices. In other words, outputs can be classified as normal or inferior, according to whether their factor elasticity of supply is positive or negative. Even though, from (3.23) and (3.30), we obtain

\[ (3.31) \quad k_i e_{ix} = \frac{F_{oi}}{F} \quad i = 1 \ldots n, \]

but, since \[ \sum_{i=1}^{n} f_i F_{oi} = F, \] then we get the aggregation condition

\[ (3.32) \quad \sum_{i=1}^{n} k_i e_{ix} = 1 \quad (i = 1 \ldots n). \]
Equation (3.30) has a specific value under the assumption of linear
homogeneity, since under this assumption one can show by using Allen
methodology

\begin{equation}
F_{0i} = \frac{F_i}{F} k_i,
\end{equation}

which, by applying above equation on (3.30) jointly with (3.23), we get

\begin{equation}
e_{iX} = 1 \quad i=1 \ldots n.
\end{equation}

The above equation states that a percentage increase in the level of the
aggregate factor will increase the output supply of each of the
commodities in the same proportion. So, this condition rules out the
possibility of inferior goods.

The output price elasticity of the factor demand can be estimated by
using Cramer's rule on the system (3.16); then,

\begin{equation}
\frac{\partial \pi}{\partial p_i} \cdot \frac{1}{P_X} = \frac{1}{P_X} \frac{F_{i0}}{F} \quad i=1 \ldots n.
\end{equation}

But, since \( F_{i0} = Q_i F \), then

\begin{equation}
\frac{\partial \pi}{\partial p_i} \cdot \frac{1}{P_X} = \frac{Q_i}{P_X}.
\end{equation}
In elasticity form and by applying (3.22), then (3.36) can be rewritten

\[
(3.37) \quad \frac{\partial P_i}{\partial P_i} \ast \frac{1}{P_i} = k_i \quad i=1 \ldots n, 
\]

which says that one percent increase in any commodity price will increase its corresponding revenue share by the same percent.

The effect on the shadow price of the aggregate factor of one percent increase on the level of the same factor is given by

\[
(3.38) \quad e_{pXX} = X \frac{F_{00}}{F} = 0.
\]

It is equal to zero by the assumption of linear homogenous production function. This also implies that the price elasticity of the composite factor is perfectly elastic; thus,

\[
(3.39) \quad e_{xPX} = \frac{1}{X} \frac{F}{F_{00}} = \infty.
\]

Now, we are in a position to rewrite the system (3.16) in a more tractable way by applying the equations and identities defined in this section. So, we have
Since the system of derived supply equations has been established in a tractable empirical way, then our interest turns to the development of the demand system, so we can form a general equilibrium model.

The Demand System

The system of demand equations is deduced by applying the theory of consumer behavior which jointly with the theoretical assumptions specialize the structure of the problem. These assumptions are in general used for empirical purposes. That is, they are thought to be a plausible set of restrictions which, when imposed, result in a demand system that can be estimated using time series data in prices and income and consumption levels. To understand the behavioral implications as well as empirical implications of the restrictions, it is important to know the basics of the consumer theory.
This section presents a general review of the consumer theory following the lines of Hassan and Johnson (35) and Goldberger (31), with the main purpose of deriving the standard testable assumptions from the theory, since they will be used to verify if the demand system is in accordance with the theoretical model.

The assumptions about the consumer behavior are introduced into the theory of consumer demand through the specification of a utility function, which represents the level of satisfaction that an individual receives as a result of consuming a bundle of goods and services per unit of time. The utility function is denoted by

\[
U = U(q)
\]

where \( q = \begin{bmatrix} q_1 \\ \vdots \\ q_n \end{bmatrix} \) denotes a vector of n-elements representing the quantity purchased of the ith commodity per unit of time. The standard assumptions about the utility function such as strictly increasing, strictly quasi-concave and twice differentiable are also assumed in this study.

The utility function is maximized subject to a budget constraint

\[
Y = p'q.
\]

where \( p \) is an n-column vector of given prices and \( y \) is the given consumer income; this constraint states that all the available income is spent on the commodities chosen by the individual.
The constrained maximization of \( U = U(q) \) subject to \( y = p'q \) may be carried out with the aid of the Lagrangian multiplier. Thus, it can be formulated as

\[
(3.43) \quad \tilde{U}(q, \lambda) = U(q) - \lambda(p'q - y),
\]

where \( \lambda \) is the Lagrangian multiplier. Differentiating this equation with respect to the arguments \((q, \lambda)\), we obtain the FOC

\[
(3.44) \quad \frac{\partial \tilde{U}}{\partial q} = U_q - \lambda p = 0 \\
\frac{\partial \tilde{U}}{\partial \lambda} = p'q - y = 0,
\]

which represent the set of \( n+1 \) FOC in \( N+1 \) unknown parameters \((p, \lambda)\). These conditions ensure a global maximum by the negative definite of the Hessian matrix \((U)\)

\[
(3.45) \quad U = \begin{bmatrix}
U_{11} & U_{12} & U_{1n} \\
U_{21} & U_{22} & U_{2n} \\
U_{n1} & U_{n2} & U_{nn}
\end{bmatrix}
\]

where \( U_{ij} = \frac{\partial^2 U}{\partial q_i \partial q_j} \) represents the rate of change of the marginal utility of the \( i \)th commodity with respect to changes in the quantity consumed of the \( j \)th good. By applying the implicit function theorem, the system (3.44) can be solved uniquely for the \( q_i \) and \( \lambda \); then,
The demand function (3.46) denotes the quantity demanded of the ith good as a function of all prices and income. Showing as well that the marginal utility of income ($\lambda$), how the consumer evaluates changes on income, is governed by the set of commodity prices and the existing income level.

When a particular functional form is specified for the utility function, then one may be able to obtain an explicit functional form for the set of demand functions. However, general features can be identified regardless of the specific functional form of the utility function. Those features can be obtained by considering the consequences of parametric shifts in the FOC. Since we are mainly concerned with the theoretical restrictions on the elasticities of demand, these general features will be presented directly in elasticity form. Let us define first

\[
(3.47) \quad H = q^{-1} Q_p p
\]

be an \(nxn\) matrix of direction cross price elasticities of demand, and \(q, p\) are \(nxn\) diagonal matrix of quantities and prices, respectively; and, finally, \(Q_p\) is an \(nxn\) matrix with the ith row given by the derivatives of the demand function for the ith commodity with respect to each of the n prices. In scalar terms, equation (3.47) would be
The income elasticity of demand will be represented by an \( n \)-column vector of the form

\[
(3.49) \quad \eta_y = y^{-1} Q_y.
\]

\( Q_y \) is an \( n \)-component vector with elements defined as the partial derivatives of the \( n \)-demand functions with respect to income. In more familiar terms, the income elasticity is given

\[
(3.50) \quad \eta_{iy} = \frac{\partial q_i}{\partial y} \cdot \frac{y}{q_i}.
\]

Another useful expression that we will need in subsequent derivations is the expenditure proportion, or the proportion of income that the consumer spent on each commodity. This expenditure share is represented by an \( n \)-elements column vector

\[
(3.51) \quad w = y^{-1} pq = y^{-1} q_p.
\]

for a specific commodity \( (3.51) \) is then

\[
(3.52) \quad w_i = y^{-1}(p_i q_i) = \frac{p_i q_i}{y} \quad i=1 \ldots n.
\]
Since the budget shares should sum to one then it is useful to define an n-elements column vector of ones

\[(3.53) \quad \mathbf{1}' = [1 \ldots 1].\]

With these definitions on hand, we can obtain the behavioral restrictions of the demand function. The Engel aggregation condition may be obtained by differentiating budget constraint with respect to income, which can be expressed in matrix-elasticity form as

\[(3.54) \quad w' \eta_y = (y^{-1}p'q)(yq^{-1}Q_y)\]
\[= p'Q_y\]
\[= 1\]

or

\[\sum_{i=1}^{n} w_i \eta_{iy} = 1.\]

The Engel aggregation condition states that the weighted sum of the income elasticities should be equal to one. This condition just imposes one constraint on the system.

The second restraint is the Cournot condition, which is also obtained by differentiating the budget constraint with respect to the ith price.
\[ (3.55) \quad H'w = (pQ_p q^{-1}) (y^{-1} q_p) \]
\[ = y^{-1} pQ_p p \]
\[ = y^{-1} p(-q) \]
\[ = -w \]

or
\[ \sum_{i=1}^{n} w_i \eta_{ij} = -w_j \quad (j=1 \ldots n). \]

In the most common notation, the Cournot condition states that the weighted sum of the own and cross price elasticities with respect to a change in the jth price should be equal to the negative of the expenditure share on the same jth commodity. This condition imposes n-constraints on the system, one for each price.

The homogeneity condition may be derived by differentiating the demand equation with respect to its arguments; then,

\[ (3.56) \quad Hk = q^{-1} Q_p p k \]
\[ = q^{-1} Q_p p \]
\[ = q^{-1} (-Q_y y) \]
\[ = -\eta_y \]

or
\[ \sum_{j=1}^{n} \eta_{ij} = -\eta_{iy} \quad (j=1 \ldots n). \]
This condition implies that the consumer does not present money illusion; that is, the purchase decisions are made on the basis of relative prices and income. Another way of explaining the homogeneity conditions which is one of the most common in the economic literature is that the demand function is homogenous of degree zero in prices and income. It is safe to say that, for an equal proportional increase in all prices and income, the quantities consumed will remain unchanged. This condition by itself imposes n-restrictions on the model, one for each equation.

The last condition implicit in the FOC that will be obtained is the symmetric condition, which is based on the symmetric characteristics of the Hessian matrix \((U)\). In matrix-elasticity notation, we have

\[
(3.57) \quad w(H + \eta w') = (H' + \eta n')w
\]

\[
= [pQ_p q^{-1} + (y^{-1} pq)(yQ'_y q^{-1})] y^{-1} qp
\]

\[
= y^{-1} p(Q'_p + QQ'_y) p
\]

\[
= y^{-1} p(Q'_p + QQ'_y) p
\]

\[
= w(H + \eta \eta')
\]

or

\[
w_i(n_{ij} + n_{ij} w_j) = w_i(n_{ji} + n_{ji} w_i) \quad (i \neq j, 1 \ldots n).
\]

Note that \(w\) stands for an \(n\times n\) diagonal matrix of expenditure shares.

This condition indicates that the compensated cross price elasticities
should be the same. The number of restrictions implied by this condition are \((n^2-n)/2\) one for each combination of two commodities.

By total differentiation of the demand equations (3.46), we have

\[(3.58) \quad dq = Q_y dy + Q_p dp,\]

which can be rewritten in terms of logarithmic differentials and elasticities as

\[(3.59) \quad d \log q = n \log (d \log y) + H(d \log p).\]

By premultiplying (3.58) by \(q^{-1}\), then

\[(3.60) \quad q^{-1} dq = q^{-1} Q_y dy + q^{-1} Q_p dp = (q^{-1} Q_y y^{-1} dy) + (q^{-1} Q_p p^{-1} dp),\]

which is exactly the same as (3.59). Thus, (3.60) in scalar terms would be

\[(3.61) \quad \frac{dq_i}{q_i} = n_i y y^{-1} dy + \sum_{j=1}^{n} n_{ij} p_j p^{-1} dp_j \quad (i, j=1 \ldots n).\]

We can see from (3.61) that the general type of demand functions may be expressed in a more explicit way by using the concept of elasticity.

As was the case for the supply side, we have to move from the individual level to the market level. This movement can be done by defining the market demand of a commodity as the horizontal summation of
the individual consumer demands, who face the same market price. The aggregation also assumes identical and homothetic preferences, which leads to equal weights for welfare purpose (Just et al., 44).

Silberberg (67) has expressed that Slusky equation in elasticity form as

\[ \eta_{ij}^m = \eta_{ij}^c - w_j \eta_{iy}^c, \]

where \( m \) denotes the Marshallian type of price elasticity (money income held constant) and \( c \) stands for the compensated or Hicks price elasticity (real income held constant). Further, it is well-recognized (Currie et al., 25) that for welfare analysis the proper demand function to be defined is the Hicks-compensated one. Therefore, and by applying this relationship between elasticities to the ordinary demand (3.61), we are able to obtain the Hicks-compensated demand equation. For example, let us take just one commodity then

\[
\frac{dq_1}{q_1} = \left( \eta_{11}^c - w_1 \eta_{1y}^c \right) \frac{dP_1}{P_1} + \left( \eta_{12}^c - w_2 \eta_{1y}^c \right) \frac{dP_2}{P_2} + \ldots
\]

\[
... + (\eta_{1n}^c - \eta_{1y}^c) \frac{dP_n}{P_n} + \eta_{1y} \frac{dy}{y}
\]

\[
= \eta_{11}^c \frac{dP_1}{P_1} + \eta_{12}^c \frac{dP_2}{P_2} + \ldots + \eta_{1n}^c \frac{dP_n}{P_n}
\]

\[
+ (\frac{dy}{y} - w_1 \frac{dP_1}{P_1} - w_2 \frac{dP_2}{P_2} - \ldots - w_n \frac{dP_n}{P_n}) \eta_{1y}^c,
\]
where the last term of the right hand side is equal to zero by the definition of the budget constraint. Thus, the set of compensated demand equations would be represented by

\[ (3.64) \frac{dq_i}{q_i} = \sum_{j=1}^{n} \eta_{ij} \frac{dP_j}{P_j} \quad (i, j=1 \ldots n). \]

This is the type of demand that we will carry out throughout the analysis on this research.

The Multicommodity Equilibrium System

Having described the system of demand and supply equations, then the multicommodity equilibrium model is almost complete; what we need to define is the supply of the composite factor. For our purpose, the supply of the aggregate factor of production will be considered as perfect inelastic, implying that it does not react to changes of its own price. This assumption is justified on the grounds of lack of information to be able to estimate it. At the same time, we recognize the shortages imposed by this assumption. Van de Wetering (74) has indicated that this type of assumption is not a satisfactory one, since it implicitly assumes that production and consumption react more quickly to changes in the system than the factor supply. Also, the lack of responsiveness of the factor supply does not eliminate the possibility of shifting it by changes in commodity prices and factor income. Finally, we also are aware that the welfare results will be different under more price-responsiveness of the factor supply.
Another point to mention is the relationship between expected and the actual prices. The multiproduct equilibrium model to be developed in this section assumes complete certainty by all the economic units involved. The role that the expected prices account for is the short-run inflexibilities on production or technology, and it is assumed that on average the expected prices are equal to the actual prices.

With these two points in mind and assuming equilibrium in any of the markets, we can pull together the demand and supply systems and build a multicommodity equilibrium model with \( n+1 \) equations and \( n+1 \) unknowns \( (P_i, P_X) \), which in a matrix form would be

\[
\begin{align*}
\frac{dP_1}{P_1} & \quad \frac{dP_2}{P_2} \quad \cdots \quad \frac{dP_n}{P_n} & \quad \frac{dP_X}{P_X} & \quad \frac{dX}{X} \\
(\eta_{11} + k_1 \sigma_{11}) & \quad (\eta_{12} - k_2 \sigma_{12}) \quad \cdots \quad (\eta_{1n} - k_n \sigma_{1n}) & \quad 0 & \quad 1 \\
(\eta_{21} - k_1 \sigma_{21}) & \quad (\eta_{22} + k_2 \sigma_{22}) \quad \cdots \quad (\eta_{2n} - k_n \sigma_{2n}) & \quad 0 & \quad 1 \\
\cdots & \quad \cdots & \quad \cdots & \quad \cdots \\
(\eta_{n1} - k_1 \sigma_{n1}) & \quad (\eta_{n2} - k_2 \sigma_{n2}) \quad \cdots \quad (\eta_{nn} + k_n \sigma_{nn}) & \quad 0 & \quad 1 \\
-k_1 & \quad -k_2 \quad \cdots \quad \cdots \quad -k_n & \quad 1 & \quad 0
\end{align*}
\]
The determinant of the endogenous variables is not singular, since, by a property of them (Pasinetti, 58), we know

\[(3.66) \quad |n_{ij} - e_{ij}| \neq |n_{ij} - |e_{ij}|.\]

Besides knowing that the determinant of each individual system of compensated function are singular by the homogeneity assumption, this nonsingularity property allows us to analyze the effects of market distortions on the system by using absolute prices instead of relative ones. These types of models have been used by Johnson (41) and Hotelling (39) in analyzing the effects of market distortions.

Some market interventions will break the equilibrium conditions. Such is the case of controlled price policies. In this case, one of the equations describing the market in consideration has to be deleted from the system (3.65). That equation will depend on the type of policy intervention, if the price paid by consumers is the controlled variable, then the equation to be disregarded would be the demand for such a product. On the other hand, if the price received by farmers is the policy variable, then the supply equation is the one to be eliminated. Other types of policy intervention do not prevent the equilibrium condition to hold, such as the case of taxes, even though transformation in some of the variables is required. The model allows us to estimate the effects on the rest of the endogenous variables by a change in the policy variable, but carefully keeping in mind that it is held constant. These estimates will be called total elasticities coefficients (Van de
Watering, 75), since they reflect all the market adjustment after the change in the policy variable. For example, if one of the n+1 endogenous variables \( z^i \) is selected as a policy variable \( z^j \), then, by applying Cramer's Rule on the system (3.65), we can obtain the total elasticity coefficient:

\[
(3.67) \quad E_{z^i z^j} = \frac{|z^i|}{\Delta} \quad (i \neq j = 1 \ldots n+1),
\]

where \(|z^i|\) stands for the cofactor of the target variable and \(\Delta\) is the determinant of the resulting matrix of endogenous variables.

Furthermore, by taking an additional variable as exogenous \( z^k \), we can obtain the following elasticities.

\[
(3.68) \quad E_{z^i z^j} = \frac{|z^i|}{\Delta} \quad (i \neq j,k = 1 \ldots n+1)
\]

\[
E_{z^i z^k} = \frac{|z^i|}{\Delta} \quad (i \neq k)
\]

The determinants in (3.67) and (3.68) are not the same, since different variables are held constant. The above elasticities may be called partial total elasticities, since they rule out a market induced adjustment in what was initially an endogenous variable.

The last point, but not the least important, that we want to mention is the model stability of equilibrium. Allen (2) has worked out the
conditions of stability for a closed general market equilibrium. In our case, those conditions should be taken as guidelines since we do not have a closed system. Nevertheless, we think that they will provide useful results in considering the stability of the model.

Consider the case of \( n \) commodities markets, with the last one being numeraire \((p_n=1)\) and the rest of the prices are determined in market equilibrium by the excess supply equations \((n-1)\) of the form

\[
(3.69) \quad S_i - D_i = y_i - (x_i - \bar{x}_i) = 0 \quad i=1 \ldots n-1
\]

where \( S_i = y_i \) stands for the net quantity produced by the economy of the ith commodity. \( D_i = (x_i - \bar{x}_i) \) represents the net demand of the ith product. Here, \( y_i \) and \( x_i \) are functions of all prices and \( \bar{x}_i \) is the initial endowment which is given.

The equilibrium is stable if all prices, once disturbed, tend to return to their equilibrium values over time. Therefore, the stability condition can only be expressed in terms of a specified dynamic model of interrelated markets. Allen (2), taking from Samuelson (63), has indicated that the dynamic model for a system of interrelated marked follows the Walrasian dynamic condition, which can be expressed as

\[
(3.70) \quad \frac{dP_i}{dt} = -u_i (S_i - D_i) \quad i=1 \ldots n-1
\]

where \( u_i \) indicates the speed of adjustment on the several markets and
$S_i - D_i$ is given by (3.60). Writing $S_i$ and $D_i$ as linear functions in all prices then (3.69) can be restated as

$$S_i - D_i = \alpha_{i0} + \sum_{j=1}^{n-1} a_{ij} P_j \quad i, j=1 \ldots n-1 \tag{3.71}$$

In the above equation, $\alpha_{i0}$ is the constant term and the coefficients $a_{ij}$ represent the equilibrium value of the excess supply equation which can be expressed as follows

$$a_{ij} = \frac{\partial}{\partial P_j} (S_i - D_i) = \frac{3Y_i}{\partial P_j} - \frac{3X_j}{\partial P_j} \tag{3.72}$$

The dynamic condition (3.70) then can be rewritten as

$$\frac{dP_i}{dt} = -u_i \sum_j a_{ij} P_j \quad i, j=1 \ldots n-1 \tag{3.73}$$

Assuming that all the speed of adjustment are equal to one, then we have

$$\frac{dP_i}{dt} + \sum_j a_{ij} P_j = 0 \quad i, j=1 \ldots n-1 \tag{3.74}$$

These equations are to be solved for the paths of $P_i$ over time, which is given by
where $\lambda$ is a constant to be found and the $A$'s are also constant but given by the initial disturbance. Substitute in (3.74) we have

$$ (3.76) \quad \frac{1}{j} \left[ a_{ij} - \lambda \delta_{ij} \right] = \begin{vmatrix} a_{11} - \lambda & a_{12} & a_{1n-1} \\ a_{21} & a_{22} - \lambda & a_{2n-1} \\ a_{n-1,1} & a_{n-1,2} & a_{n-1,n-1} - \lambda \end{vmatrix} $$

where $\delta_{ij}$ is the kronecker delta. This system of homogenous equations must be satisfied by some nonzero set of $A$'s so that (3.75) holds.

The value of the $X$'s are given by (3.75) which are the same as the characteristic roots of the matrix $A = \begin{bmatrix} a_{ij} \end{bmatrix}$.

The equilibrium condition (3.69) is stable on the dynamic model (3.70) if the path of each price, given by (3.75), is such that $P_i \rightarrow 0$ as $t \rightarrow \infty$. This is possible only if all the characteristic roots $(\lambda_j)$ are positives. A negative and real $\lambda$ introduces a steadily explosive term. A particular case arises when the matrix $A = \begin{bmatrix} a_{ij} \end{bmatrix}$ is symmetric.\(^1\) Under these characteristics, all the principal minors of $A$ will have a real latent root and the symmetric discriminant $A = |a_{ij}|$ is

\(^1\)A symmetric matrix can be obtained by using compensated slopes or by neglecting the income effect as Hicks assumed.
positive definite, thus all the principal minors are also positive. It is under this specific circumstance that the Walrasian stability condition (all characteristic roots being positive) is the same as the Hicks stability condition (all principal minors are positive). If symmetry is lacking all that one can say about stability is that the roots (λ) must be all positives.
In this chapter, we are going to define the different concepts that are used in the welfare analysis of the different market interventions, basically concepts such as consumer and producer surplus. Even though the main focus of this discussion will be placed on the relationship between the different definitions of those concepts, and the market demand and supply functions.

The Consumer Surplus

Consumers' surplus is the mean used in applied empirical work to measure the consumer welfare and it is defined as the area under the demand curve and above the price line. There are at least two reasons why the change in consumer surplus is a good approximation to the change in the consumer welfare (Currie et al., 25): it represents the sum of cost differences as the price of the commodity is reduced (Hicks approach) and second, it also represents the change between what the consumer is willing to pay and what he actually paid (Dupuit approach). But, what this area really means has been the focus of a great discussion in the economic literature. The consumer surplus as an income-equivalent measure presents the problem that is not unique when we have simultaneous price-income or multiple price changes because of the path-dependent problem (Just et al., 44). That is, the change in surplus from the
sequence price-income is not the same as the change from the income-price sequence.

The consumer surplus measure may be unique under strong restrictions on the consumer preferences. In the case of price-income sequence, the change in surplus will be unique only if the income effect is null, and, in the case of multiple price change, the uniqueness condition is satisfied under the restriction that all income elasticities are equal to one. However, for a change in a subset of prices, the necessary and sufficient condition for the change in consumer's surplus being unique is that all the income elasticities must be equal, but not necessarily equal to one (Just et al., 44). Another important restriction on the consumer surplus as an income-equivalent measure is that it does not measure the true change in utility or standard of living of the consumer, just in the case when the marginal utility of income is constant. We want to emphasize that, in order to have a meaningful measure of the change in utility by using the concept of consumer's surplus, the latter condition should be satisfied, which also implies uniqueness. This relationship between these two problems is unidirectional, since uniqueness does not imply constancy of the marginal utility.¹

The economists, for all the above restrictions imposed on the consumer behavior, have developed alternative measures, which are not so stringent. Hicks (37) was one of the first to come up with such alternatives. He developed two concepts that are unique (path-independence) and

¹For mathematical proof, see Appendix B in Just et al. (44).
ordinarily related to utility (Just et al., 44). The first one is the compensating variation, which is the amount of income that must be taken away from the consumer after a price change such as the consumer is left in the original utility level. Equivalent variation is the second concept; it is the amount of income that must be given to the consumer in view of a price change, such as the individual is as well off as with the price change.

In order to apply these two concepts in empirical work, we have to define the differences between the Marshallian (ordinary) demand and the Hicksian (compensated) demand curve. The former gives the relation between quantities demanded and different levels of price, holding money income constant by varying the level of utility or real income. On the other hand, the Hicksian demand gives the same relationship, but holding constant the levels of utility by allowing the money income to change.

The relationship between these two demand curves and the welfare measurement related to them are described in Figure 4.1.

At the initial point \((P_1, Q_1)\), both curves the Marshallian demand \(D^M\) and the compensated demand \(D^H_1\) cross to each other. For a price decrease, the \(D^H_1\) lies below and to the left of the ordinary demand curve, and for a price increase, the reverse is true. If the market price is reduced to \(P_2\), the quantity demanded according with \(D^M\) would be \(Q_2\), which implicitly accounts for the income effect making the consumer able to obtain a higher utility level or standard of living. This change is represented by the areas \(a+b\), which is called the ordinary consumer's
surplus change. For the same reduction in price, the quantity demanded along $D_1^H$ is $Q_3$, which is lower than $Q_2$, reflecting the adjustment in money income (in this case taking away from the consumer) so that the consumer is left at the original utility level represented by $D_1^H$. Thus, the change in the Hicksian consumer's surplus or compensated variation is given by the area $a$.

The third measure or equivalent variation indicates how much income the consumer is willing to accept for not taking a price decrease but which will allow him to reach the same utility level as it would be by letting the price fall. This measure is represented by the areas $a+b+c$ under the compensated demand $D_2^H$. 

Figure 4.1. Relationship between the Marshallian and Hicksian demand curves
The ordinary consumer's surplus is bounded from the left by the compensating variation and from the right by the equivalent variation for a price decrease as it is deducted from Figure 4.1. To this respect, Hicks (37) indicated that, in some circumstances, we can accept the Marshallian measure of the consumer welfare as a good approximation for the true change in welfare. This can be done when the income share of the good in question is small or what is the same as low income elasticity. Therefore, areas b or c could be omitted under this particular assumption.

The Producer's Surplus

The most immediately appealing measure of producer welfare under profits maximization is the profit itself, where profits is defined as total revenue minus total cost. The problem with this type of measure is the lack of symmetry in the sense that it will not measure the true welfare change of a forced shutdown of a firm by a price decrease (Just et al., 44). Alfred Marshall (50) defined the producer surplus as

\[ \ldots \text{the excess of the gross receipts which a producer gets for any of his commodities over their prime cost, that is over the extra cost which he incurs in order to produce those things and which he could have escaped if he had not produced them.} \]

He also indicates that the measurement of this surplus is the area above the supply curve and below the price line. But, further developments in this field have shown that careful consideration has to be taken on the economic meaning of the area described by Marshall as producer surplus. For two points have to be clearly defined, what producer means and the time horizon. If producers are defined as the owner of the firm, where
firms stand for units producing intermediate or final goods, then the short-run supply of a profit maximization firm will be that portion of its marginal curve which is above its average cost curve. Then, by definition of short-run, one or more factors of production are fixed to the firm and by the assumption of competitive markets in both inputs and outputs, the area described by Marshall will, in fact, measure the producer welfare as measured by the producer's surplus or quasi-rent, since they reflect the rent accruing to them as the owners of those fixed factors and under this characteristic the producer's surplus or quasi-rent measurement are exactly the same to both the compensating variation and equivalent variation as willingness to pay measurements (Just et al., 44).

The short-run industry supply, which is the horizontal summation of the individual firm's supplies, the area above such a curve and below the price line reflects the aggregate quasi-rent received by the firms only in the case when the supplies of the variable factors of production are considered perfect elastic; in other words, the industry itself is considered a price taker in the variable input markets. In the long-run, the industry supply represents the locus of minimum average cost, since each firm in the industry is producing at its minimum average cost; thus, total revenue equals total expenses, meaning that the quasi-rent variable vanishes in the long run. Therefore, the relevant area under the long-run industry supply does not have any meaning in economic welfare (Currie

---

1 Quasi-rent is defined as total revenue less total variable cost.
et al., 25) so, the producer surplus concept under the definition of a producer as the owner of the firm is pretty much a short-run concept.

If the producer is defined as the owner of factor of production, then the relevant area above the long-run industry supply would have meaning in terms of producer welfare, only if this supply curve represents an average cost including economic rent\(^1\) and, at the same time, reflects a marginal cost curve excluding the economic rent (Mishan, 52). He also has pointed out that these characteristics are possible only in those cases where the rent is accrued only by a fixed single factor and the rest of them have a perfect elastic supply. Some examples indicated by them where the required characteristics of the long-run industry supply are met are the Ricardian model of economic rent to land. Another is drawn from Robinson (61), where a necessary input is considered almost price inelastic and the rest of factors of production are price elastic. In these cases, the area above the industry supply represents the rent to the owners of the fixed factor. Finally, Just et al. (44) have analyzed in detail the case of consumer-resource owners, where the individual maximizes his utility given the set of prices for his initial endowment and the set of prices of the consumption commodities; and, in this case also, the relevant area above the long-run industry supply has economic meaning.

\(^1\)The classical definition of economic rent is the payment of a factor of production over and above the minimum necessary to induce it to do its work (Currie et al., 25).
Multicommodity Equilibrium and Welfare Measurements

Under this section, we will analyze the relationship between the ordinary or compensated market demand and supply curves with the multicommodity equilibrium demand and supply schedules, as well as the relation and economic meaning of the areas behind those curves.

The market demand (supply) curve gives the different quantities demanded (supplied) at different prices holding all other prices constant. This is true whenever we are talking about ordinary or compensated market curves. On the other hand, the derived equilibrium demand (supply) gives the quantity demanded (supplied) at different levels of its own price, but after allowing equilibrium adjustment in all other related markets.

Before going on, we have to mention that the theoretical analysis that will be presented, pretty much follows the exposition made by Van de Wetering (76), where he proved the interesting conclusion that the net social welfare effect over the economy as a whole of an intervention in any single market can be measured completely in that market using equilibrium supply and demand curves of sufficient generality. In those instances where the welfare economist is more interested with overall effects, this conclusion saves him a lot of time and resources, since he does not have to go through all related markets measuring the welfare effects caused by a single market distortion.

The way that we are going to pursue the analysis will be to divide the economy in its two major components, the demand side and the supply
side. For each one, we will establish the required theoretical background necessary to prove the relations between the areas enclosed by the demand and supply curves. Once the analysis has been carried out for both sides of the economy, we will pull them together and obtain the relationship between areas under a general equilibrium framework.

The Welfare Analysis of the Producer Side

We will restate the firm maximization problem developed in Chapter 3, with the idea of formally developing the willingness to pay measurements and their relations among the different markets. For we are most interested in the dual properties of the model.

We will carry on all the basic assumptions of the model; that is, a revenue maximization firm which uses in the production process a single aggregate input and which is constrained by the technology represented by the implicit production function which is assumed to be linear homogenous.

For simplicity in the mathematical exposition, we will assume that the firm produces just two commodities where the results so obtained are readily applicable to the n-commodity case. The derived supplies (3.14) obtained from the revenue maximization problem can be applied to the total revenue equations (3.22) to obtain the indirect revenue function.

\[
(4.1) \quad R^*(P_1, P_2, X) = P_1Q_1^*(P_1, P_2, X) + P_2Q_2^*(P_1, P_2, X).
\]
By the envelop theorem, we have

\[
(4.2) \quad \frac{\partial R^*}{\partial P^*_1} = \frac{\partial L}{\partial P^*_1} = Q^*_i(P_1, P_2, X) \quad i = 1,2.
\]

\[
\frac{\partial R^*}{\partial X} = \frac{\partial L}{\partial X} = \lambda = \lambda^*(P_1, P_2, X).
\]

Partial differentiation of the indirect revenue function with respect to output prices \(P^*_1\) yields the compensated output supplies \(Q^*_i\), compensated since the firm is restricted to make the price adjustments along the same transformation curve. Partial differentiation of \(R^*\) with respect to the aggregate factor \(X\) yields the marginal revenue function for the composite factor.

We have shown in (3.8) and (3.12) that under the assumption of linear homogenous transformation function, \(\lambda\) is equal to the marginal revenue as well as the average revenue.

\[
(4.3) \quad \lambda = \frac{\partial R^*}{\partial X} = \frac{R^*}{X}.
\]

Upon rearrangement of (4.3), we obtain an equality between two partial differential equations

\[
(4.4) \quad \frac{\partial R^*(P_1P_2X)}{R^*(P_1P_2X)} = \frac{\partial X}{X}.
\]
Integration of both sides, with output prices held constant, we get the multiplicatively separable indirect revenue function (Silberberg, 67).

\( R^* = X \cdot H(p_1, p_2). \)

Applying the envelop theorem to (4.5), we have two multiplicatively separable output supply function.

\[ \frac{\partial L}{\partial p_1} = \frac{\partial R^*}{\partial p_1} = Q_1^*(p_1, p_2 X) = X \cdot \frac{\partial H(p_1, p_2)}{\partial p_1} \]

\[ \frac{\partial L}{\partial p_2} = \frac{\partial R^*}{\partial p_2} = Q_2^*(p_1, p_2 X) = X \cdot \frac{\partial H(p_1, p_2)}{\partial p_2} \]

Differentiating (4.1) with respect to aggregate factor, we obtain a marginal revenue function which is input (scale) independent.

\[ \frac{\partial L}{\partial X} = \frac{\partial R^*}{\partial X} = \lambda^*(p_1, p_2 X) = H(p_1, p_2) \]

for a competitive industry, marginal revenue equals marginal cost.

\[ P_X = H(p_1, p_2) \]

\( Q_1^*, Q_2^* \) and \( H \) characterize the revenue maximization behavior of the joint product firm. In order to determine the competitive equilibrium of
the industry, it is necessary to introduce three additional relationships. The commodity supply equations must each be complemented by a commodity demand equation. The implicit factor demand equation must be complemented by a factor supply equation.

This system of six equations is represented in Figure 4.2.

Figure 4.2. Basic geometric properties of the 2x1 model
Each of the three markets contains an exogenously given, unstarred, relationship and a counterpart endogenously derived, starred, relationship. The derived commodity supply function $S^*(Q_i)$ is written as

\[(4.9) \quad Q_i = Q_i[P_i, P_j(P_i), P_X(P_i)] \quad i,j=1,2,\]

so as to emphasize that along the general equilibrium supply $S^*(\cdot)$, the remaining commodity markets and the factor market are in continuous equilibrium. This implies that the equilibrium prices in those markets are subject to change when moving along $S^*(\cdot)$. Similar interpretation is to be given to the derived factor demand $D^*(X)$.

In what follows, it is assumed that the exogenously specified commodity demand curves $D(Q_i)$ and the factor supply curve $S(X)$ are specified such that the areas under (or above) these curves represent willingness to pay measures. This implies that the demand curves should be compensated demands for the case of final goods, or they could be ordinary demands if the commodity is an intermediate output, since the area below the demand will represent quasi-rent for the consumer industry. The factor supply should be a compensated supply for the case of consumer-resource supplier or an ordinary supply if the input is considered an intermediate factor of production; in both cases, the area above the supply will represent factor rents for the supplier industry. Finally, it is assumed that the commodity demands and the factor supply are just functions of their respective prices.
\[(4.10) \quad D(Q_i) = Q_i(p_i) \quad i=1,2\]

\[S(X) = X(p_X)\]

Let the symbol \( M \) represent the sum of areas \( a, c \) (consumer's surplus) and \( f \) (factor rents).

\[(4.11) \quad M(Q_1, Q_2) = a + c + f.\]

The money measure \( M \) is a function of outputs \( Q_1 \) and \( Q_2 \), because the choice of the latter dictates factor demand \( X \). Given output and factor levels, the corresponding equilibrium prices \( p_1, p_2, p_X \), as well as triangles \( a, c \), and \( f \), are determined. Given linear homogeneity and revenue maximization, Van de Wetering (76) has demonstrated that the competitive equilibrium of the industry maximizes the money measure \( M \). Conversely, if an auctioneer or planning authority wants to maximize \( M(p_1, p_2) \), it should set price \( p_1 \) and \( p_2 \) such that the dual set of efficiency conditions (4.6) and (4.7) are satisfied.

The following geometric properties of the 2x1 model will be proved following the Van de Wetering procedure.

1) The area above the derived supply curve (and below the price line) equals the sum of consumers' surplus and factor rents in the related markets.

2) The area below the derived factor demand (and above the price line) equals the sum of consumers' surpluses in related markets.
The first proposition implies that the sum of willingness to pay measures \( M \) can be measured as the area enclosed between a commodity demand and derived supply in Figure 4.2. Thus,

1.1) If \( b = c + f \), then \( M = a + b \);
1.2) If \( d = a + f \), then \( M = c + d \).

The second proposition also indicates that \( M \) can also be measured in the factor market as the area enclosed between the factor supply and derived factor demand.

2.1) If \( e = a + c \), then \( M = e + f \).

What these two propositions are stating is that the welfare position of all the consumers as well as of all the producers are captured in any one of the interrelated markets.

The assumed equality \( b = c + f \) can also be expressed using integral notation.

\[
\begin{align*}
(4.12) \quad \int_{P_1}^{P_2} Q_1 P_1 \, dP_2 &= -\int_{P_1}^{P_2} Q_2 P_2 \, dP_2 \\
&\quad + \int_{P_X}^{P_X} X P_X \, dP_X
\end{align*}
\]

The limits of \( P_2 \) and \( P_X \) represent the constant intercepts of \( D \) and \( S(X) \) with their respective price axes. Substituting these values in the marginal revenue function \( P_X = H P_1 P_2 \), we can obtain the corresponding
lower limit $\bar{P}_1$ of the left-hand side integral. The integral of area c is
preceded by a negative sign because of the interchange of $\bar{P}_2$, which
appears as an upper limit in Figure 4.2, to a lower limit in the
corresponding integral. The upper limits are considered a function of
$P^1$. In Chapter 3, the multicommodity equilibrium model (3.65) can be
used to obtain analytical expressions which can be used to determine
those upper limits. Of course, the output demands have to be considered
as given.

Differentiation of the left and right hand side integrals with
respect to upper limit $P^1$ yields

\begin{equation}
Q_1 P^1 P^2 P_X P^1 = -Q_2 D \frac{dP_2}{dP^1} + X^S \frac{dP_X}{dP^1}.
\end{equation}

Rewriting this, we obtain

\begin{equation}
Q_1^S dP^1 + Q_2^D dP_2 = X^S dP_X.
\end{equation}

By differentiating the competitive equilibrium condition for the
industry (4.8), we have

\begin{equation}
dP_X = \frac{H}{P^1} dP^1 + \frac{H}{P^2} dP_2.
\end{equation}

Premultiplication by $X^D$ and using (4.6) yields

---

1 The superscripts D and S are used to discriminate between
counties demanded or supplied.
\[ (4.16) \quad X^d P_X = Q_1^s P_1 + Q_2^s P_2. \]

But, by the assumption, all markets are in continuous equilibrium, 
\[ Q_1^d = Q_2^s, \quad Q_2^d = Q_2^s, \quad X_1^d = X_2^s, \]
then upon substitution on (4.16),

\[ (4.17) \quad S^d P_X = Q_1^s P_1 + Q_2^d P_2, \]

which is exactly the same as (4.14), which was obtained by integrating 
the areas \( b = c + f \).

The quality \( e = a + c \) in Figure 4.2 using integral notation appears as

\[ (4.18) \quad \int_{P_1}^{P_X} X[p_1(P_1),P_2(P_1)] dP_X = - \int_{P_1}^{P_2} Q_1(P_1) dP_1 \]
\[ - \int_{P_2}^{P_X} Q_2(P_2) dP_2. \]

The lower limits \( \bar{P}_1, \bar{P}_2 \) are the constant intercepts of \( D(Q_1) \) and 
\( D(Q_2) \) in their respective price taxes. Substitution of these values in 
\( P_X = H(P_1 P_2) \) will yield the lower limit \( \bar{P}_X \). The upper limits are defined 
as functions of \( P_X \); analytical expression for them can be obtained from 
(3.65).

Differentiating (4.18) with respect to \( P_X \), we have

\[ (4.19) \quad X^d(P_X) dP_X = Q_1^d(P_1) dP_1 + Q_2^d(P_2) dP_2. \]
Again, by using the revenue maximization conditions (4.6), we can obtain (4.16), which jointly with the assumption of competitive equilibrium in all markets, we ended up with two differential equations (4.19) and (4.16), which must hold simultaneously.

Based on the relations among the relevant areas of a system of interrelated markets, then the next step is to analyze those relationships under the effect of a market policy measure. Let us assume that a unit tax on joint product $Q_2$ in Figure 4.3 is established. In a two-goods world, the supply of $Q_1$ will shift to the right and the derived factor demand will decrease.

By proposition (1), the change $\Delta M$ can be measured most conveniently in the distorted market as

$$\Delta M = (c_2+c_3) + (d_1+d_2).$$

But, $M$ also measures the area enclosed between the demand and supply curves in the remaining markets. Then,

$$\Delta M = b_2 + b_4 = e_2 + f_2.$$  

According to the definition of $M$ in (4.11), it can be restated to include the areas of Figure 4.3 before tax as follows:

$$M^0 = a_1(c_1+c_2+c_3) + (f_1+f_2+f_3).$$
After tax, we have

$\frac{1}{e}(4.23) + c^2 + f^2$.

Figure 4.3. Welfare effect of a tax on a joint product

After tax, we have

$M^1 = a + (b_1 + b_2) + c_1 + f_3$. 
The effect of the tax policy on the money measure $M$ is then obtained by subtraction.

\[(4.24) \Delta M = M^1 - M^0 = (b_1 + b_2) - (c + c_3) - (f_1 + f_2).\]

The measure $\Delta M$ indicates the presence of three components. A gain in consumers' surplus by the users of $Q_1$ given by $(b_1 + b_2)$. A loss in consumers' surplus by the users of the taxed commodity $Q_2$ represented by the areas $(c + c_3)$ and, lastly, the loss in factor rents by the suppliers of $X$; loss represented by $(f_1 + f_2)$.

The loss in factor rents on the input markets $X$, as well as the loss in consumers' surplus on the taxed commodity $Q_2$, can be measured in any of the markets. In the commodity market for $Q_1$, the factor rents before taxes is obtained by apply proposition (1).

\[(4.25) (b_1 + b_3) = (c_1 + c_2 + c_3) + (f_1 + f_2 + f_3).\]

After the imposition of the tax,

\[(4.26) (b_3 + b_4) = c_1 + f_3.\]

By subtracting (4.25) from (4.26),

\[(4.27) (b_4 - b_1) = -(c_2 + c_3) - (f_1 + f_2).\]
The change in area under the derived supply \( S^*(Q_1) \) is equal to the sum of the change in consumers' surplus in the taxed commodity plus the change in factor rents on the factor market.

On the factor market \( X \) and by applying the second proposition, the consumers' surplus area before taxes is given by

\[
(4.28) \quad (e_1 + e_2) = a + (c_1 + c_2 + c_3).
\]

After tax, we have

\[
(4.29) \quad (e_1' + e_2') = (a + b_1 + b_2) + c_1.
\]

Subtracting (4.28) from (4.29),

\[
(4.30) \quad (f_1 - e_2) = (b_1 + b_2) - (c_2 + c_3).
\]

Therefore, the change in area of the triangle under the derived factor demand curve \( D^*(X) \) equals the sum of the changes in consumers' surpluses of related markets.

The economic meaning of the areas between demand and supply curves in the distorted market can also be analyzed by applying proposition 1. Thus, the factor rents before taxes is as

\[
(4.31) \quad (d_1 + d_2 + d_3) = a + (f_1 + f_2 + f_3).
\]
After tax,

\[(4.32) \quad d_3 = (a+b_1+b_2) + f_3.\]

By subtraction, we have

\[(4.33) \quad -(d_1+d_2) = (b_1+b_2) - (f_1+f_2).\]

The change in the area above the derived supply \(S^*(Q_2)\) is equal to the sum of the change in consumers' surplus in the commodity market \(Q_1\) plus the change in factor rents in the input market \(X\). This indicates that all the private welfare effects are captured in the distorted market. Such a private welfare effect constitutes a loss given by (3.20). The revenue is accrued by the government; such a revenue is represented by the area

\[(4.34) \quad tR = c_2 + d_1.\]

If we subtract the tax revenue from the private welfare loss, we obtain the social efficiency loss

\[(4.35) \quad w = c_3 + d_2.\]
The Welfare Analysis of the Consumer Side

On this side of the model, the relevant functions are obtained by making use of the dual properties of the model presented in Chapter 2. That is by differentiating the indirect expenditure function with respect to commodities prices and factor prices, we obtain the compensated commodities demands and the compensated factor supply (Mishan, 52).

Due to the parallelism of the consumer model with the one presented for the producers, we are going to skip the mathematical background and focus our attention to the geometric properties.

The derived commodity demands and factor supply have to be matched with their corresponding commodities supplies and factor demand to be able to reach the industry competitive equilibrium. Again, it is assumed that the last two functional relationships are given and sole function of their respective prices. For a two commodities world, we have the following system of equation.

\[(4.36) \quad D^*(Q_1) = Q_1 \left[ P_1 P_2 (P_1) P_X (P_1) \right] \]
\[\quad D^*(Q_2) = Q_2 \left[ P_1 P_2 (P_2) P_X (P_2) \right] \]
\[\quad S^*(X) = X \left[ P_1 (P_X) P_2 (P_X) P_X \right] \]
\[\quad S(Q_1) = Q_1 (P_1) \]
\[\quad S(Q_2) = Q_1 (P_2) \]
\[\quad D(X) = X (P_X).\]
The superscript, starred, functions denote multicommodity equilibrium equations which allow for adjustments in all related markets. In this case, the symbol "X" denotes the factor of production supplied by the consumers.

The system (4.36) is represented in Figure 4.4.

Figure 4.4. Welfare effects of a commodity tax in a system of interrelated markets.
The triangle $(e_3 + e_4 + e_5)$ will represent a money measure of welfare, since that area expresses the factor rents of the industry demanding the input $X$.

$Q_1$ may be thought of as an output produced by firms having one or more fixed factors of production with all other factors required in the production of $Q_1$ available at constant prices. The commodity supply $S(\cdot)$ then represents an ordinary supply curve for the industry producing $Q_1$ and the area above this supply represents quasi-rent accruing to the fixed factors. If the variable inputs used on production are available only at increasing cost, then the commodity supply $S(\cdot)$ will represent the derived supply curve $S^*(\cdot)$ for the industry producing $Q_1$. The area above this curve will measure not only quasi-rents accruing to firms producing $Q_1$, but also quasi-rents accruing to the firms producing the variable inputs used in producing $Q_1$ (Van de Wetering, 76).

Applying the same procedure presented in the last section, one can demonstrate the following propositions.

1) The area below the derived commodity demand (and above the price line) equals the sum of consumers' surplus and factor rents in the related markets.

2) The area above the derived factor supply (and below the price line) equals the sum of factor rents in the related markets.

The first proposition implies that, in Figure 4.4, the sum of the willingness to pay measures $M = (e_3 + e_4 + e_5) + (d_1 + d_2 + d_3) + b_5$ can be measured as the area enclosed between a derived commodity demand and the supply curve.
1.1) If \((a_1 + a_3) = (e_3 + e_4 + e_5) + (d_1 + d_2 + d_3)\)

then \(M = (a_1 + a_3) + b_5\).

1.2) If \((c_1 + c_2 + c_3) = (e_3 + e_4 + e_5) + b_5\)

then \(M = (c_1 + c_2 + c_3) + (d_1 + d_2 + d_3)\).

The second proposition implies that \(M\) can also be measured in the factor market as the area enclosed between the derived factor supply curve and the factor demand curve.

2.1) If \((f_4 + f_5) = b_5 + (d_1 + d_2 + d_3)\)

then \(M = (e_3 + e_4 + e_5) + (f_4 + f_5)\).

Knowing the relation between the areas in Figure 4.3, we want to analyze the effects on those areas by the imposition of a market policy. Let us consider the introduction of a tax per unit of \(Q_2\) supplied. In Figure 4.3, the derived factor supply will shift to the left, since the effective price for the consumers is the equilibrium price plus the corresponding share of the tax, making the price of the factor supplied by them to increase. If the sum of the elasticity of commodity substitution and the price elasticity of demand for the factor of production \(X\) is positive, then the derived demand curve \(D^X(Q_2)\) will shift to the right (Van de Wetering, 74).

The change in the money measure, \(\Delta M\), in the distorted market \((Q_2)\) is given by.
\[ (4.37) \quad \Delta M = (c_2 + c_3) + (d_1 + d_2). \]

The same measure, but in market one \((Q_1)\)

\[ (4.38) \quad \Delta M = a_2 + a_4. \]

In the factor market, we have

\[ (4.39) \quad \Delta M = e_3 + f_5. \]

We have defined \(M^0\) (before tax) as

\[ (4.40) \quad M^0 = (e_3 + e_5 + e_5) + (d_1 + d_2 + d_3) + b_5. \]

The same money measure, but after tax, is given by

\[ (4.41) \quad M^1 = e_3 + d_3 + (a_3 + a_4) + b_5. \]

The effect of tax on \(M\) is then obtained by subtracting \(M^0\) from \(M^1\).

\[ (4.42) \quad \Delta M = M^1 - M^0 = -(e_4 + e_5) - (d_1 + d_2) + (a_3 + a_4). \]

From this equality, we see that the effect of a tax on the money measure \(M\) which may serve as a social benefit indicator of the changes in resource allocation induced by the distortion, it is formed by three elements; the user of the factor of production \(X\) suffers a decrease in
the willingness to pay measure of consumers' surplus given by \((e_4 + e_5)\). The producer of the taxed commodity \((Q_2)\) also suffers a loss in the factor rents given by \((d_1 + d_2)\) and, finally, the procedures of commodity \(Q_1\) registered a gain in factor rents represented by \((a_3 + a_4)\).

The consumers' surplus loss on factor \(X\) and producers' surplus loss on commodity \(Q_2\) can be captured in any of the other markets. In the commodity market \(Q_1\) the consumers' surplus before tax is given by (1.1), the same measure but after tax is then

\[
(4.43) \quad (a_1 + a_2) = e_3 + d_3.
\]

By subtraction, we have

\[
(4.44) \quad (a_2 - a_3) = -(e_4 + e_5) - (d_1 + d_2).
\]

Thus, the change in the area under the derived commodity demand \(Q_1\) equals the sum of the change in consumers' surplus on the factor market \(X\) plus the change in factor rents on commodity market \(Q_2\).

On the factor market \(X\), the producers' surplus before tax was defined in (2.1). After tax, this area is equal to

\[
(4.45) \quad (e_4 + f_4) = d_3 + (a_3 + a_4) + b_5.
\]

By subtraction, then, we have
Therefore, the change in the area above the derived factor supply $S^*(X)$ is equal to the sum of the change in factor rents on the remaining of the markets $(Q_1, Q_2)$.

Now, we turn our attention toward the distorted markets $(Q_2)$. The consumers' surplus for this market and before tax is defined in (1.2); the same measure, but after tax is

(4.47) $c_1 = e_3 + (a_3 + a_4) + b_5$.

Again, but subtraction, we have

(4.48) $-(c_2 + c_3) = -(e_4 + e_5) + (a_3 + a_4)$.

Thus, the change in the area below the derived commodity demand $D^*(Q_2)$ is equal to the sum of the change in consumers' surplus on the factor market plus the change in factor rent on the commodity market $Q_1$. In other words, all the private welfare effects can be measured in the distorted market.

In the same market $Q_2$, the private welfare loss ($\Delta M$) is given by (4.37), but, at the same time, the government receives some revenue from the tax policy; such a revenue is represented by

(4.49) $tR = c_2 + d_1$. 
Subtracting the tax revenue from the private welfare loss, we obtain the dead weight loss or social efficiency loss.

\[(4.50) \quad w = c_3 + d_2.\]

We have demonstrated all the relations between the areas enclosed under and above the demand and supply curves in a system of interrelated markets for both sides of the economy. What we need now is to put both systems together and, in doing so, we are going to get a complete multi-commodity equilibrium model where all the equations in the system are fully specified, that is there are no equations which are exogenous or given to the system. This system of equations can be formulated as

\[
\begin{align*}
D^*(Q_1) &= Q_1 [P_1 P_2 (P_1) P_X (P_1)] \\
S^*(D_1) &= Q_1 [P_1 P_2 (P_1) P_X (P_1)] \\
D^*(Q_2) &= Q_1 [P_1 (P_2) P_2 P_X (P_2)] \\
S^*(Q_2) &= Q_2 [P_1 (P_2) P_2 P_X (P_2)] \\
D^*(x) &= x [P_1 (P_X) P_2 (P_X) P_X] \\
S^*(x) &= x [P_1 (P_X) P_2 (P_X) P_X],
\end{align*}
\]

where the star superscript means derived equilibrium demand (D*) and supplies (S*).
We are interested in the welfare significance of the areas enclosed between the derived demand and supply of the distorted market. This market is represented in Figure 4.5.

Note that the derived demand and supply curves (Figure 4.5) do not shift with the imposition of a tax on the commodity; this happens because those curves reflect continuous equilibrium in all related markets or, in other words, all prices are allowed to adjust to a new equilibrium along both of those curves.

The change in the money measure $\Delta M$ or the social indicator of the resource allocation measured in the distorted market is given by

$$\Delta M = (c_2 + c_3) + (d_1 + d_2).$$

But, what does the area $(c_2 + c_3)$ mean? The answer is given by (4.48) by

Figure 4.5. Welfare effect of a tax under a multicommodity equilibrium framework
which we know that this area is equal to the change in consumers' surplus on the factor market plus the change in factor rents on related commodity markets. The answer for the same question, but with respect to the second term in the right-hand side of (4.51) is given by (4.33) from which we know that this area represents the change in consumers' surplus on the related commodity markets plus the change in factor rents on the input markets.

The effect of the tax on the social indicator was defined in (4.24) for the supply side of the model and in (4.42) for the demand side. If we substitute (4.33) on (4.24) or substitute (4.48) on (4.42), we obtain in either case (4.51). This indicates that all the changes on private welfare are completely captured in the distorted market. The same argument implies that these welfare measures, consumers' surplus, factor rents, as well as the money measure M should be taken as net overall effects. These same results were obtained by Just et al. (44) and Harberger (33), but without formally demonstrating the relation between the relevant areas.

Finally, note that the dead weight loss area defined by (4.35) and (4.50) are exactly the same.

One point worth mentioning is that, by using compensated curves, any redistribution of the government revenues back into the economy will not affect the market curves nor the derived curves, since they do not account for changes on the money income.

Lastly, the change in consumer surplus under a general equilibrium demand curve cannot be associated directly with the welfare of the final
consumers or industries using it as an input. Neither the change in producer's surplus under a derived supply can be associated directly with the welfare of producer or resource owners. Because what we are measuring is the overall effect, not just the consumer or producer welfare effect.

The latter paragraphs have been dealing with the introduction of a price policy on an economy which is free of any distortion on any other market. This characteristic is not common in the real world. It is normal to find several distortions, especially in the agricultural sector, by which the government tries to accomplish different policy objectives. Therefore, it is interesting to analyze what possible effects of a new proposed policy will have on the different welfare measurements given a possible set of distortions already in place on related markets. Harberger (33) has analyzed this type of problem and he has concluded that, under certain considerations, explicit measures of welfare are only required in the target market. Just et al. (44), in the Appendix D of their book, analyzed in a rigorous way what are those specific characteristics. If the change in price or quantity in one market does not affect the level of the policy variable in the other distorted markets, and assuming equilibrium in all markets before and after the change in policy, then they concluded that for a distortion of the type of an ad valorem tax, subsidy, and price stabilization through buffer stocks, all the private effects (consumer and producer welfare) are captured completely in the market where the distortion is introduced, only if the derived curves are the ones used in the analysis. The net
social welfare effect (private plus government) can be obtained only if the change in government revenues or costs on the other distorted markets are taken into account. This can be done by measuring that change on those affected distorted markets by using their respective general curves. For the case of price floor or price ceiling policies with efficient rationing mechanism, the effect on the private groups has to be analyzed in each market affected. Finally, in the case of a quota, all the welfare effects are captured in the market for which the policy is aimed.

Welfare Measures of Single Policy Interventions

Developing countries often use market interventions as a means to ensure cheap food prices for the urban population and, at the same time, ensure a reasonable return to the producers.

There are several ways upon which the same policy objectives can be achieved; thus, it is important for the decision-maker to have different alternatives from which to choose the one which is most suitable in terms of the welfare of the society as a whole. Clearly, the final decision depends upon the value judgment of the decision-maker. But, the welfare economist can help by evaluating the different alternatives, a process that involves the measurements of the changes in the welfare of the private groups, as well as changes in the government revenue or expenses.

Efficiency rationing is defined so that the consumer (suppliers) gaining access to the market are those willing to pay more (receive less) at the margin than those who do not (Just et al., 44).
In this section, we will focus on the actual measurement of those changes, using the compensating variation measure as reflecting the willingness to pay.

**Price Control**

Price ceilings the first market policy to be analyzed. Where this policy represents the case when the government sets the market price lower than the equilibrium price. The welfare effects can be measured under two assumptions by allowing an efficiency rationing and/or allowing the government to intervene in the market by supplying the excess quantity demanded, which, for most of the case, that quantity is equal to imports. Figure 4.6 reflects both cases.

Assuming an initial general equilibrium represented by $P_0Q_0$ (Figure 4.6), then allowing the government to put a price ceiling equal to $P_1$. The producers will supply only the quantity $Q_1$, which represents the quantity available to consumers, requiring at the same time the imposition of a rationing system, or the other alternative is that the government supplies the excess demand $(Q_2 - Q_1)$ by importing the same quantity.

From Figure 4.6, the initial consumer's surplus is given by the areas $a+b+c$; after the price change, the same surplus is $a+b+d$, when efficiency rationing is imposed. The net effect on consumers will be the gain of area $d$ minus the loss of area $c$. 
On the supply side, the initial producer's surplus is equal to the sum of d+e+i; after introducing the price floor policy, the same area is given by the triangle i. The net effect on producers will be a loss of areas d+e. At this point, it is important to remember that these areas do not just reflect the welfare effects on the economics agencies involved in this particular market; rather, they reflect the net effects on consumers and producers in all the markets affected by this policy.

The net welfare effect to the economy is given by the sum of the gains and the losses, which comes up to be a loss equal to the areas c+e.

Turning to the problem of measurement, we stated at the beginning of this section that the compensated variation measure will be the one used in the welfare analysis. This measure is defined in terms of the initial position of the individual or firm, then the initial consumer expenditure.
or the initial producer income earnings on the commodity in question will be taken as the reference point.

To begin with, the loss in producer's surplus is represented by the sum \((d+e)\) when the efficiency rationing is assumed; such area is estimated by

\[(4.52) \quad PS = dP \times Q_1 + \frac{1}{2} (dP \times dQ),\]

where \(dP = P_0 - P_1\) and \(dQ = Q_0 - OQ_1\). Taking the first term of the right hand side or area \(d\) and dividing it by the initial income earnings, we have

\[(4.53) \quad \frac{d}{P_0 \times Q_0} = \frac{dP \times Q_1}{P_0 \times Q_0}.\]

Since \(Q_0 = Q_1 + Q_1 Q_0\), then

\[(4.54) \quad \frac{d}{P_0 \times Q_0} = \frac{dP}{P_0} - \frac{dP}{P_0} \times \frac{dQ}{Q_0}.\]

Transforming \((4.54)\) into elasticity form, we have

\[(4.55) \quad \frac{d}{P_0 \times Q_0} = \frac{dP}{P_0} \left(1 - E^S \times \frac{dP}{P_0}\right),\]

where \(\frac{dP}{P_0}\) stands for the percentage price change which is given and \(E^S\) is the total price elasticity of supply.
The area $e$ in terms of the original income is

\[ (4.56) \quad \frac{e}{p_0 \cdot q_0} = \frac{1}{2} \frac{dP}{p_0} \cdot \frac{dQ}{q_0}, \]

which, in terms of elasticity,

\[ (4.57) \quad \frac{e}{p_0 \cdot q_0} = \frac{1}{2} E^S \left( \frac{dP}{p_0} \right)^2. \]

The sum of both areas ($d+e$),

\[ (4.58) \quad \frac{\Delta PS}{p_0 \cdot q_0} = \frac{dP}{p_0} \left( 1 - \frac{1}{2} E^S \frac{dP}{p_0} \right). \]

The change in consumer's surplus is given by the rectangle $d$ minus the triangle $c$. Note that we already calculated the area $d$; thus, the area $c$ is the only one to be defined.

\[ (4.59) \quad \frac{c}{p_0 \cdot q_0} = \frac{1}{2} \frac{dP_2}{p_0} \cdot \frac{dQ}{q_0}, \]

where $dP_2 = P_2 - P_0$.

Since by definition, the total elasticity of demand is

\[ (4.60) \quad E^D = \frac{dQ}{dP_2} \cdot \frac{p_0}{q_0}, \]
therefore,

\[(4.61) \quad \frac{dP^2}{P_0} = \frac{dQ}{Q_0} / E^D.\]

Substituting (4.61) into (4.59) and expressing it in elasticity form,

\[(4.62) \quad \frac{c}{P_0 \times Q_0} = \frac{(E^S)^2}{2E^D} \cdot \left(\frac{dP}{P}\right)^2.\]

The net change in consumer welfare is given by both areas \((d-c)\)

\[(4.63) \quad \frac{\Delta cs}{P_0 \times Q_0} = \frac{dP}{P} \left(1 - E^S \frac{dP}{P}\right) - \frac{(E^S)^2}{2E^D} \left(\frac{dP}{P}\right)^2.\]

The net welfare effect for the economy which in this case is a loss is equal to the sum \((c+e)\).

\[(4.64) \quad \frac{\Delta w}{P_0 \times Q_0} = \frac{1}{2} E^S \left(\frac{dP}{P}\right)^2 \left(1 + \frac{E^S}{E^D}\right).\]

In the case where everybody can consume as much as he wants at the new lower price, the government has to come up with the difference to match the excess demand by importing the quantity \(Q_2 - Q_1\); it is assumed that the international price is equal to \(P_0\).

The effect on the producer welfare will be the same as the case of efficiency rationing. But, the change in consumer's surplus is different
in this case, since, after imposing the price ceiling, the same area is
given by the sum \( a+b+c+d+e+f+g \), reflecting a change of \( d+e+f+g \). The
government by importing the quantity \( (Q_2-Q_1) \) at a price \( P_0 \) incurs in a
cost given by the sum of areas \( e+f+g+h \). Lastly, the net effect on the
economy is equal to \( (e+h) \).

The compensated variation for the consumer is \( (d+e+f+g) \), where the
areas \( d, e, f \) are already defined by (4.55) and (4.57). The area of the
triangle \( g \) is estimated as

\[
(4.65) \quad \frac{g}{P_0 \times Q_0} = 1/2 \frac{dP}{P_0} x \frac{Q_0 Q_2}{Q_0}.
\]

By applying (4.60), we have

\[
(4.66) \quad \frac{Q_0 Q_2}{Q_0} = E^D \frac{dP}{P}.
\]

Substituting it in (4.65),

\[
(4.67) \quad \frac{E}{P_0 \times Q_0} = 1/2 E^D (\frac{dP}{P})^2.
\]

The net change in consumer welfare is thus given by

\[
(4.68) \quad \frac{\Delta c_s}{P_0 \times Q_0} = \frac{dP}{P_0} \left[ (1-1/2 E^S \frac{dP}{P}) + 1/2 \frac{dP}{P_0} (E^S + E^D) \right].
\]

\[\text{\textsuperscript{1}}\text{The triangle } f \text{ is equal to the triangle } e.\]
The cost incurred by the government by applying this type of policy is the sum of areas e+f+g+h. Note that the triangles g and h are equivalents as well as e and f; thus, the government cost is estimated by adding twice (4.57) and (4.67), resulting in

\[
\frac{Gc}{P_0 x Q_0} = \left( \frac{dP}{P} \right)^2 \left( E^S + E^D \right).
\]

Finally, the net efficiency loss is estimated by adding (4.57) and (4.67).

\[
\frac{\Delta \omega}{P_0 x Q_0} = \frac{1}{2} \left( \frac{dP}{P} \right)^2 \left( E^S + E^D \right).
\]

Note that on all these estimated areas, two parameters play the key roles; those are the total price elasticity of supply and demand. So, it is time to turn to the procedure that will be used to estimate such elasticities.

But, first, it is important to recognize that this type of policy (price control) breaks down the equilibrium condition in the target market. Thus, one of the equations (demand or supply) has to be deleted from the system of equations (3.65). To estimate the total price elasticity of supply, we assumed that the price of the specific product is given, which is the same as assuming perfect elastic demand. In doing so, and assuming that the price ceiling is imposed in the ith market, the system (3.65) becomes (4.71).
\[
\begin{array}{cccccc}
\frac{dX}{X} & \frac{dX}{p'_{X}} & \frac{dP_{i}}{p'_{i}} & \frac{dP_{l}}{p'_{l-1}} & \frac{dP_{n}}{p'_{n}} & \frac{dP_{l+1}}{p'_{l+1}} \\
\phi_{X} & e_{i} & \eta_{i+1,1} & \eta_{i+1,n} & \eta_{n+1,1} & \eta_{n+1,n} \\
\end{array}
\]

\[(4.71)\]
By applying Cramer's Rule, we can obtain the total elasticity of supply, as well as the general equilibrium effects on the rest of endogenous variables

\[(4.72) \quad E_{i}^{s} = \frac{|Q_{i}|}{\phi}\]

where \( |Q_{i}| \) is the cofactor of the target variable and \( \phi \) is the determinant of the matrix of endogenous variables.

The estimation of the total elasticity of demand follows the same procedure, but, in this case, the equation deleted is the supply of the \( i \)th market; thus, the system is now represented by \((4.73)\).

\[(4.73)\]

\[
\begin{array}{cccccc|cc}
\frac{dQ_{i}}{Q_{i}} & \frac{dP_{1}}{P_{1}} & \cdots & \frac{dP_{i-1}}{P_{i-1}} & \frac{dP_{i+1}}{P_{i+1}} & \frac{dP_{n}}{P_{n}} & \frac{dP_{X}}{P_{X}} & \frac{dP_{i}}{P_{i}} & \frac{dX}{X} \\
-1 & \xi_{i,1} & \xi_{i,i-1} & \xi_{i,i+1} & \cdots & \xi_{i,n} & 0 & -\xi_{i,i} & 0 \\
0 & & & & & & & & \\
0 & 0 & -e_{i,j} & 0 & & \cdots & \cdots & 0 & e_{jX} \\
i,j=1,2\ldots i-1,i+1\ldots n & & & & & & & & j=1\ldots i-1,i+1\ldots n \\
0 & -k_{i} & -k_{i-1} & -k_{i+1} & \cdots & -k_{n} & 1 & k_{i} & 0 \\
\end{array}
\]
Again, solving by Cramer's Rule, we obtain the total elasticity of demand

\[
(4.74) \quad E^D_{Q_i, P_i} = \frac{|Q_i|}{\phi}.
\]

Note that the determinants are not equal, since different equations are held constant.

**Ad Valorem Tax and Quotas**

In order to get revenue, the government follows the policy of putting taxes on commodities, especially those which are internationally traded. As it happens with all price interventions, a tax on a commodity will not only affect the specific market, but also will have effects on the production and consumption of other related commodity markets.

For our purposes, we are most interested in the imposition of an ad valorem tax on an agricultural product, which is heavily traded on the international market. Therefore, we begin assuming that the international price is higher than the domestic equilibrium price; also, we assume that the foreign demand for the commodity taxed is perfectly elastic.
The relationship between the international price and the domestic price is given by

\[(4.75) \quad P_D = P_w - t P_w = P_w(1-t),\]

where \(P_D\) denotes the domestic price, \(P_w\) denotes the international price and \(t\) stands for the level of ad valorem tax. The relative change in the domestic price may be represented as

\[(4.76) \quad \frac{dP_D}{P_D} = \frac{d(1-t)}{(1-t)} + \frac{dP_w}{P_w}.\]

If there is not an initial level of tax, then (4.76) can be rewritten as

\[(4.77) \quad \frac{dP_D}{P_D} = \frac{dP_w}{P_w} - t.\]

By assuming the small country case which implies that whatever the policy the domestic government undertakes it will not affect the international price, then we can assume that the relative change of \(P_w\) is equal to zero, resulting in the relative change of the domestic price being equal to the negative of the ad valorem tax.

\[(4.78) \quad \frac{dP_D}{P_D} = -t.\]
Note also that this assumption implicitly indicates that the whole amount of the tax is borne by the domestic producers.

The welfare effects of an ad valorem tax are represented in Figure 4.7 where $D_n^*$ and $S_n^*$ represent the compensated equilibrium demand and supply, respectively. The foreign demand is shown by the horizontal line $P_w - P_w$; at this price, the domestic quantity consumed is $Q_1$ and the quantity produced is $Q_2$. Thus, the excess supply or quantity exported would be given by the distance $Q_2 - Q_1$.

Figure 4.7. Ad valorem tax or quota on exports
The imposition of the tax will reduce the domestic price by its full amount, which is shown by the distance \( P_w - P_D \); then, at this new domestic price, the quantity consumed will increase by the amount \( Q_3 - Q_1 \), and the quantity produced will be reduced by the distance \( Q_2 - Q_4 \). Therefore, the quantity available for exports is then \( Q_4 - Q_3 \). But, this quantity is sold at the international market at a price \( P_w \), giving to the government a revenue equal to \( 0_{Q_4 - Q_3}^{0_{P_D - P_w}} \).

The welfare effects of an ad valorem tax can be calculated by analyzing Figure 4.7. The change in consumer's surplus is represented by areas b+c. The change in producer welfare is the sum of areas b+c+d+e+f. The government tax revenues are shown by area e and finally, the net loss to the economy is given by areas d+f.

The consumer compensating variation is estimated by

\[
(4.79) \quad \phi_{cs} = dP^0Q_1 + 1/2 \, dQ^4,
\]

where \( dP = P_w - P_D = t \) and \( Q_1 \) denotes the quantity demanded before the imposition of the tax and the change in the same variable due to the tax policy is \( dQ = Q_3 - Q_1 \). Equation (4.79) can be rewritten as a proportion of the pre-tax expenditure.

\[
(4.80) \quad \frac{\phi_{cs}}{P_w \times Q_1} = \frac{1}{Q_1} + \frac{q_d Q}{Q_1} \times \frac{dP}{P_w},
\]

which, in elasticity form is
where $E^D$ is the total price elasticity of demand. Now, by applying (4.78), the above equation can be conveniently expressed as

$$(4.82) \quad \frac{\Delta cs}{P_w \times Q_1} = (t + 1/2 E^D t^2).$$

The compensated variation for the producers is estimated as a proportion of the pre-tax income

$$(4.83) \quad \frac{\Delta Ps}{P_w \times Q_2} = \frac{dP}{P_w} \left( Q_2 - 1/2 dQ \right).$$

where $Q_2$ represents the quantity supplied at free-trade prices. This equation in elasticity notation and by applying (4.78) then becomes

$$(4.84) \quad \frac{\Delta Ps}{P_w \times Q_2} = t - 1/2 E^S t^2.$$
(4.85) \[ g.R = \frac{\Delta P_s}{P_x Q_2} - \frac{\Delta q_s}{P_w Q_1} - d - f \]

where \(d\) and \(f\) can be calculated as

(4.86) \[ \frac{d}{P_x Q_1} = 1/2 \ E^D \ t^2, \quad \frac{f}{P_x Q_2} = 1/2 \ E^S \ t^2 \]

Then, by substituting (4.82), (4.84) and (4.86) into (4.85),

(4.87) \[ g.R = -(t)^2 \ (E^S + E^D) \]

The efficiency loss \((d+f)\) is estimated as

(4.88) \[ w = 1/2 \ t^2 \ (E^S + E^D) \].

Now, we turn to the problem of how to estimate the different total elasticities coefficients from the matrix system (3.65). In doing so, we have to realize first that the market for the export product is not in equilibrium, since an excess supply exist, quantity which is exported. Also, we mentioned before that the demand price is given to the domestic economy and any change of that price within the domestic boundaries should be equal to the tax imposed by the government. Following these lines, the total elasticity of supply will be estimated by deleting the domestic demand. The resulting matrix system is exactly the same as the
one presented for the price ceiling program or the matrix system (4.71),
with the only difference that the exogenous variable $\frac{dP_i}{P_i}$ should be
rewritten as $\frac{dp_i}{P_i} = -t$. By the same token, the total elasticity of
demand is estimated by using the matrix system (4.73) where again the
exogenous variable $\frac{dP_i}{P_i}$ has to be transformed as stated above.

The last market intervention that we are going to analyze is the
export quota. This is the case when a fixed export quantity is imposed
on the supplier country. This type of quantity intervention is very
common on agricultural exportable commodities, such as the sugar and beef
quota imposed by the U.S. and the coffee quota imposed by the Coffee
International Agreement.

Figure 4.7 also will help us to understand the effects of such a
policy on the domestic economy. For simplicity of exposition, let us
assume that the quota level (k) is such that it has the same effect on
the domestic price as was the case of an export tax. That is, there will
be an excess supply in the domestic market due to the imposition of the
quota, which will drive down the domestic price to the same level as an
ad valorem tax.

The introduction of a quota on exports then will reduce the domestic
price from $P_w$ to $P_D$, which will cause an increase in the domestic
quantity consumed from $Q_1$ to $Q_3$; at the same time, the amount supplied
will be reduced from $Q_2$ to $Q_4$. The quantity given by the distance $Q_3Q_4$
is the imposed quota on exports. From these changes in quantities and
prices, the consumers will end up with a net gain of areas $b+c$, while the
producers will lose areas $b+c+d+e+f$. 
The quota system will establish a preferential market and those able to get into it will acquire extra benefits. That is, the quota or the quantity \( Q_3 Q_4 \) is bought at the domestic price \( P_d \), but it is sold at the international price \( P_w \); therefore, an excess profit (area \( e \)) is produced. If the government is the only one that has the right to export the commodity in question, then the area \( e \) will represent a revenue, but, at the same time, will also show a loss to the domestic producers. Another possibility is that the government distributes export licenses among the producers without charging. In this case, the ones with the license are those producers who are going to get the quasi-rent, but under this scenario, it is easy to see that a black market for licenses will be developed, allowing the inefficient producer to get part of that quasi-rent.

The last distributional alternative which is the one that we are most interested in is when the Commodity Boards are the only ones allowed to export. As in the case of Costa Rica, they are in charge of discounting the export tax, transportation and administrative costs from the international price and then, by established mechanisms, the remnant is distributed among the domestic producers. Therefore, under this scenario, the area \( e \) will be considered as a part of the producer surplus. Even though an explicit measure of area \( e \) will be developed below. Finally, the efficiency loss produced by the quantity constraint is given by the areas \( d+f \).

The sum of the areas \( b+c \) or the net change in consumer's welfare is estimated.
(3.89) \[ \Delta cs = (Q_1 + 1/2 \, dQ) \, dP, \]

where \( Q_1 \) stands for the domestic pre-quota quantity consumed and \( dP \) states the change in the domestic price caused by the quota. According to the definition of total elasticity, we have

(4.90) \[ dP = E_{p \cdot k} k \cdot P \cdot w, \]

where \( E_{p \cdot k} \) is the equilibrium effect of the quota on the domestic price and \( k \) is the level of the quota as a percentage of the initial production. Also, from the same definition, we may write the change in quantity demanded as

(4.91) \[ dQ = E_{Q \cdot p}^D \frac{Q_1}{P \cdot w} \, dP, \]

where \( E_{Q \cdot p}^D \) is the total price elasticity of demand.

Substituting the last two equations into (4.89), we obtain the net change in consumer's welfare as a percentage of the initial expenditure.

(4.92) \[ \frac{\Delta cs}{P \cdot x \cdot Q_1} = E_{p \cdot k} \cdot k + 1/2 \, E_{Q \cdot p}^D (E_{p \cdot k})^2 \cdot k^2. \]
On the other hand, the net change on the welfare of the producers will be estimated by the sum of the areas $b+c+d+e+f$, or by the equation (4.93).

\[(4.93) \quad \Delta PS = (Q_2 - 1/2 \, dQ) \, dP,\]

where $Q_2$ expresses the quantity supply at the pre-quota price. Then, by applying (4.91) along with (4.90) on the equation (4.93), we obtain the net change in quasi-rent as a fraction of the pre-quota income.

\[(4.94) \quad \frac{\Delta PS}{P \times Q_2} = E_{p \times k}^{-1/2} \, E_{Q \times P}^S \left( E_{p \times k} \right)^2 \, k^2.\]

The quasi-rent accrue to the exporters (area $e$) can be estimated as follows:

\[(4.95) \quad e = \eta \, \frac{\Delta PS}{P \times Q_2} - \left( \frac{\Delta CS}{P \times Q_1} + \frac{d}{P \times Q_1} \right).\]

where the area $d$ is equal to

\[(4.96) \quad d = 1/2 \left( E_{Q \times P}^D \left( E_{p \times k} \right)^2 \, k^2 \right) \, P \times Q_1.\]

Then, by substituting (4.92), (4.94) and (4.96) into (4.95), we have

\[(4.97) \quad e = \left( E_{p \times k} \right)^2 \, k^2 \right) \, P \times Q_2
- \left( E_{p \times k} + E_{Q \times P}^D \left( E_{p \times k} \right)^2 \, k^2 \right) \, P \times Q_1.\]
Finally, the efficiency lost \((d+f)\) is then estimated as

\[
(4.98) \quad \Delta w = \frac{1}{2} \left( E_{p+k} \right)^2 k^2 \left( E_{Q^D} + E_{Q^S} \right).
\]

The set of parameters to be estimated in order to have all the required information to calculate the above areas are the total elasticities coefficients. But, we have to recognize two things: the quantity supplied is determined by the domestic quantity demanded plus the quota or foreign demand; thus, \(Q^S = Q^D + k\), and second the domestic price is still determined by the interaction of the market demand and supply.

Keeping this in mind, the effect on the domestic price by the introduction of an export quota can be estimated by solving the matrix system \((4.99)\), assuming that the quota is imposed in market one.

\[
(4.99)
\]

\[
\begin{array}{cccc|cc}
\frac{dP_1}{P_1} & \frac{dP_2}{P_2} & \cdots & \frac{dP_n}{P_n} & \frac{dP_X}{P_X} & k & \frac{dX}{X} \\
(n_{11} - e_{11}) & (n_{12} - e_{12}) & \cdots & (n_{1n} - e_{1n}) & 0 & -1 & e_{1X} \\
(n_{21} - e_{21}) & (n_{22} - e_{22}) & \cdots & (n_{2n} - e_{2n}) & 0 & 0 & e_{2X} \\
\vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\
(n_{n1} - e_{n1}) & (n_{n2} - e_{n2}) & \cdots & (n_{nn} - e_{nn}) & 0 & 0 & e_{nX} \\
-k_1 & -k_2 & \cdots & -k_n & 1 & 0 & 0 \\
\end{array}
\]
By applying Cramer's Rule, we are able to estimate the total effect on the price by the quota level

\[(4.100) \quad E_{p \cdot k} = \frac{|dP_i/P_i|}{\Delta} \quad i=1 \ldots n.\]

The total price elasticity of demand is given by the interaction of the compensated market demand elasticity and the general equilibrium adjusted price

\[(4.101) \quad E^D_{Q \cdot p} = n_{ii} E_{p \cdot k} \quad i=1 \ldots n.\]

By the same token, the total price elasticity of supply is estimated by the interaction of the respective elasticities

\[(4.102) \quad E^S_{Q \cdot p} = e_{ii} E_{p \cdot k} \quad i=1 \ldots n.\]
It has become increasingly apparent that effective policies for agriculture require a comprehensive view of the sector. Such policies, whether private or public, must account for interrelationships within the agricultural sector, as well as with the rest of the economy. For Costa Rica, these interrelationships are of crucial importance, since the agricultural sector plays one of the most important roles in the national economy. Policies that fail to incorporate them may be highly sensitive to the changing nature of the sector and national economy.

Producer supply and consumer demand for agricultural products are the obvious more important components of the structure within which the sector must operate. Since the demand for those products is, in general, price inelastic and the production or supply somewhat variable, accurate estimates of the corresponding parameters are important as inputs in the development of national price and/or quantity intervention policies, stabilization policies, trade, storage, and the like. Another point that complicates a little more the policy analysis is that the demand, as well as the supply, of agricultural products are highly interrelated within themselves. Thus, estimates of cross-elasticities are also important in the formulation of agricultural policies.

The economic theory provides a useful framework for analyzing problems related to the demand and supply of agricultural products, by indicating plausible types of assumptions that make the estimation of the
parameters statistically tractable. In particular, the economic theory offers a means by which own and cross price elasticities can be estimated in a consistent and complete logical framework.

The estimation procedure that we are going to explain and use is one that requires minimal or no assumptions about the functional forms of the underlying utility or production function. Most of the demand and supply systems are based on specific functional forms of the objective function, which, in turn, implies further restrictions on the parameters, as well as nonparametric estimation by the most cases.

The Demand System

As it was explained in Chapter III, the main hypothesis about consumers is that they maximize the utility obtained from the consumption of a bundle of goods subject to the income constraint. This maximization problem was solved by the Lagrangian technique from which we obtain the set of implicit demand functions (3.46).

The subject of this section is to explain how that set of demand functions will be estimated and how restrictions indicated by the theory are incorporated in the estimation procedure. Recalling from Chapter III, we know that by differentiation of the FOC (3.44) the set of behavioral restrictions is obtained, which are

\[
(5.1) \quad \sum_{i=1}^{n} w_i y_i = 1 \quad \text{[Engel condition]}
\]
\[ \frac{\eta_{ij}}{w_j} + \eta_{iy} = \frac{\eta_{ij}}{w_i} + \eta_{iy} \]  

[Cournot condition]

\[ \sum_{i=1}^{n} w_i \eta_{ij} = -w_j \]  

[Homogeneity condition]

\[ \sum_{j=1}^{n} \eta_{ij} = -\eta_{iy} \]  

[Symmetric condition]

If the individual maximizes his utility, these four conditions should be satisfied regardless of the functional form of the utility function. The first two conditions are derived from the budget constraint; therefore, they depend solely on the definition of income as the sum of expenditures. They apply automatically in any demand system where the income variables is equal to the sum of expenditures on the individual commodities (Court, 24). The last two conditions, homogeneity and symmetry, are obtained from the utility function. The symmetry condition may be expressed in matrix form by using the compensated substitution term or what is also called the elasticity of substitution between commodities \( \sigma_{ij} = \frac{\eta_{ij}}{w_j} + \eta_{iy} \).

\[
\begin{bmatrix}
\sigma_{11} & \sigma_{12} & \ldots & \sigma_{1n} \\
\sigma_{21} & \sigma_{22} & \ldots & \sigma_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
\sigma_{n1} & \sigma_{n2} & \ldots & \sigma_{nn}
\end{bmatrix}
\]
This matrix is symmetric, as well as negative semi-definite, which implies that its principal minors will alternate in sign, with the exception of \((\sigma_{ij})\), which is zero (Samuelson, 63).

The system of demand equations (3.46) can only be estimated if a specific functional form relates the independent variables with the dependent ones. The functional forms that we assume approximate the true function are the lineal in variables and the double logarithmic functions. The reason we choose these two is because they are the most widely used in empirical analysis. Even though we are aware that, if a complete system is specified entirely by one of the equations, the budget constraint or the Engel aggregation condition is not satisfied (Goldberger, 31). However, as Court (24) has expressed, the economic theory does not indicate that all the functional forms have to be of the same nature, so a complete demand system may have equations of the type stated above as well as some other forms, such as the complete set will satisfy those adding-up conditions. Furthermore, not all the demand systems satisfy those conditions, where the linear expenditure and the indirect addilog systems are among the very few that satisfy the Engel condition (Yoshihara, 80).

The demand system will be estimated under any of the following functional forms.
(5.3) Linear

\[ Q_i = \alpha_{i0} + \sum_{j=1}^{n} \alpha_{ij} P_j + \alpha_{iy} y + u_i \quad i, j = 1 \ldots n \]

logarithmic:

\[ \log Q_i = \alpha_i + \sum_{j=1}^{n} \alpha_{ij} \log P_j + \alpha_{iy} \log y + u_i \]

where

- \( Q_i \) = per-capita consumption of the ith commodity;
- \( P_j \) = price paid by consumers;
- \( y \) = per-capita income
- \( \alpha_{ij} \) = parameters to be estimated
- \( u_i \) = random error.

Court (24) has proposed a procedure that helps to decide which of the above functional form is more suitable for estimation, such that the symmetric condition will have a better probability to show an acceptable fit. He stated

If quantities consumed are more highly correlated with one another than are reciprocal proportions, the symmetric restrictions apply better to the linear demand functions, if otherwise, they are more appropriate to the lineal double logarithmic functions.

The choice between these two statistical functions will be made by examining the characteristic roots of the respective correlation matrix.

The demand system can be expressed in matrix form which for simplicity of presentation the linear model is used and the constant term \( (\phi_{i0}) \) is omitted.
(5.4) \( Q = Z\alpha + U, \)

where

- \( Q = (n \times t) \times 1 \) vector of quantities consumed. \( n = \) number of commodities, \( t = \) time period;
- \( Z = (n \times t) \times [n \times (n+1)] \) matrix of independent variables;
- \( \alpha = [n \times (n+1)] \times 1 \) vector of parameters;
- \( U = (n \times t) \times 1 \) vector of random errors.

This system in its full expression is shown below.

Before including the restriction in the system (5.4), we have to mention that some of the restrictions are not lineal on the parameters, since they include budget shares which are also a function of the parameters. In order to linearize them, the elasticities will be evaluated at a specific value which as it is common in applied economics that figure will be the mean values of the parameters involved.

The first restriction to be analyzed is the Engel condition, which imposes just one constraint on the system. Applying such a condition to the linear system and realizing that \( \frac{\partial q_i}{\partial y} = \alpha_{iy} \), then,

(5.5) \( \sum_{i=1}^{n} p_i \alpha_{iy} = 1. \)
\[
\begin{pmatrix}
Q_{11} & P_{11} & P_{21} & \cdots & P_{n1} & y_1 \\
Q_{12} & P_{12} & P_{22} & \cdots & P_{n2} & y_2 \\
\vdots & \vdots & \vdots & & \vdots & \vdots \\
Q_{1t} & P_{1t} & P_{2t} & \cdots & P_{nt} & y_t \\
\end{pmatrix}
\begin{pmatrix}
Q_{11} & P_{11} & P_{21} & \cdots & P_{n1} & y_1 \\
Q_{12} & P_{12} & P_{22} & \cdots & P_{n2} & y_2 \\
\vdots & \vdots & \vdots & & \vdots & \vdots \\
Q_{1t} & P_{1t} & P_{2t} & \cdots & P_{nt} & y_t \\
\end{pmatrix}
= 
\begin{pmatrix}
\alpha_{1,1} & U_{11} \\
\alpha_{1,2} & U_{12} \\
\vdots & \vdots \\
\alpha_{1,n+1} & U_{1t} \\
\alpha_{21} & U_{21} \\
\alpha_{22} & U_{22} \\
\vdots & \vdots \\
\alpha_{2,n+1} & U_{2t} \\
\vdots & \vdots \\
\alpha_{n,1} & U_{n1} \\
\alpha_{n,2} & U_{n2} \\
\vdots & \vdots \\
\alpha_{n,n+1} & U_{nt} \\
\end{pmatrix}
\]
For the double log model, the same conditions will be

\[(5.6) \quad \sum_{i=1}^{n} w_i a_{iy} = 1,\]

where \(P_i\) and \(w_i\) are evaluated at mean values. This aggregation condition stated in matrix notation is

\[(5.7) \quad R \times \alpha = 1,\]

where \(R_i = 1x(n(n+1))\) row vector of zeros and mean prices.

Its full representation would be

\[
\begin{bmatrix}
0 & 0_{11} & \cdots & 0_{1n} \\
0_{11} & 0_{12} & \cdots & 0_{1n} \\
\vdots & \vdots & \ddots & \vdots \\
0_{1n} & 0_{22} & \cdots & 0_{nn}
\end{bmatrix}
\begin{bmatrix}
\alpha_1 \\
\alpha_2 \\
\vdots \\
\alpha_n
\end{bmatrix}
= 1.
\]

The homogeneity condition will impose \(n\) constraints on the system, one for each equation. This condition applied to the linear model and again using the definition of elasticity would appear as

\[(5.8) \quad \text{Linear:} \quad \sum_{j=1}^{n} \frac{P_i}{Q_i} a_{ij} + \frac{Y}{Q_i} a_{iy} = 0;
\]

\text{Logarithmic:}

\[\sum_{j=1}^{n} a_{ij} + a_{iy} = 0.\]
In matrix form, the same condition is given by (5.9)

\[(5.9) \quad R_2x\alpha = 0\]

where

\[R_2 = nx[n(n+1)] \text{ matrix;}
0 = nx1 \text{ vector of zeros.}\]

Its full representation is shown below.

\[
\begin{bmatrix}
\frac{P_1}{Q_1} & \frac{P_2}{Q_1} & \cdots & \frac{P_n}{Q_1} & y \\
\frac{P_1}{Q_2} & \frac{P_2}{Q_2} & \cdots & \frac{P_n}{Q_2} & y \\
\frac{P_1}{Q_n} & \frac{P_2}{Q_n} & \cdots & \frac{P_n}{Q_n} & y \\
\end{bmatrix}
\begin{bmatrix}
x \\
|\alpha| \\
\end{bmatrix}
= 0.
\]

The symmetric condition states the restriction between pair of commodities; thus, the condition imposes \((n^2-n)/2\) independent restrictions on the system. This symmetric condition applied to the linear model would look like

\[(5.10) \quad \frac{P_i}{Q_i} j \cdot \alpha_{ij} + \frac{y}{Q_i} \alpha_{iy} - \frac{P_i}{Q_j} i \cdot \alpha_{ji} - \frac{y}{Q_j} \alpha_{ji} y = 0,\]

but recognizing that \(\frac{P_i}{Q_i} j = \frac{y}{Q_j Q_i}\) at the mean values, then (5.10) can be rewritten
The same condition, but applied to the logarithmic model is

\[
\frac{y}{Q_jQ_i} \alpha_{ij} + \frac{y}{Q_i} \alpha_{iy} - \frac{y}{Q_iQ_j} \alpha_{ji} - \frac{y}{Q_j} \alpha_{yj} = 0.
\]

In matrix notation, the above condition would be

\[
R_3 \alpha = 0.
\]

where \( R_3 = nx(n(n+1)) \) matrix of cross equation restrictions; \( \alpha = nx1 \) vector of zeros.

For simplicity of exposition, we will show only one restriction in its full expression. Taking, for example, the relation between the first and third commodity, then the symmetric condition would be

\[
\begin{vmatrix}
0_{11} & 0_{12} & \frac{y}{Q_3Q_1} & \cdots & 0_{1n} & \frac{y}{Q_1} & 0_{21} & \cdots & 0_{2,n+1} & \frac{-y}{Q_1Q_3} & 0_{32} & \cdots & 0_{3n} & \frac{-y}{Q_3} & 0_{n,1} & \cdots & 0_{n,n+1}
\end{vmatrix} = | \alpha | = |0 |.
\]

Having described each restriction separately, we can pull all together in just one matrix equation.
\[(5.14) \quad R \alpha = T \]

where \( R = (2n+1) \times (n(n+1)) \) matrix of restriction; 
\( \alpha = (n(n+1)) \times 1 \) vector of parameters; 
\( T = (2n+1) \times 1 \) vector of zeros and one.

We can include the whole set of restrictions in our original system (5.4) given the final model (5.15).

\[(5.15) \quad \begin{bmatrix} Q \\ T \end{bmatrix} = \begin{bmatrix} Z \\ R \end{bmatrix} \alpha + \begin{bmatrix} U \\ 0 \end{bmatrix} \]

where

\( Q \) = \([n(t+2)+1] \times 1\) matrix of dependent variables and constant values of the constraints;

\( Z \) = \([n(t+2)+1] \times [n(n+1)]\) matrix of independent variables plus the restraints within equations;

\( \alpha = [n(n+1)] \times 1 \) vector of parameters;

\( U \) = \([n(t+2)t1] \times 1\) vector of random errors and zeros.

Before getting into the supply side of the model, we want to mention that the Cournot condition is not explicitly included in the system of constraints, because once the Engel aggregation is satisfied, then the Cournot condition is implicitly satisfied, too (Wold and Jureen, 79).
The Supply System

The supply side of the model, according to its development in Chapter III, is based on the assumption that the country maximizes its revenue out the production of the commodities included in the model, subject to a given technology represented by the multiple-output production function. By solving the FOC obtained from the maximization problem, we get the derived supplies and the derived demand for the composite factor. The derived supplies will be estimated by applying the linear and double logarithmic statistical models. The problem encountered in the demand side with respect to the type of the functional form is less restrictive in this case, since in the supply side the firm does not have a budget constraint to satisfy.

The supply equations will be expressed

\[(5.16) \text{ Linear: } \quad i,j=1 \ldots m\]

\[Q_i = \beta_i 0 + \sum_{j=1}^{n} \beta_{ij} P_j + \beta_{iX} X + U_i\]

Double log:

\[\log Q_i = \beta_{i0} + \sum_{j=1}^{n} \beta_{ij} \log P_j + \beta_{iX} \log X + U_i,\]

where

\[Q_i = \text{quantity produced of the } i\text{th commodity; }\]

\[P_i = \text{price received by the producers of the } i\text{th commodity; }\]

\[X = \text{quantity of the composite factor.}\]
The composite factor conforms all those factors of production which are used in the production of $Q_i$, and this variable, according to the theory, should be one that reflects the level available of those resources. Ideally, it would be the aggregate physical units of those factors, a task which is impossible to satisfy due to the lack of information on the amounts of the individual inputs, as well as for aggregation problems. For our purpose, a proxy variable for $X$ will be used and that is the sum of the individual commodities value added at constant prices, with the hope that it reflects the changes in the amounts of primary inputs used in production.

In Chapter III, we also established the four constraints on the elasticities of supply; they are

$$\sum_{i=1}^{n} k_i e_{iX} = 1 \quad \text{[Aggregation]}$$

$$\sum_{j=1}^{n} k_{e_{ji}} = 0 \quad \text{[Cournot]}$$

$$\sum_{j=1}^{n} e_{ij} = 0 \quad \text{[Homogeneity]}$$

$$k_{e_{ij}} = k_{e_{ji}} \quad \text{[Symmetric]}$$

---

1We called Cournot condition with the purpose to keep the similarity with the demand side, but note that they are different.
It is interesting to compare the symmetric condition on both the demand and supply models. In consumer theory, the compensated cross price slopes are symmetric. For the individual, the income effect of a price change has to be subtracted from the total effect to obtain the symmetric condition. Unlike here, the total effects of a price change are symmetric. This is because price changes do not have income effect to the firm; the scale variable in the supply side is the volume of fixed factors, and this is invariant to price changes. For given inputs, the firm response to a change in output prices is constrained to movements around the transformation surface and these are symmetric (Clements, 19).

As we mentioned before, the aggregation condition as a long-run characteristic, since to be held, it requires that the average revenue product be equal to the marginal revenue of product X, otherwise, the sum of income shares \( k_i = \frac{P_i Q_i}{\lambda R} \) will not be equal to one (Silberberg, 67).

The elasticity constraints in terms of the linear models mentioned above will be

\[
(5.18) \text{Aggregation} \quad i,j=1 \ldots n
\]

\[
\text{Linear:} \quad \sum_{i=1}^{n} k_i \frac{X_i}{Q_i} \beta_i X = 1
\]
As it was the case for the demand side, we have to linearize the restrictions by evaluating the elasticities at the mean values.

The method to incorporate these restrictions in the supply model is exactly the same as it was proposed for the demand case with the only difference the absence of income effects.

Interest now turns to the statistical estimation procedure to be applied on the demand and supply systems. This statistical method is the seemingly unrelated least square (S.U.L.S.) (Zellner, 81) by which the

\[ \frac{P_i}{Q_i} \beta_{ij} - \frac{P_j}{Q_j} \beta_{ji} = 0. \]
coefficients in all the equations are estimated simultaneously by applying Aitken's generalized least square method. The gain in efficiency of the estimates comes out whenever the independent variables are not highly correlated and if the disturbance term in different equations are highly correlated. Another advantage of this procedure is that it allows to make linear restrictions across equations which are taken into account on the simultaneous estimated coefficients. Also, under certain characteristics, this statistical method becomes exactly the same as the Restricted Least Square estimation procedure (R.L.S.).

For exposition purposes, we will present the general lines of the latter method, since it is easier to see the role of the restrictions in the estimation procedure, beside the demand system, for its own characteristics, is estimated by using it, that is, by applying the Restricted Least Squares method.

According to Johnson (42), from which the remainder of this section is based upon, the exact linear restrictions can be represented as it was in (5.14), where the main characteristics are that the matrix R should have a dimension \((2nx1) \times (n(n+1))\), which says that the number of rows are less than the number of columns, otherwise it would imply that the coefficients were known apart from the sample information. Further, it is required that the same matrix has a rank \((2n+1)\) indicating that the equations do not contain any redundant information about the coefficients.

The assumption on the model (5.4) are those of the classical linear hypothesis, namely, the matrix Z is nonstochastic and of full rank, the
random errors $U$ are independently distributed with zero mean and variance $\sigma^2$. Under this assumption, the parameters $\alpha$ are estimated by

$$
(5.21) \quad \hat{\alpha} = (Z'Z)^{-1}Z'Q
$$

where $\alpha$ is a linear unbiased estimator.

The process of obtaining the R.L.S. estimator is simple to minimize the sum of square residuals, subject to the condition $T = Ra$. So, it is possible to form a Lagrangian for this minimization problem.

$$
(5.22) \quad L = (Q-Za)'(Q-Za)-2\lambda'(Ra-T)
$$

where $\lambda$ is a $(2n+1)x1$ vector of Lagrangian multipliers. Setting the partial derivatives to zero gives

$$
(5.23) \quad \frac{1}{2} \frac{\partial L}{\partial \delta} = -Z'Q + Z'Z\alpha^* - R'\lambda = 0,
$$

or

$$
\alpha^* = \hat{\alpha} + (Z'Z)^{-1}R\lambda.
$$

By algebraic manipulation, the unobservable Lagrangian can be eliminated, where those manipulations make use of the condition $R\alpha^* = T$. Premultiplying $(5.23)$ by $R$ yields

$$
(5.24) \quad R\alpha^* = Ra + R(Z'Z)^{-1}R'\lambda.
$$
If the condition that the restrictions must hold for the estimated values is imposed, then

\[(5.25) \quad T = R\hat{\alpha} = R\hat{\alpha} + R(Z'Z)^{-1}\lambda R^1\lambda.\]

Solving for \(\lambda\)

\[(5.26) \quad \lambda = [R(Z'Z)^{-1}R']^{-1}(T - R\hat{\alpha}).\]

Substituting (5.26) into 5.23)

\[(5.27) \quad \hat{\alpha}^* = \alpha + (Z'Z)^{-1}R'[R(Z'Z)^{-1}R']^{-1}(T - R\hat{\alpha}).\]

Note that, if the restrictions are in agreement with the sample data, then \(\alpha^* = \alpha\), which is, for most cases, highly unlikely. A more reasonable assumption is that the expected value for the restrictions is equal to zero.

\[(5.28) \quad E(T - R\hat{\alpha}) = 0.\]

Johnson (42) concluded:

The result is then that whenever unbiased information is added to a standard least square problem and such information is not redundant, the result is an improvement in the sampling variance. That is, the R.L.S. estimator has a smaller sampling variance than the O.L.S. estimator, even if the restrictions happen to be biased.
We stated above that the actual estimation procedure to be used in this research will be the S.U.L.S., where the coefficient estimator is given by (Zellner, 81)

\[(5.29) \quad \hat{\alpha} = (Z' \Omega^{-1} Z)^{-1} Z' \Omega^{-1} Q,\]

where \( \Omega \) is the Aitken's variance-covariance matrix of random errors. But, as he has expressed, if \( \Omega \) is a diagonal matrix or the set of independent variables is the same for each equation, then the generalized Aitken's estimator will yield exactly the same results as the single equation O.L.S. estimator. Further, if the latter condition is present, the results also will be the same, even if the disturbance terms in different equations are correlated. By extending this result into the linear restriction framework, the R.L.S. equation (5.27) holds for any case when one of the conditions explained above is present. As we will see in the next chapter, this situation happens to be the case of the demand system, specifically, the set of independent variables in each equation is the same. Unlike the demand case, the set of independent variables on each supply equation is not the same; thus, the R.L.S. estimator (5.27) still hold, but realizing that the vector of coefficients (\( \hat{\alpha} \)) is now given by (5.29), whose properties are at least asymptotically more efficient than those obtained by equation by equation application of O.L.S. (Zellner, 81).

Lastly, we want to test if the restrictions are in accordance with the sample data, or, in other words, that the restrictions are unbiased.
The general linear hypothesis is $R\hat{\alpha} = r$, where $R$ contains the $(2n+1)$ independent linear hypothesis to be evaluated. This test can be handled by applying an $F$ statistic (Johnson, 42); thus, we have

\[
F_{j,t-k} = \frac{[SSE(\alpha^*) - SSE(\alpha)]/j}{SSE(\alpha)/t-k}
\]

where $j = (2n+1)$ independent restrictions;
$t = (nxt)$ number of observations on $Q$;
$k = (n(n+1))$ number of independent variables on $Z$;
$SSE(\alpha^*) = \text{calculated sum of squares for the restricted estimator}$;
$SSE(\hat{\alpha}) = \text{calculated sum of squares for the unrestricted estimator}$.

This test should be taken as an approximation in the case when $\alpha^*$ is given by the Aitken's generalized least square estimator (Zellner, 81).
CHAPTER VI.
STATISTICAL RESULTS

The statistical method described in Chapter V is now applied to obtain all price and income elasticities for the group of agricultural products mentioned in Chapter I (corn, rice, sugar cane, coffee and beef).

The Demand System

The demand system was estimated separately from the supply system, then it is reasonable to explain one at a time. The consumption of each of these five products per head of population is explained in terms of the retail price of each product, the per capita consumption expenditure in each of them and a random error

\[ \frac{Q_i}{N} = d_i (RP, SP, CFP, BP, CP, ML, U_i) \quad i=1, 2 \ldots 5 \]

where

\( Q_i \) = total domestic consumption of the ith product

\( N \) = population

\( RP \) = retail price of rice

\( SP \) = retail price of sugar

\( CFP \) = retail price of coffee

\( BP \) = retail price of beef

\( CP \) = retail price of corn

\( ML \) = the sum of the per capita consumption expenditures in each of the products

\( U_i \) = random error.
Since \( M_i = \prod_{i=1}^{M} P_i Q_i \), one of the equations is redundant, therefore it is required to express the system in relative terms, here the price of corn was chosen as the numeraire. Before proceeding with the estimation it is desirable to choose the type of function for the \( d_i \) that appears to provide the better fit to the restrictions according to the criterion suggested earlier. This criterion determines whether the actual quantities consumed are generally more highly correlated with one another than are the budget proportion reciprocals.

Correlating these sets of quantities using a time series of 21 observations from 1960 to 1980 inclusive, the following two matrices of simple correlations are obtained.

Table 6.1. Simple correlations of per capita consumption

<table>
<thead>
<tr>
<th></th>
<th>Corn</th>
<th>Rice</th>
<th>Sugar</th>
<th>Coffee</th>
<th>Beef</th>
<th>Roots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>1.00</td>
<td>.92</td>
<td>.91</td>
<td>.81</td>
<td>.33</td>
<td>3.76</td>
</tr>
<tr>
<td>Rice</td>
<td>.92</td>
<td>1.00</td>
<td>.99</td>
<td>.82</td>
<td>.16</td>
<td>.96</td>
</tr>
<tr>
<td>Sugar</td>
<td>.91</td>
<td>.99</td>
<td>1.00</td>
<td>.87</td>
<td>.18</td>
<td>.20</td>
</tr>
<tr>
<td>Coffee</td>
<td>.81</td>
<td>.82</td>
<td>.87</td>
<td>1.00</td>
<td>.40</td>
<td>.08</td>
</tr>
<tr>
<td>Beef</td>
<td>.33</td>
<td>.16</td>
<td>.18</td>
<td>.40</td>
<td>1.00</td>
<td>.01</td>
</tr>
</tbody>
</table>

Table 6.2. Simple correlations of the budget proportion reciprocal \( \left(\frac{1}{w_i}\right) \)

<table>
<thead>
<tr>
<th></th>
<th>Corn</th>
<th>Rice</th>
<th>Sugar</th>
<th>Coffee</th>
<th>Beef</th>
<th>Roots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>1.00</td>
<td>.13</td>
<td>-.03</td>
<td>.29</td>
<td>-.57</td>
<td>2.20</td>
</tr>
<tr>
<td>Rice</td>
<td>.13</td>
<td>1.00</td>
<td>-.11</td>
<td>.07</td>
<td>-.67</td>
<td>1.09</td>
</tr>
<tr>
<td>Sugar</td>
<td>-.03</td>
<td>-.11</td>
<td>1.00</td>
<td>.02</td>
<td>-.31</td>
<td>.98</td>
</tr>
<tr>
<td>Coffee</td>
<td>.29</td>
<td>.07</td>
<td>.02</td>
<td>1.00</td>
<td>-.50</td>
<td>.71</td>
</tr>
<tr>
<td>Beef</td>
<td>-.57</td>
<td>.67</td>
<td>-.31</td>
<td>-.50</td>
<td>1.00</td>
<td>.03</td>
</tr>
</tbody>
</table>
The first set of correlations appears to be generally higher. All the coefficients except for those of beef are greater than the 5 percent significance value of .413 (for 21 d.f.), whereas only three coefficients of the second set are greater than this value. A better idea is given by the size of the largest characteristic root of each matrix. By analogy with the concept of principal components, whereby the matrix with the largest root is said to contain the largest component of variance (Court, 24), the first matrix (Table 6.1) has the largest value of 3.76 which can be said to have the larger component of correlation.

As it seems that closer linear relationships exist between actual per capita consumption than budget proportional reciprocals, then a linear in variables formulation of the set of demand functions gives a greater likelihood to the restrictions than does a logarithmic functional form.

Even though the proceeding test indicates the use of linear in variable function form, we also estimated the double logarithmic formulation and in each case, the previous result was confirmed on the grounds of the expected sign of the coefficients as well as the statistical significance of them. Several different specifications of the demand system were estimated. The first attempt was the estimation of the demand system with the income variable as the national per capita income and all monetary variables were deflated by the consumer price index. The symmetric and homogeneity conditions were imposed on both the value of the parameters or on the value of elasticities. In neither of these
cases were the results satisfactory, the expected signs; particularly those on the own price and income elasticities, were not as expected, further the statistical significance of most of the coefficients were well above the 5 percent confidence limit.

Having these kind of results, we decide to close the system in the sense of making the income variable equal to the sum of the specific per capita consumption expenditure. As it was mentioned before, under this specification of the system one of the equation is redundant. The choice of the numeraire was based on the performance of each of the products which by turn were chosen as the numeraire. Again, the symmetric and homogeneity conditions were imposed on the value of the parameters or on the value of the elasticities. The former procedure was the one with the better results.

The value of the estimated coefficients, both with and without the homogeneity and symmetry conditions imposed are given below. The per capita consumption of corn, rice, sugar cane, coffee, and beef are denoted by C, R, SC, CF, B respectively and the price and income variables are as before.

The corn coefficients were calculated by using the set of restrictions discussed in Chapter III.

The estimated coefficients by ordinary least square or the first step of the simultaneous estimation, without imposing the restrictions were as follows.
Table 6.3. Estimated demand coefficients by OLS without restrictions

<table>
<thead>
<tr>
<th></th>
<th>R</th>
<th>SC</th>
<th>CF</th>
<th>B</th>
<th>M1</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>7.3</td>
<td>-14.2</td>
<td>-1.7</td>
<td>1.4</td>
<td>.06</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>(5)</td>
<td>(1)</td>
<td>(3)</td>
<td>(27)</td>
<td>(19)</td>
<td></td>
</tr>
<tr>
<td>SC</td>
<td>7.1</td>
<td>-9.8</td>
<td>-2.7</td>
<td>2.5</td>
<td>.03</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>(11)</td>
<td>(9)</td>
<td>(1)</td>
<td>(10)</td>
<td>(63)</td>
<td></td>
</tr>
<tr>
<td>CF</td>
<td>-.46</td>
<td>-.40</td>
<td>-.08</td>
<td>-.22</td>
<td>.02</td>
<td>81</td>
</tr>
<tr>
<td></td>
<td>(54)</td>
<td>(67)</td>
<td>(59)</td>
<td>(39)</td>
<td>(7)</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>-5.2</td>
<td>1.9</td>
<td>.45</td>
<td>-1.42</td>
<td>.05</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(37)</td>
<td>(21)</td>
<td>(2)</td>
<td>(3)</td>
<td></td>
</tr>
</tbody>
</table>

*The numbers in parentheses are the significant level of the estimated parameters.*

The same set of coefficients but subject to the homogeneity and symmetry restrictions are presented below.

Table 6.4. Estimated demand coefficients subject to homogeneity and symmetric conditions

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>R</th>
<th>SC</th>
<th>CF</th>
<th>B</th>
<th>M1</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>- .83</td>
<td>.5</td>
<td>.07</td>
<td>-2.2</td>
<td>- .64</td>
<td>.07</td>
</tr>
<tr>
<td>R</td>
<td>-2.6</td>
<td>-6.3</td>
<td>-8.7</td>
<td>-.35</td>
<td>- .73</td>
<td>.12</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(1)</td>
<td>(13)</td>
<td>(6)</td>
<td>(1)</td>
<td></td>
</tr>
<tr>
<td>SC</td>
<td>-3</td>
<td>-7.7</td>
<td>-9.6</td>
<td>-.36</td>
<td>-1.1</td>
<td>.14</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(1)</td>
<td>(10)</td>
<td>(1)</td>
<td>(1)</td>
<td></td>
</tr>
<tr>
<td>CF</td>
<td>-3.7</td>
<td>-.97</td>
<td>-1.5</td>
<td>.25</td>
<td>-.73</td>
<td>.04</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(1)</td>
<td>(1)</td>
<td>(1)</td>
<td>(1)</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>- .49</td>
<td>.21</td>
<td>-.11</td>
<td>-.33</td>
<td>-.26</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td>(45)</td>
<td>(73)</td>
<td>(1)</td>
<td>(21)</td>
<td>(4)</td>
<td></td>
</tr>
</tbody>
</table>
The imposition of the restrictions give the right sign for the own price effect for rice, sugar cane and beef, but not for coffee. Also, they produce some changes in the magnitude of the slopes, where the most notorious is the change on the beef coefficient which changes from -1.42 to -.26. The level of statistical significance also was increased for almost all the own price effects, except for beef which decreases from a level of 2 percent to 21 percent. With respect to the income effect the restrictions show a big improvement in the level of significance since all of them are lower than the 5 percent. The magnitude of the income effect coefficients also presents some changes where the most important are on rice and sugar cane.

Comparing the cross price coefficients we can see that they are the ones that present the most drastic changes in both the magnitude and sign. The relevant changes are presented by the coffee and beef demand equations. The former presents an increase in the magnitude of all of its coefficients as well as in the level of significance, but on the other hand the beef demand equation shows a decrease in the magnitude and in the level of significance of all its estimated parameters. Further, it is the equation that presents the most changes in the signs of the cross price effects.

In order to avoid future problems on the stability condition of the model, a problem that will be discussed later, it is necessary to have the right sign for all the own price effects. Therefore, the negativity assumption was imposed on the coffee own price effect, where the results are presented below.
Table 6.5 Estimated demand coefficients subject to homogeneity, symmetry and negative coffee own price effect

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>R</th>
<th>SC</th>
<th>CF</th>
<th>B</th>
<th>M1</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>-9.1</td>
<td>2.2</td>
<td>.33</td>
<td>-7.2</td>
<td>.43</td>
<td>.05</td>
</tr>
<tr>
<td>R</td>
<td>-2.4</td>
<td>-10.6</td>
<td>-10.9</td>
<td>+ .6</td>
<td>-1</td>
<td>.14</td>
</tr>
<tr>
<td>SC</td>
<td>-3.2</td>
<td>8.6</td>
<td>9.7</td>
<td>-.34</td>
<td>-.48</td>
<td>.13</td>
</tr>
<tr>
<td>CF</td>
<td>-7.8</td>
<td>.6</td>
<td>.7</td>
<td>-.25</td>
<td>-.22</td>
<td>.02</td>
</tr>
<tr>
<td>B</td>
<td>-.39</td>
<td>-.27</td>
<td>-.33</td>
<td>.12</td>
<td>-.87</td>
<td>.03</td>
</tr>
</tbody>
</table>

Forcing the coffee direct price coefficient to be negative brings about significant changes on the magnitude of the direct price effect particularly for corn and rice. Also, this restriction increased the statistical significance of the beef direct price coefficient from 21 percent to 1 percent. The effects produced on the income parameters are minor, where most of them presented a slight decrease.

The significant effects on the cross price coefficients were the changes in the sign of some of them. Thus, the corn-beef cross price effect became positive, also the rice-coffee and coffee-rice cross effects became positive. Lastly, the beef-rice cross effect turned out to be negative.

The weighted $R^2$ for the system is .98. This $R^2$ corresponds to the approximate F test on all nonintercept parameters in the system.
The homogeneity restrictions imposed were specified as follows

\[ 2.27 \beta_{i,R} + 1.36 \beta_{i,SC} + 8.75 \beta_{i,CF} + 9.11 \beta_{i,B} + 313 \delta_{i,MI} = 0 \]

\[ i = 1 \ldots 4 \]

The figures before the coefficients represents the average relative prices of rice, sugarcane, coffee, beef and the average relative income expenditure, as they were explained by (5.8) but recognizing that what we are restricting in this case are the parameters and not the elasticities. The symmetry conditions imposed for each pair of product combinations were as follows.

\[ \alpha_{i,j} + \bar{Q}_{j} \alpha_{i,MI} - \bar{Q}_{i} \alpha_{j,MI} = 0 \quad i \neq j = 1 \ldots 4 \]

where the \( \alpha_{i,j} \) represents the cross product first derivative of the demand function and \( \alpha_{i,MI} \) stands for the income effect slope. The symbol \( \bar{Q}_{i} \) defines the average per capita quantity consumed of the corresponding commodities. The values of this latter variable for the different products were for rice, 28.51 kilos; sugar, 43.48 kilos; coffee, 4.11 kilos; and beef, 12.1 kilos.

A test on the restrictions was performed to see if the information provided by them was bias, or in other words if the homogeneity, symmetry and negativeness conditions were in accordance with the sample data.

Because the independent variables in each of the demand equations are the same, the estimation procedure used (S.U.L.S.) turns out to be
the same as the restricted O.L.S. Thus, the system satisfied the conditions required by the $F$ test, the results are presented in the table below.

Table 6.6. $F$ test on the demand restrictions

<table>
<thead>
<tr>
<th>Restriction</th>
<th>DF</th>
<th>$F$</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homog.</td>
<td>4, 60</td>
<td>4.68</td>
<td>2.53</td>
<td>3.65</td>
</tr>
<tr>
<td>Symmm.</td>
<td>6, 60</td>
<td>3.55</td>
<td>2.25</td>
<td>3.12</td>
</tr>
<tr>
<td>Homog., Symmm.</td>
<td>10, 60</td>
<td>3.57</td>
<td>1.99</td>
<td>2.63</td>
</tr>
<tr>
<td>Negat., Hom., Symmm.</td>
<td>11, 60</td>
<td>3.26</td>
<td>1.96</td>
<td>2.57</td>
</tr>
</tbody>
</table>

According with the test performed all the restrictions imposed on the model in a single way or any combination are highly significant. In other words, the restricted model is significantly different from the one without restrictions.

The main objective of estimating the demand slopes is to apply them on the welfare calculations and to do this we need them in compensated terms as is required by the consumer welfare theory. By applying the Slusky equation (3.62) to the last demand system, the compensated slopes were obtained.

Table 6.7. Compensated demand coefficients

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>R</th>
<th>SC</th>
<th>CF</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>-6.96</td>
<td>3.64</td>
<td>24.9</td>
<td>-1.96</td>
<td>1.03</td>
</tr>
<tr>
<td>R</td>
<td>3.64</td>
<td>-6.72</td>
<td>-4.96</td>
<td>1.16</td>
<td>.66</td>
</tr>
<tr>
<td>SC</td>
<td>2.49</td>
<td>-4.96</td>
<td>-4.16</td>
<td>.19</td>
<td>1.07</td>
</tr>
<tr>
<td>CF</td>
<td>-1.96</td>
<td>1.16</td>
<td>.19</td>
<td>-.17</td>
<td>.02</td>
</tr>
<tr>
<td>B</td>
<td>1.03</td>
<td>.66</td>
<td>1.07</td>
<td>.02</td>
<td>-.49</td>
</tr>
</tbody>
</table>
As it is expected all the compensated direct price slopes are lower or less responsive than the Marshallian type.

The Supply Systems

The supply system was specified as the quantity produced as a function of the lagged set of prices, the quantity produced lagged one period and the sum of the value added at constant monetary units.

\[
Q_i = S_i \left( \frac{CP_{t-1}}{WPI_{t-1}} \cdot \frac{RP_{t-1}}{WPI_{t-1}} \cdot \frac{SCP_{t-2}}{WPI_{t-1}} \cdot \frac{CFP_{t-1}}{WPI_{t-1}} \cdot \frac{BP_{t-1}}{WPI_{t-1}} \cdot Q_{i,t-1} \cdot X_t \cdot \varepsilon_t \right)
\]

\(i = 1, 2 \ldots 5\)

where

- \(Q_i\) = domestic production of the ith commodity
- \(WPI_{t-1}\) = wholesale price index lagged one period, as a proxy for the price paid by farmer index
- \(X_t\) = the sum of values added at constant Costa Rican currency (year base: 966)
- \(CP_{t-1}, RP_{t-1}, SCP_{t-2}, CFP_{t-1}, BP_{t-1}\) = average price received by farmers lagged one period for corn, rice, coffee and beef respectively and lagged two period for sugar cane.

The statistical functional forms applied to the supply system were as before the linear invariables and the double logarithmic formulation. The characteristic roots procedure used on the demand system as a guide to choose between both statistical forms was not applied here since the symmetric conditions on the supply side gives no indication of the types of relation between the variables, particularly for the linear in variables model. Thus, both types of linear equations were fitted for each one of the different specifications applied and the choice was made.
on the base of statistical significance of the supply price coefficients as well as the expected sign. In general terms, the linear invariables formulation presented the best results. As mentioned previously, different specifications of the model were tried, when the key issue was the use of nominal, deflated, or expected lagged prices. Therefore, and because of the lack of any guidance, each of these price formulations were fitted under two alternatives—the first one was just using the price variables and the second alternative was to use both the price and the respective quantities lagged one period. The best results were obtained by applying the linear invariable formulation to the lagged prices and the lagged quantity produced for corn, rice, coffee, and beef, but for sugarcane the best result was obtained by lagging the producer price two years, which may reflect the long production period that sugarcane requires since the harvesting time takes place 14 to 16 months after the planting period.

The next step was to choose the set of constraints to be applied. The most appealing set were the homogeneity and the symmetry. The aggregation condition was disregarded because it requires that total revenue be equal to total factor income condition which is satisfied just for a close system which is not the case considered here. Further, this condition is related to a variable that is not just considered exogenous to the supply system but also in the multicommodity equilibrium formulation.

Both constraints, homogeneity and symmetry, were applied jointly as well as separate to the estimated coefficients, where the former procedure gave the best results.
The homogeneity conditions were specified as follows

\[ 439.4\alpha_{i,C} + 997.5\alpha_{i,R} + 491\alpha_{i,SC} + 4639.2\alpha_{i,CF} + 1861.3\alpha_{i,M} = 0 \]

\[ i = 1 \ldots 5 \]

The values that appear in front of the estimated coefficients represent the average deflated producer price of corn, rice, sugar cane, coffee, and beef, respectively.

The symmetry conditions were applied as follows

\[ \alpha_{i,j} - \alpha_{j,i} = 0 \quad i \neq j = 1 \ldots 5 \]

The algebraic derivation of these specifications used for the homogeneity and symmetry conditions were presented in (5.19) and (5.20) but keeping in mind that what we are restricting over here are the supply slopes or its first derivatives.

The value of the estimated supply coefficients without restrictions are presented in Table 6.8. The same set of coefficients but applying both conditions are presented in Table 6.9.

The results obtained when the restriction were imposed gave the right sign for the direct price effect and their level of significance are fairly good for corn, rice, and beef but not for sugarcane and coffee where both have a significance level well above 5 percent. Comparing the supply system with and without restrictions we can say, in general terms, that the magnitude of the estimated coefficients are reduced. For
### Table 6.8. Estimated supply coefficients without restrictions

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>R</th>
<th>SC</th>
<th>CF</th>
<th>B</th>
<th>X</th>
<th>Qt-1</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>133.3</td>
<td>44</td>
<td>38</td>
<td>-3.9</td>
<td>-8.4</td>
<td>.11</td>
<td>.23</td>
<td>.66</td>
</tr>
<tr>
<td></td>
<td>(16)</td>
<td>(31)</td>
<td>(61)</td>
<td>(28)</td>
<td>(51)</td>
<td>(12)</td>
<td>(36)</td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>-232</td>
<td>6.3</td>
<td>-70.8</td>
<td>-8.6</td>
<td>-59</td>
<td>.25</td>
<td>.11</td>
<td>.96</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(85)</td>
<td>(14)</td>
<td>(1)</td>
<td>(1)</td>
<td>(1)</td>
<td>(49)</td>
<td></td>
</tr>
<tr>
<td>SC</td>
<td>170.7</td>
<td>-10.6</td>
<td>84.8</td>
<td>3.3</td>
<td>20.7</td>
<td>.11</td>
<td>.52</td>
<td>.97</td>
</tr>
<tr>
<td></td>
<td>(7)</td>
<td>(79)</td>
<td>(12)</td>
<td>(28)</td>
<td>(7)</td>
<td>(21)</td>
<td>(5)</td>
<td></td>
</tr>
<tr>
<td>CF</td>
<td>-63</td>
<td>-1.4</td>
<td>-22</td>
<td>-.5</td>
<td>3.8</td>
<td>.12</td>
<td>-.18</td>
<td>.99</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(87)</td>
<td>(13)</td>
<td>(52)</td>
<td>(11)</td>
<td>(1)</td>
<td>(27)</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>177.3</td>
<td>15.9</td>
<td>58.4</td>
<td>6.2</td>
<td>20.4</td>
<td>.09</td>
<td>.50</td>
<td>.96</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(61)</td>
<td>(13)</td>
<td>(1)</td>
<td>(1)</td>
<td>(10)</td>
<td>(10)</td>
<td></td>
</tr>
</tbody>
</table>

### Example, the magnitude of the direct price coefficient for the export
crops, sugar, coffee, and beef are reduced significantly but at the same
time the coefficients for corn and rice are increased, particularly for
rice.
The restrictions also made some changes on the sign of the estimated slopes. The direct price coefficient for coffee turns out positive, which is the one expected, but some cross effects changed their signs too, notorious are the rice-corn, sugar-corn, and beef-corn cross effects where the first become positive and the last two negative, and showing also a drastic decrease in the magnitude of their respective coefficients.

A test on the restrictions imposed were made by applying the F test, which has to be taken as an approximation, since different sets of independent variables are used in each equation, specifically the lagged quantity produced.

As was the case for the demand system, the homogeneity and symmetry conditions did not pass the test as indicated in Table 6.10.

<table>
<thead>
<tr>
<th>Restriction</th>
<th>DF</th>
<th>F</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hom.</td>
<td>5, 64</td>
<td>5.52</td>
<td>2.36</td>
<td>3.31</td>
</tr>
<tr>
<td>Sym.</td>
<td>5, 64</td>
<td>5.55</td>
<td>1.98</td>
<td>2.61</td>
</tr>
<tr>
<td>Hom., Sym.</td>
<td>15, 64</td>
<td>4.11</td>
<td>1.84</td>
<td>2.30</td>
</tr>
</tbody>
</table>

The Multicommodity Model

By adding the system of compensated demand with the system of supply coefficients, we would obtain the general equilibrium matrix of first derivatives implicitly described in (3.65). We are now in the position to get back to the problem of stability of the model, a problem that we are going to address by showing the effect of forcing the coefficient of the demand for coffee to be negative.
We have said before that the key issue for the model stability is that the characteristic roots of the excess supply matrix have to be all positives. Another important characteristic that the model should satisfy and, which depends solely on the stability condition, is its ability to predict the right sign for both the change on the quantity demanded and on the quantity supplied. These two characteristics will be examined when the coffee demand coefficient is forced to be negative and for the case when the same coefficient is not forced.

The characteristics roots for both excess supply matrix are presented in Table 6.11, where the matrix without forcing the coffee coefficient shows two negative latent roots, especially for rows four and five.

Table 6.11. Characteristic roots of the excess supply matrix

<table>
<thead>
<tr>
<th>Row</th>
<th>No forcing coffee</th>
<th>Characteristic roots</th>
<th>Forcing coffee</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>147.5</td>
<td>155.7</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>69.1</td>
<td>72.6</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>29.6</td>
<td>31.1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>-</td>
<td>-3.66</td>
<td></td>
</tr>
</tbody>
</table>

Yet, the excess supply matrix with the restriction on the coffee coefficient presents just one negative root. This improvement is more evident when the predicted signs for the change in quantity demanded and supplied are examined. To do this, we submitted both matrix to individual market intervention (a price increase) and allowing the rest
of the market to adjust to the new situation. Because we are most interested, at this point, in the predicted signs and not in the magnitude of the change, the former are the results that are presented in Table 6.12.

Table 6.12. Predicted signs for the changes in quantity demanded and supplied

<table>
<thead>
<tr>
<th>Product</th>
<th>No forcing coffee</th>
<th>Forcing coffee</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D</td>
<td>S</td>
</tr>
<tr>
<td>C</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>R</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SC</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>CF</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>B</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

For a raise in price we expect that the quantity supplied will increase and the quantity demanded will decrease even when the other markets are allowed to reach a new equilibrium. The predicted signs of the excess supply matrix without forcing the coffee demand coefficient does not match the expectation in three out of five cases on the supply side and in two cases on the demand side. On the other hand, when we forced the coffee coefficient, the predicted signs were the correct ones, except for the demand of beef which has a positive sign. This error may be the reflection of the changes on the cross effects of the demand of beef caused by the imposition of the negative condition on the coffee coefficient, particularly the corn-beef and beef-rice cross effects.

Based on the results presented above, the excess supply matrix with the coffee condition enforced appears to be the best choice, even though
we recognize that the matrix does not satisfy in full the stability condition and that we have to assume that the change in the quantity demanded of beef would be the same but with the proper sign. Under these circumstances, the multicommodity equilibrium matrix which will be the framework for all the welfare analysis is presented in Table 6.13.

Table 6.13. The multicommodity equilibrium matrix

<table>
<thead>
<tr>
<th></th>
<th>dCP</th>
<th>dRP</th>
<th>dSCP</th>
<th>dCFP</th>
<th>dBP</th>
<th>dPX</th>
<th>dX</th>
</tr>
</thead>
<tbody>
<tr>
<td>147.9</td>
<td>12.5</td>
<td>-8.7</td>
<td>-5.9</td>
<td>-21.5</td>
<td>0</td>
<td>.09</td>
<td></td>
</tr>
<tr>
<td>12.5</td>
<td>64.5</td>
<td>7.3</td>
<td>-2.7</td>
<td>-28.3</td>
<td>0</td>
<td>.27</td>
<td></td>
</tr>
<tr>
<td>-8.7</td>
<td>-7.3</td>
<td>32.4</td>
<td>-3.2</td>
<td>7</td>
<td>0</td>
<td>.09</td>
<td></td>
</tr>
<tr>
<td>-5.9</td>
<td>-2.7</td>
<td>-3.2</td>
<td>.43</td>
<td>2.9</td>
<td>0</td>
<td>.10</td>
<td></td>
</tr>
<tr>
<td>-21.5</td>
<td>-28.3</td>
<td>7</td>
<td>2.9</td>
<td>10.8</td>
<td>0</td>
<td>.08</td>
<td></td>
</tr>
<tr>
<td>-0.04</td>
<td>-0.11</td>
<td>.1</td>
<td>.48</td>
<td>.27</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

The above matrix is formed with the compensated slopes of the excess supply functions and the factor income shares of the different product markets. The submatrix of excess supply functions must be symmetric since its elements are, as we said before, the compensated slopes.

The Partial Equilibrium Results

To have a point of reference for comparison purpose, the demand and supply for each commodity were estimated under the partial equilibrium assumption. Cross commodity price effects were included in the initial specifications, but in many cases these terms were of the wrong sign or not significant.
The linear invariables and the double logarithmic functional forms were fitted under different sets of independent variables. The final choice was made on the basis of the statistical significance of the coefficients as well as on the expected signs.

The double logarithmic formulation gave the best results for the demand and supply for corn.

Demand of corn:

(6.3) \[ \text{LC} = 5.57 - .12 \text{LCP} + .68 \text{LM} + .22 \text{DC} \]

\[ R^2 = .99 \]
\[ DW = 1.90 \]

\[ \text{where} \]

\[ \text{LC} = \text{per capita consumption of corn in logarithmic form} \]

\[ \text{LCP} = \text{retail price of corn deflated by the CPI} \]

\[ \text{LM} = \text{deflated per capita income} \]

\[ \text{DC} = \text{dummy variable accounting for the change in the retail price (1971-80=1)} \]

The numbers in parentheses represent the level of significance of the respective coefficient and since it is a logarithmic formulation those coefficients also represent the partial equilibrium elasticities.

Supply of corn:

(6.4) \[ \text{LC} = 5.14 + .94 \text{LCP}_{t-1} + .96 \text{LY} + .02 \text{L} + .18 \text{DCA} \]

\[ R^2 = .75 \]
\[ DW = 1.45 \]
where

\( LC \) = the current quantity produced of corn in logarithmic form

\( LCP_{t-1} \) = the deflated price of corn received by the farmers lagged on period

\( LY \) = the current yield of corn per hectare

\( Lt \) = a trend variable

\( DCA \) = dummy variable accounting for those years reporting a higher than usual are planted (1973, 75, 80=1)

The double logarithmic formulation also presented the best results for both the demand and supply of rice.

Demand of rice:

\[
(6.5) \quad LR = 1.13 - .94 LRP + .6 LM + .37 DR
\]

\( R^2 = .96 \)
\( DW = 1.63 \)

where

\( LR \) = per capital consumption of rice in logarithmic form

\( LRP \) = retail price of rice

\( LM \) = per capita income

\( DR \) = dummy variable representing the change on the basic grain policy (1971 - 80 = 1)

Supply of rice:

\[
(6.6) \quad LR = 4.31 + 1.28 LRP + .91 LShP + .25 LR_{t-1} + .40 Lt
\]

\( R^2 = .98 \)
\( DW = 1.45 \)
where

\[ LR = \text{current quantity produced of rice in logarithmic form} \]

\[ LRP_{t-1} = \text{the deflated (WPI) price of rice received by farmers lagged one period} \]

\[ LShP_{t-1} = \text{the deflated price of sorghum received by farmers lagged one period} \]

\[ LR_{t-1} = \text{the quantity of rice produced lagged one period} \]

\[ Lt = \text{trend variable} \]

The sugar case is represented by a double logarithmic demand equation and a linear invariables supply equation which was corrected for autocorrelation.

Demand of sugar:

\[
(6.7) \quad LSC = 1.55 - 0.32 \ LSCP + 0.65 \ LM + 0.02 \ Lt \\
R^2 = 0.99 \\
DW = 2.13
\]

where

\[ LSC = \text{per capital consumption of sugar in logarithmic form} \]

\[ LSCP = \text{retail price of sugar deflated by the CPI} \]

\[ LM = \text{deflated per capita income} \]

\[ Lt = \text{a trend variable} \]

Supply of sugar:

\[
(6.8) \quad SC = 6274.4 + 61.4 \ SCP_{t-1} + 4.14 \ CFP_{t-1} + 22.3 \ ISCP_{t-1} + 1.67 \ St \\
R^2 = 0.91
\]
where

\[ SC = \text{current quantity produced of sugar} \]
\[ SCP_{t-1} = \text{deflated (WPI) price of sugar received by farmers lagged one period} \]
\[ CFP_{t-1} = \text{deflated price of coffee received by farmers lagged one period} \]
\[ ISCP_{t-1} = \text{deflated world price of sugar lagged one period} \]
\[ St = \text{beginning of the year stocks of sugar} \]

The linear invariable formulation was the one that presented the best results for the demand and supply of coffee even though the demand price coefficient is just significant at the 25 percent level.

Demand of coffee:

\[(6.9) \quad CF = 2.99 - .10 \ CFP + .0004 \ M + 1.71 \ DCF \]
\[ (25) \quad (7) \quad (1) \]
\[ R^2 = .90 \]
\[ DW = 1.21 \]

where

\[ CF = \text{per capital consumption of coffee} \]
\[ CFP = \text{retail price of coffee deflated by the CPI} \]
\[ M = \text{deflated per capita income} \]
\[ DCF = \text{dummy variable which take account of the change in the retail price policy (1973-80=1)} \]

Supply of coffee

\[(6.10) \quad CF = 32563.8 + .78 \ CFP_{t-1} + .52 \ CF_{t-1} \]
\[ R^2 = .80 \]
where

\[ CF = \text{current quantity produced of green coffee} \]

\[ CFP_{t-1} = \text{the price of green coffee received by farmers lagged one year} \]

\[ CF_{t-1} = \text{lagged quantity produced of green coffee} \]

Finally, the demand of beef is explained by a logarithmic equation, unlike the supply where the best results were obtained by the linear invariable formulation. In both cases, the price coefficient were not highly significant.

Demand of beef:

\[(6.11) \quad LB = -0.42 - 0.22 \text{LBP} + 0.42 \text{LM} - 0.27 \text{DB} \]
\[ R^2 = 0.70 \]
\[ DW = 1.80 \]

where

\[ LB = \text{per capita consumption of beef in logarithmic form} \]
\[ LBP = \text{deflated retail price of beef} \]
\[ LM = \text{deflated income} \]
\[ DB = \text{dummy variable accounting for those observations out of the price trend (1973, 75, 76 = 1)} \]

Supply of beef

\[(6.12) \quad B = 6415.6 + 5.51 \text{BP} + 0.86 B_{t-1} \]
\[ R^2 = 0.90 \]
where

\[ B = \text{current live weight beef cattle supplied to the market} \]

\[ BP = \text{average price received by the beef cattle growers for the live weight cattle, deflated by the WPI and lagged one period} \]

\[ B_{t-1} = \text{the quantity supply of beef cattle lagged one period} \]

The set of relevant partial equilibrium elasticities is presented in Table 6.14. In the next chapter, these are compared to the elasticities derived by the multicommodity equilibrium model.

Table 6.14. Partial equilibrium elasticities

<table>
<thead>
<tr>
<th>Product</th>
<th>Demand</th>
<th>Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pr</td>
<td>M</td>
</tr>
<tr>
<td>Corn</td>
<td>- .12</td>
<td>.68</td>
</tr>
<tr>
<td>Rice</td>
<td>-.94</td>
<td>.60</td>
</tr>
<tr>
<td>Sugar</td>
<td>-.32</td>
<td>.65</td>
</tr>
<tr>
<td>Coffee</td>
<td>-.17</td>
<td>.33</td>
</tr>
<tr>
<td>Beef</td>
<td>-.22</td>
<td>.42</td>
</tr>
</tbody>
</table>

\(^a\text{Compensated elasticities.}\)
From Chapter I, we can deduce what have been the most important price policies in the last decade for the five products included in this study. As a matter of a brief review, we will point out these policies, the levels set by the government, and the time period on which the policy in question is relevant.

The price support policy has been the key market intervention in the basic grain subsector with the idea of reaching the national self-sufficient level. Thus, for corn, the average support price during the period 1974-77 was 719.2 colones ($85.6) per metric ton, above the international market price and for the period 1978-80 the level was 1365.9 colones ($166.3) above the corresponding international price. In relative terms, and for the first period mentioned, it would mean that the domestic price support for corn was set 74.4 percent above the free market price, and 146 percent for the second period. Despite these huge differences between prices, the country has not been able to obtain its self-sufficiency on corn.

The same kind of policy has been applied to the rice industry and the results obtained have been completely different from those in the corn industry, because the country has become a rice exporter since the mid-1970s. Removing the years when the international price of rice increased dramatically (1973-74), the support price of rice has been, in general, set above the international market level. Thus, for the period
1975-77, the domestic support price was 319 colones ($38) per metric ton higher, which corresponds to a 12.5 percent relative to the free market price. In the second period (1978-80), the average level was higher on 455.8 colones/m.t. or 14.3 percent above its international opportunity cost.

The sugar market has been influenced by two types of market policies, taxes on exports and a ceiling price policy at the domestic wholesale level. In general terms, the wholesale price of sugar has been lower than the international price except during 1977-78 when the international market suffered a significant decrease. Thus, the domestic wholesale price of sugar was on average 2486 colones ($230) lower than the export price during the period (1974-76) and 418.6 colones ($50) per metric ton during the more recent period of 1979-80.

The second policy of interest on the sugar industry has been the tax on exports. Two major taxes have been imposed on sugar, the export right in 1961 and the ad valorem export right in 1974. According to their respective schedules presented in Chapter II and jointly with the average export price of 3228 colones/m.t. ($384.3) during the period 1974-80, the export right tax would be 5 percent and the ad valorem tax would be 1 percent on average, making a total of 6 percent tax on sugar exports. This would mean a total amount of 190 colones/m.t. ($22.6) based on the average export price.

The coffee market also has some export taxes that are its major market policies. The ad valorem tax on production which was reviewed in 1974 and its final schedule was presented in Chapter I; the other tax is
the ad valorem export tax which has been 8 percent of the export price since 1976 and raised to 13 percent in 1980. The average export price for the 1974-80 period is 22685.7 colones/m.t. ($2,700.7), therefore and according with the schedule the average tax on production has been 10 percent which added with the export tax makes a total tax of 18 percent on the coffee industry. This relative figure represents an amount equal to 4006.8 colones/m.t. ($477) that the government will take per metric ton of coffee.

Finally, the beef market has had an export tax of 1 percent since 1974. The average export price for the 1979-80 period is 13536.4 colones/m.t. ($1,587.7) then the 1 percent tax would represent an amount equal to 133.4 colones/m.t.

The policy objective of the tax policies reviewed above is to generate revenue that the government will administer as a regular income to support its normal functions.

This set of policies can be analyzed in different ways. For example, one can take the chronological path and see what would be the effect of a specific policy on the target market but recognize the existence of distortions on the other markets at the time that such a policy was implemented. This can also be analyzed by assuming no distortion at all on the target market before the implementation of the policy in question or considering as a new policy the change on the level of an existing distortion.

For our purpose, we will assume that no predistortion exists in the target market, which implies that the level of the policy variable will
be the difference with respect to the free market level and it will not reflect the change between different levels of the same policy variable.

Another issue that we have to decide is the time framework one which the different policies will be analyzed. We considered that the most recent level of variables set by the government would be the best representative of the policy pursued by it. Thus, the set of policies to be analyzed for the different markets are the following:

Table 7.1. The set of market policies chosen for the welfare analysis

<table>
<thead>
<tr>
<th>Market</th>
<th>Policy</th>
<th>Average level (%)</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>Pr. Supp.</td>
<td>146</td>
<td>1978-80</td>
</tr>
<tr>
<td>Rice</td>
<td>Pr. Supp.</td>
<td>14.3</td>
<td>1978-80</td>
</tr>
<tr>
<td></td>
<td>Pr. Ceiling</td>
<td>12</td>
<td>1979-80</td>
</tr>
<tr>
<td>Sugar</td>
<td>Exp. taxes</td>
<td>6</td>
<td>1974-80</td>
</tr>
<tr>
<td></td>
<td>Both</td>
<td>18</td>
<td>1979-80</td>
</tr>
<tr>
<td>Coffee</td>
<td>Exp. taxes</td>
<td>18</td>
<td>1976-80</td>
</tr>
<tr>
<td>Beef</td>
<td>Exp. tax</td>
<td>1</td>
<td>1974-79</td>
</tr>
</tbody>
</table>

This set of policies can be analyzed in all possible combinations. For example, taking one, two, three, and four markets at a time. The most logical combination would be the last one, since it is the one that will reflect better the markets' reality. To make this possible for all markets, we need a specific year when all the policies are implemented; otherwise, some markets will not present the required characteristics for the necessary combination of policies. For example, and according with the table above, the tax policies on the coffee and beef markets were implemented in 1976 and 1974, respectively, but at that time only the
sugar tax policy was in place, therefore constituting their only combination possible. In order to avoid this type of problem and looking for the same set of policy combination for each market, all the elasticities will be evaluated at 1979 prices and quantities, year in which all the policies stated in the table above were implemented. Finally, the single market case will also be analyzed, which will be compared with the results obtained from the partial equilibrium assumption and with the rest of the policy combinations.

Basic Grains

The analysis of the support price policy on corn is presented in Table 7.2. The welfare analysis was carried out by using the formulation presented in the Appendix. Comparing the results obtained by using the partial equilibrium elasticities with the results from the multicommodity equilibrium model, where all the markets are allowed to adjust to the new price of corn introduced by the government, the results show that they are quite different since the estimated private effects using the more general model are just about 60-65 percent of those obtained by the common method of partial equilibrium. This difference indicates the effect that the interrelated markets have on the target market when they are allowed to adjust.

The single policy case (corn only) indicates that imposing a price support level of 146 percent above the free market price of corn and assuming that all other markets are free of any intervention would produce a net loss of 82.1 percent of the initial consumer expenditure
Table 7.2. Welfare effects of the support price on corn in 1979 percentage change^a

<table>
<thead>
<tr>
<th>Effects</th>
<th>Partial equilib.</th>
<th>Corn</th>
<th>Case 1 (SC)</th>
<th>Case 2 (R)</th>
<th>Case 3 (CF)</th>
<th>Case 4 (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.S. (-)</td>
<td>134.3</td>
<td>82.1</td>
<td>119.4</td>
<td>124.7</td>
<td>70.9</td>
<td>1.08</td>
</tr>
<tr>
<td>P.S. (+)</td>
<td>246.2</td>
<td>159.9</td>
<td>324</td>
<td>273.9</td>
<td>321.2</td>
<td>183.3</td>
</tr>
<tr>
<td>E.L. (-)</td>
<td>77.9</td>
<td>73</td>
<td>142.3</td>
<td>104.5</td>
<td>189.8</td>
<td>171.3</td>
</tr>
<tr>
<td>G.R.(+)</td>
<td>104.7</td>
<td>94.8</td>
<td>233.6</td>
<td>194.6</td>
<td>291.6</td>
<td>301.6</td>
</tr>
<tr>
<td>G.R.R.</td>
<td>+ 8.04</td>
<td>+ 60.6</td>
<td>+ 34.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.R.SC.</td>
<td>- .7</td>
<td></td>
<td>- 31.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.R.CF.</td>
<td>- 39</td>
<td>+ 25.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.R.B.</td>
<td>- 39</td>
<td></td>
<td>+ 6.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net</td>
<td>- 39</td>
<td>+ 85.3</td>
<td>+ 10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ΔG.S.SC.</td>
<td>+ 53.8</td>
<td></td>
<td>+ 56.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ΔP.S.SC.</td>
<td>+ 47.3</td>
<td></td>
<td>- 22.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E.S.</td>
<td>.94 .13</td>
<td>1.67</td>
<td>1.20</td>
<td>.35</td>
<td>1.65</td>
<td></td>
</tr>
<tr>
<td>E.D.</td>
<td>- .11 - .6 - .25</td>
<td></td>
<td>2.0</td>
<td>- 1.38</td>
<td>- .31</td>
<td></td>
</tr>
</tbody>
</table>

^a Of the five commodities, corn (C), rice (R), sugarcane (SC), coffee (CF), and beef (B), one must always be free of government intervention and allowed to adjust to the other commodity policies. In each case the commodity in parentheses is the one free of government intervention.

^b Unadjusted welfare effects.

^c Adjusted welfare effects for government revenues (losses) in the other markets, and from price control policies, as follows: Adj. C.S. = Sim. + ΔG.S.SC., Adj. P.S. = Sim. + ΔP.S.SC., Adj. G.R. = Sim. + Net, Adj. E.L. = the residual.
that is 159.9 percent higher than their initial producer income. This benefit is just a little higher than the institutionalized price level of 146 percent. The interesting part is that the government by importing corn to satisfy the domestic demand and selling it at the established level will receive an income of about 94.8 percent of the initial consumer expenditure. The implementation of this policy will result in a loss for the society as a whole of 73 percent of the consumer expenditure, a figure that is about 77 percent of what the government gets as a revenue.

The next four cases refer to the possible combinations of the different agricultural policies. These cases have to be understood as the analysis of the effects produced by introducing the support price policy on corn when three of the other markets already have a certain type of intervention. Hence, Case 1 (SC) means that the corn support price is implemented when the rice market has been intervened by a support price, the coffee and beef markets by export taxes and the sugar market is considered free of any intervention.

To understand the meaning of the figures in the columns, take Case 2, which is the combination of corn, rice, coffee, and sugarcane policies. So, the implementation of the corn support price at a level 146 percent above the international price would produce the following welfare effects without adjustments (Sim.) or without taking account of changes in government revenues on the related markets, neither accounts for changes in consumer and producer surplus due to the presence of the wholesale ceiling price in the sugar market. Under these circumstances,
the corn support policy would result in a net consumer loss of 124.7 percent of the initial consumer expenditure. The producers, on the other hand, will receive a gain of 274 percent of their initial income. The government through imports will get an income which is about 157.8 percent of the initial consumer expenditure and the net efficiency lost would be 104.5 percent of the same consumer expenditure.

The corn support policy will have effects on the government revenues or losses that are not taken into account by the above figures or by the welfare analysis of the target market. Specifically, the government revenue obtained from the corn market has to be adjusted by the change in the government losses on the rice market and by the changes on tax revenues on the coffee and sugar market. These adjustments are included in the (Adj.) columns, and they have to be calculated in terms of the initial consumer expenditure of corn in order to be added or subtracted.\(^1\) Hence, the corn support price policy will decrease the losses in the rice market (G. R. R.), change that has to be taken as an increase in the revenues from the corn market and this increase is about 60.6 percent. The revenues on the sugar market (G.R.SC) suffer a decrease of .7 percent in terms of the corn market, figures that have to

\(^1\)The change in government revenues on the related markets was estimated by taking account of the direction and magnitude of the cross effect predicted by the model on the supply and demand side. And these changes were then calculated in terms of the corresponding initial base. The general formula was

\[
\frac{p_i x_q_{i,j}}{w_p_j x q_j} = \frac{p_i}{w_p_j} x \frac{e_{i,j}}{w_{p_j}} x \frac{p_i}{w_p_j} x \frac{q_i}{q_j}, \quad i \neq j = 1 \ldots 5.
\]
be subtracted from the corn government income. The last adjustment in this income comes from the change on the tax revenue of coffee (G.R.CF.) which increases about 25 percent.

Taking all this adjustment together will give the net adjustment effect (net) on the corn government revenue, which is an increase of 85 percent.

We mentioned in Chapter IV that the private effects (C.S., P.S.) on the target market do not capture the changes on the same effects in those markets with price ceiling or price floor. In our case, the sugar market presents a wholesale ceiling price whose changes on the private effects also have to be considered. As was the case for the government revenue, those changes have to be estimated in terms of the corresponding base. The change on the corn consumer surplus, then has to be adjusted by the change on the same effect but in the sugar market (ΔC.S.SC.) which was estimated to increase about 54 percent. Also, the producers (ΔP.S.SC.) will enjoy a 47 percent increase. Considering all these adjustments, the net effects of the support price on corn are presented in column (Adj.) where we can see that the adjustment effects are quite

\[ \frac{\Delta C.S.SC}{WP_j \times Q_j} = \frac{\Delta PSC}{WP_j} \times ED_{SC_i,j} \times \frac{\Delta P_i}{WP_j} \times \frac{Q^{PSC}}{Q^B_j} \quad j = 1 \ldots 4 \]

The change on C.S. of the sugar market in terms of the initial consumer expenditure of the target product was estimated by

The same formula can be used for P.S. by changing the respective parameters.
significant. For example, the loss in consumer surplus is reduced in 57 percent, the producer surplus is increased in 17 percent, the government revenue is also increased in 54 percent, and, finally, the net efficiency loss presents an increase of 82 percent.

In terms of the efficiency loss to the society, the best alternative is presented when all other markets are assumed to be free of any intervention. Because we have to deal with more than one market price policy, the best way to analyze the problem is to compare all the possible combinations and find that one that minimizes the losses to the country as a whole as well as to the particular private group for which the policy is biased against. In the case of the corn support price, the consumers are the ones most hurt by this policy. Looking throughout the different cases, the one that presents the better results for the consumers is Case 3 or the combination corn, rice, beef, and sugar, because under this set of policies the consumers will not only eliminate their losses but also a gain of about 58 percent. The producers, which are the beneficiaries of the corn policy, will not enjoy as much as the other combination suggested. The government revenue generated by this set of policies is the highest, and the efficiency loss produced is also the highest. The corn support price policy has been implemented mainly to reach the domestic self-sufficiency on corn. In view of this policy goal and the results obtained on all the combinations, it seems possible that the government can compensate the consumers by covering their net losses and still get some income.
The last point worth mentioning before leaving the corn market is the kind of results obtained for the demand and supply total elasticities. The interesting point is that they present significant differences according to the set of distortions included in the model, a fact that has deep repercussions on the welfare analysis.

The other basic grain involved in the analysis is rice for which a traditional support price policy has been applied throughout the period. The policy has the same goal of reaching self-sufficiency. The results obtained in the rice market have been quite different from those in corn because the country has become an exporter of rice since 1976. The main point in the rice policy is that the support price generally has been above its international price, therefore, what the government is doing is to subsidize domestic producers. The only two possible reasons for this economic behavior are the difficulty of the government to lower the level of the support price due to pressures from the rice producers, who are very well-organized. The other reason, which jointly with the last one could explain the government's reluctance of lowering the price, is the need of foreign exchange caused by the balance of payment problems.

The welfare analysis for the rice policy is presented in Table 7.3; where those areas were estimated by the formulas presented in the Appendix.

As in the case for corn, the partial equilibrium results are quite different from those obtained by the single policy equilibrium case (rice only). Particularly different are the results for the government and net
Table 7.3. Welfare effects of the support price on rice in 1979 percentage change$^a$

<table>
<thead>
<tr>
<th>Effects</th>
<th>Partial</th>
<th>Rice</th>
<th>Case 1 (SC)</th>
<th>Case 2 (B)</th>
<th>Case 3 (CF)</th>
<th>Case 4 (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.S. (-)</td>
<td>7.7</td>
<td>14.02</td>
<td>8.7</td>
<td>11</td>
<td>12.9</td>
<td>13.8</td>
</tr>
<tr>
<td>P.S. (+)</td>
<td>23.5</td>
<td>15.02</td>
<td>22.2</td>
<td>16.4</td>
<td>17.9</td>
<td>21</td>
</tr>
<tr>
<td>E.L. (-)</td>
<td>15.8</td>
<td>1</td>
<td>13.4</td>
<td>10.9</td>
<td>5.7</td>
<td>16.1</td>
</tr>
<tr>
<td>G.R.(-)</td>
<td>31.6</td>
<td>2</td>
<td>26.9</td>
<td>24.4</td>
<td>11.3</td>
<td>21.1</td>
</tr>
<tr>
<td>G.R.C.</td>
<td>-1.3</td>
<td>-9.4</td>
<td>+2.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.R.SC.</td>
<td>- .4</td>
<td>+ .20</td>
<td>- .3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.R.CF.</td>
<td>+ 3.4</td>
<td>- .3</td>
<td>+ 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.R.B.</td>
<td>+ .42</td>
<td>+ .18</td>
<td>- .4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net</td>
<td>+ 2.5</td>
<td>-10.1</td>
<td>+ 2.6</td>
<td>+ 3.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ΔC.S.SC.</td>
<td>- 1.9</td>
<td>- 3.6</td>
<td>- 4.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ΔP.S.SC.</td>
<td>+ 1.5</td>
<td>- 5</td>
<td>- 1.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E.S.</td>
<td>1.28</td>
<td>.10</td>
<td>- .29</td>
<td>.95</td>
<td>1.13</td>
<td></td>
</tr>
<tr>
<td>E.D.</td>
<td>- .93</td>
<td>- .04</td>
<td>- .50</td>
<td>.07</td>
<td>- .70</td>
<td></td>
</tr>
</tbody>
</table>

$^a$Of the five commodities, corn (C), rice (R), sugarcane (SC), coffee (CF), and beef (B), one must always be free of government intervention and allowed to adjust to the other commodity policies. In each case the commodity in parentheses is the one free of government intervention.

$^b$Unadjusted welfare effects.

$^c$Adjusted welfare effects for government revenues (losses) in the other markets, and from price control policies, as follows: Adj. C.S. = Sim. + ΔC.S.SC., Adj. P.S. = Sim. + ΔP.S.SC., Adj. G.R. = Sim. + Net, Adj. E.L. = the residual.
efficiency losses, which are just about 6 percent of the figures obtained from the partial equilibrium analysis. The consumer surplus doubles while the producer surplus is 65 percent of the corresponding figures on the traditional method.

The results from the single policy case indicate that the consumer will suffer a loss of 14.02 percent of the initial equilibrium expenditure, which is almost the same, in relative terms, as the increase in price. On the other hand, the producers will have a gain of 15 percent of the initial equilibrium income, which by assumption is the same as the equilibrium expenditure (see the Appendix). The government would have a loss of 2 percent and the society would have to pay 1 percent of the initial equilibrium income with the implementation of this policy. These figures are the result of the low demand and supply price elasticities obtained under the specified characteristics.

Quite different results are obtained when we analyzed the rice policy joined with three other market price policies. The adjustment to the government revenues in this case comes from the corn, sugar, coffee, and beef markets. And the private adjustment effects still come from the sugar market. One difference in the adjustment process of the G.R. is that in the case of rice we are dealing with government losses, so, any G.R. increase in any other market has to be considered as a reduction of the government losses in the rice market. It is confirmed again that the adjustment effects are quite significant.

In addition to being difficult to justify the rice market price policy, we would analyze it by looking at that policy combination that
minimizes the domestic consumer losses as well as the net efficiency loss. The set of policies that gave the best results is the corn, rice, coffee, and beef or Case 1, which after the adjustments only allows 8.7 percent on consumer losses and 11 percent on the efficiency loss. If the government wants to minimize its loss by transferring the burden to the domestic consumers, the best choice would be Case 3, because it just allows 12 percent on government losses but at the same time increases the consumers' burden up to 17 percent.

Sugarcane

The sugarcane market has two price policies, the wholesale ceiling price and the export tax. The welfare effects of the former are presented in Table 7.4. It is remarkable the similarities of the results from the partial equilibrium and those from the multicommodity model. Each method of estimation indicates that this type of price policy, particularly when the government does not receive any income directly from its implementation, it is merely a transfer of resources from the producers to the consumers in an amount more or less equal to the level of the price ceiling. The estimated efficiency loss for all cases analyzed is very low. It ranged from .13 to .25 of 1 percent of the initial consumer expenditures. A result quite different from the one obtained on the basic grain analysis is that it does not matter what type of policy combination is in place, the results would be quite similar.

This price ceiling policy does not produce any government income by itself, but some changes on it come from the other interrelated markets,
Table 7.4. Welfare effects of the sugar wholesale ceiling price in 1979 percentage change.

<table>
<thead>
<tr>
<th>Partial Sugar Effects</th>
<th>Partial Sugar Equilib. only</th>
<th>Case 1 (B)</th>
<th>Case 2 (CF)</th>
<th>Case 3 (R)</th>
<th>Case 4 (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.S. (+)</td>
<td>12.2</td>
<td>12.3</td>
<td>12.2</td>
<td>12.1</td>
<td>12.2</td>
</tr>
<tr>
<td>P.S. (-)</td>
<td>12.5</td>
<td>12.5</td>
<td>12.4</td>
<td>12.3</td>
<td>12.4</td>
</tr>
<tr>
<td>E.L. (-)</td>
<td>.22</td>
<td>.25</td>
<td>.21</td>
<td>.13</td>
<td>.2</td>
</tr>
<tr>
<td>G.R.</td>
<td>1.1</td>
<td>.87</td>
<td>-.44</td>
<td>.91</td>
<td></td>
</tr>
<tr>
<td>G.R.C.</td>
<td>- .37</td>
<td>+ 1.7</td>
<td>- 1.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.R.R.</td>
<td>+ .58</td>
<td>- .65</td>
<td>+ .36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.R.CF.</td>
<td>+ .85</td>
<td>+ .67</td>
<td>+ .55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.R.B.</td>
<td>- .14</td>
<td>+ .01</td>
<td>+ .01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net</td>
<td>+ 1.1</td>
<td>+ .87</td>
<td>- .44</td>
<td>+ .91</td>
<td></td>
</tr>
<tr>
<td>E.S.</td>
<td>.33</td>
<td>-.07</td>
<td>-.18</td>
<td>-.04</td>
<td>-.22</td>
</tr>
<tr>
<td>E.D.</td>
<td>- .31</td>
<td>.36</td>
<td>.29</td>
<td>.17</td>
<td>2.8</td>
</tr>
</tbody>
</table>

\(^a\)Of the five commodities, corn (C), rice (R), sugarcane (SC), coffee (CF), and beef (B), one must always be free of government intervention and allowed to adjust to the other commodity policies. In each case the commodity in parentheses is the one free of government intervention.

\(^b\)Unadjusted welfare effects.

\(^c\)Adjusted welfare effects for government revenues (losses) in the other markets, as follows: Adj. G.R. = Net.
thus, Case 1 will bring about 1.1 percent increase in the government revenue from the corn, rice, and coffee markets. On the other hand, the set of policies included in Case 3 would produce a decrease on the G.R. of about one half of 1 percent.

The second sugar cane policy is the tax on exports (6 percent) where the welfare analysis is shown by Table 7.5. As with the wholesale price ceiling case, the results obtained from the partial equilibrium analysis and those from the single policy multicommmodity model (sugar only) are very similar.

The results from the single policy case indicates that an export tax of 6 percent would produce an increase in the consumer surplus of about 6.1 percent of the initial consumer expenditure, the producers would report a loss of 6.0 percent of the free trade income. The government would receive an income tax, which is .16 of a 1 percent of the initial producers' income. The country as a whole will suffer a net efficiency loss of .08 of 1 percent in terms of the same producers' income.

The analysis of the different policy combinations indicates that quite similar nonadjusted results are obtained despite the set of market price policies included in the estimation.

The adjustment to the welfare calculations came from the corn (G.R.C.), rice (G.R.R.), coffee (G.R.CF.) and beef (G.R.B.) markets. These adjustments made the difference on the final welfare estimation for the net efficiency loss as well as for the government revenue.

Judging from the principal goal of the sugar export tax of just producing an income to the government, the best set of policies is given
Table 7.5. Welfare effects of the sugarcane export tax policy in 1979 percentage change

<table>
<thead>
<tr>
<th>Effects</th>
<th>Partial</th>
<th>Sugar Case 1 (B)</th>
<th>Case 2 (CF)</th>
<th>Case 3 (R)</th>
<th>Case 4 (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.S. (+)</td>
<td>6.1</td>
<td>6.1</td>
<td>6.05</td>
<td>6.03</td>
<td>6.05</td>
</tr>
<tr>
<td>P.S. (-)</td>
<td>5.9</td>
<td>6.0</td>
<td>5.97</td>
<td>5.99</td>
<td>5.96</td>
</tr>
<tr>
<td>E.L. (-)</td>
<td>.12</td>
<td>.08</td>
<td>.09</td>
<td>.69</td>
<td>.04</td>
</tr>
<tr>
<td>G.R. (+)</td>
<td>.23</td>
<td>.16</td>
<td>.17</td>
<td>.77</td>
<td>.03</td>
</tr>
<tr>
<td>G.R.C.</td>
<td>- .17</td>
<td>+ .90</td>
<td>- .56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.R.R.</td>
<td>+ .33</td>
<td>- .40</td>
<td>+ .16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.R.CF.</td>
<td>+ .44</td>
<td>+ .33</td>
<td>+ .27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.R.B.</td>
<td>- .03</td>
<td>+ .01</td>
<td>- .0001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net</td>
<td>+ .60</td>
<td>+ .47</td>
<td>- .22</td>
<td>+ .43</td>
<td></td>
</tr>
<tr>
<td>E.S.</td>
<td>.33</td>
<td>- .07</td>
<td>- .18</td>
<td>- .04</td>
<td>- .22</td>
</tr>
<tr>
<td>E.D.</td>
<td>- .31</td>
<td>.36</td>
<td>.29</td>
<td>.17</td>
<td>.28</td>
</tr>
</tbody>
</table>

\(^a\)Of the five commodities, corn (C), rice (R), sugarcane (SC), coffee (CF), and beef (B), one must always be free of government intervention and allowed to adjust to the other commodity policies. In each case the commodity in parentheses is the one free of government intervention.

\(^b\)Unadjusted welfare effects.

\(^c\)Adjusted welfare effects for government revenues (losses) in the other markets, as follows: Adj. G.R. = Sim. + Net, Adj. E.L. = the residual.
by Case 1, because it would produce an income tax of .77 of 1 percent. At the same time, the net efficiency loss to the country would be about the same magnitude. On the other hand, the worst set of policies in terms of the income tax produced would be Case 3, which would produce a loss of .04 percent of 1 percent in government incomes, but the country will enjoy an increase in efficiency of .13 of 1 percent.

Coffee

The welfare analysis of the coffee market price policy is presented in Table 7.6. These areas were estimated by applying the formulas presented in Chapter III as was the case for the sugarcane export tax.

Again there is not much difference between the results from the partial equilibrium and the single policy case under the multicommodity model (coffee only). The latter analysis indicates that an 18 percent tax on the coffee international price would result in an increase of 18.3 percent of the consumer surplus (C.S.) in terms of the free market consumer expenditure. The same policy would also produce a loss to the producers of about 18 percent of the free trade farmers income. The government will accrue an income tax which is lower than 1 percent (.68 percent) of the initial free trade producers revenue and the country would lose .34 of 1 percent of the same quantity.

According to the results for the different combination of policies, there is not much difference among the consumer and producer nonadjusted estimated surplus areas. The same is not true for the government revenue and the efficiency loss areas, where the former presents a gain that
Table 7.6. Welfare effects of the coffee set of taxes in 1979 percentage change\(^a\)

<table>
<thead>
<tr>
<th>Effects</th>
<th>Partial equilib. only</th>
<th>Coffee Csise only</th>
<th>Case 1 (SC)</th>
<th>Case 2 (B)</th>
<th>Case 3 (R)</th>
<th>Case 4 (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sim. (^b)</td>
<td>Adj. (^c)</td>
<td>Sim.</td>
<td>Adj.</td>
<td>Sim.</td>
<td>Adj.</td>
</tr>
<tr>
<td>C.S. (+)</td>
<td>18.3</td>
<td>18.3</td>
<td>18.6</td>
<td>18.7</td>
<td>18.9</td>
<td>18.5</td>
</tr>
<tr>
<td>P.S. (-)</td>
<td>17.9</td>
<td>18</td>
<td>18</td>
<td>17.8</td>
<td>16.6</td>
<td>17.9</td>
</tr>
<tr>
<td>E.L. (-)</td>
<td>.41</td>
<td>.34</td>
<td>.60</td>
<td>3.42</td>
<td>.86</td>
<td>-6.7</td>
</tr>
<tr>
<td>G.R. (+)</td>
<td>.81</td>
<td>.68</td>
<td>1.23</td>
<td>4.03</td>
<td>1.72</td>
<td>-4.28</td>
</tr>
<tr>
<td>G.R.C.</td>
<td></td>
<td></td>
<td>+3.5</td>
<td>-5.8</td>
<td></td>
<td>+3.9</td>
</tr>
<tr>
<td>G.R.R.</td>
<td></td>
<td></td>
<td>-.66</td>
<td>-.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.R.SC.</td>
<td></td>
<td></td>
<td>+.10</td>
<td>+.09</td>
<td></td>
<td>+.20</td>
</tr>
<tr>
<td>G.R.B.</td>
<td></td>
<td></td>
<td>-.04</td>
<td></td>
<td>-.02</td>
<td></td>
</tr>
<tr>
<td>Net</td>
<td></td>
<td></td>
<td>+.28</td>
<td>-6.0</td>
<td></td>
<td>+4.0</td>
</tr>
<tr>
<td>ΔC.S.SC.</td>
<td></td>
<td></td>
<td>+.30</td>
<td></td>
<td>+.03</td>
<td></td>
</tr>
<tr>
<td>ΔP.S.SC.</td>
<td></td>
<td></td>
<td>+1.22</td>
<td></td>
<td>+.84</td>
<td></td>
</tr>
<tr>
<td>E.S.</td>
<td></td>
<td></td>
<td>.08</td>
<td>-.03</td>
<td></td>
<td>.01</td>
</tr>
<tr>
<td>E.D.</td>
<td></td>
<td></td>
<td>-.17</td>
<td></td>
<td>.18</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Of the five commodities, corn (C), rice (R), sugarcane (SC), coffee (CF), and beef (B), one must always be free of government intervention and allowed to adjust to the other commodity policies. In each case the commodity in parentheses is the one free of government intervention.

\(^b\)Unadjusted welfare effects.

ranged from 1.07 percent to 2.01 percent of the initial producers' revenue and the latter shows a range of .54 to 1.0 percent of the same quantity.

When we include the adjustment effects, these two areas show the most significant changes, unlike the private adjusted areas which just have minor changes.

The best combination of policies in terms of the income generated would be Case 3, because it would generate a revenue that is 5.1 percent of the initial producer income, but the net efficiency figure indicates a loss of 72.4 percent of that government income. In terms of society, the best combination would be given by Case 2, because the government would suffer a loss of revenues of 4.3 percent and the country would gain an increase in efficiency of 6.7 percent.

Beef

The last market policy analyzed is the beef export tax (1 percent) whose welfare results are presented in Table 7.7. As was the case for the other tax policies studied, there are no differences between the results of the two methods presented here. The more general model under the single policy assumption (beef only) indicates that the producers would suffer a loss of 1.03 percent of the free trade revenue. The consumers, on the other hand, would perceive a gain equal to 1.03 percent of their pre-tax expenditure on beef. The government would get an income which is equal to .014 of 1 percent of the free trade producers revenue
Table 7.7. Welfare effects of the beef export tax policy in 1979 percentage change^a

<table>
<thead>
<tr>
<th>Effects</th>
<th>Partial equilib. only</th>
<th>Beef Case 1 (SC)</th>
<th>Case 2 (CF)</th>
<th>Case 3 (R)</th>
<th>Case 4 (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.S. (+)</td>
<td>1.036</td>
<td>1.037</td>
<td>1.035</td>
<td>1.065</td>
<td>1.032</td>
</tr>
<tr>
<td>P.S. (-)</td>
<td>1.032</td>
<td>1.028</td>
<td>1.028</td>
<td>1.128</td>
<td>1.03</td>
</tr>
<tr>
<td>E.L. (-)</td>
<td>.006</td>
<td>.007</td>
<td>.009</td>
<td>-.24</td>
<td>.008</td>
</tr>
<tr>
<td>G.R. (+)</td>
<td>.003</td>
<td>.014</td>
<td>.018</td>
<td>-.227</td>
<td>.016</td>
</tr>
<tr>
<td>G.R.C.</td>
<td>- .10</td>
<td>- .16</td>
<td>- .34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.R.R.</td>
<td>- .10</td>
<td>+ .30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.R.SC.</td>
<td>- .01</td>
<td>- .13</td>
<td>+ .02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.R.CF.</td>
<td>- .04</td>
<td>+ .20</td>
<td>- .10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net</td>
<td>- .24</td>
<td>-1.3</td>
<td>- .30</td>
<td>- .18</td>
<td></td>
</tr>
<tr>
<td>ΔC.S.SC.</td>
<td>+ .03</td>
<td>+ .16</td>
<td>- .21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ΔP.S.SC.</td>
<td>- .10</td>
<td>- .01</td>
<td>- .03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E.S.</td>
<td>.10</td>
<td>.14</td>
<td>.43</td>
<td>.45</td>
<td>.09</td>
</tr>
<tr>
<td>E.D.</td>
<td>- .21</td>
<td>-1.17</td>
<td>-1.29</td>
<td>-1.01</td>
<td>- .36</td>
</tr>
</tbody>
</table>

^a Of the five commodities, corn (C), rice (R), sugarcane (SC), coffee (CF), and beef (B), one must always be free of government intervention and allowed to adjust to the other commodity policies. In each case the commodity in parentheses is the one free of government intervention.

^b Unadjusted welfare effects.

and the country would have an efficiency loss equal to .007 of 1 percent of the same producers revenue.

The different combination of policies analyzed indicate the importance of the adjustment effects, particularly for the government revenue and the welfare efficiency. For all the policy combinations, the government would suffer an income loss, which ranges from .17 to 1.28 percent of the free trade beef revenues. So, in terms of the government income loss, the combination that minimizes it is the R, CF, B, SC, or Case 4 with a .17 of 1 percent. However, society still would suffer a loss of .07 of 1 percent. The same set of policies also presents the lower consumer surplus loss after the adjustment from the sugar wholesale ceiling price.

As a final analysis of these different agriculture price policies that have been applied to the Costa Rican agricultural sector, we want to mention that the results obtained from the model indicate significant differences between the partial equilibrium analysis and the general equilibrium, particularly for the price support policies. Also, the results indicate that under this kind of price policy there will be major differences on the estimated welfare areas depending on the set of market interventions on the related markets included in the analysis. Policies like the price ceiling on the sugar market and the export taxes on sugar, coffee and beef did not present the same characteristics mentioned above. In fact, the results showed a great deal of similarity on the magnitude of the estimated areas. Lastly and for all the markets and all sets of policies, the adjustment effects on the government revenue and on the net social welfare loss were highly significant.
CHAPTER VIII.
SUMMARY AND CONCLUSIONS

The main concern of this study is a comparison of techniques to measure welfare effects of commodity policies. A multicommodity equilibrium technique is developed and used to analyze the welfare implications of the different price policies that the Costa Rican government has pursued in the agricultural sector. A comparison is made with measures from the simplest partial equilibrium technique. Five major commodities were chosen which together would have a good representation of the mentioned economic sector. Corn and rice represent agricultural production that goes mainly to the domestic consumers, while sugarcane, coffee and beef cattle represent the export agriculture subsector.

The task of evaluating the different price interventions in those markets were performed by first determining and characterizing the relevant government policies and then by developing a theoretical economic framework to evaluate those policies could be evaluated. About the first topic, the Costa Rican economy has been dominated by the performance of the agricultural sector during the period analyzed (1960-1980) even though its performance has not been smooth or stable during those decades. Much of this variation comes from the change in the government development policies. During the 1960s, when the Central America Common Market (CACC) was just being implemented, the agricultural sector was the government's principal focus, particularly agricultural
export crops. During this decade, this sector showed a healthy growth rate of 6.4 percent. However, with the development of the CACC, which basically opened and enlarged the markets for industrial products and excluded agricultural commodities, a new opportunity occurred for Costa Rican economic development to make some important changes in the policy objectives. During the later 1960s and most of the last decade, the sector that has enjoyed most of the government support through different production and export incentives has been the manufacture-industrial sector. However, the primary sector did not enjoy the same type of support as it was in the decade before. The result was a sharp decrease in the rate of growth, down to 2.7 percent as well as a reduction on the export share of agricultural products. Based on the five most important export crops, the primary sector represented about 73 percent of the total exports of the country in 1970, but that figure fell to 55 percent by the end of the 1970s. Meanwhile, the modern sector showed an increase from 25 percent to 35 percent of its share in exports.

Looking at the government policies through the different agricultural markets, we realized that those policies were pretty much stable during the 1960s and early 1970s; but a turning point occurred during the years 1973–75 for all the commodities involved in this study and for that matter to the agricultural sector. This important change in the government market interventions was prompted by an increasing deficit in the domestic production of basic grains, which jointly with problems in the balance of payment forced the government to increase substantially the level of price support for those grains. To take advantage of some
price advantages in the world markets, the government introduced or made significant changes in the rate of export taxes.

The relevant government market intervention on the grain markets has been the price support policy, which in general has been set above the assumed free market price or the international price. The average support price levels chosen for corn and rice were 146 percent and 14.3 percent, respectively a level that was implemented during the years 1978-80.

In addition to all the discussions that occurred in the middle 1970s about the implementation and enforcement of the basic grain ceiling price at the retail levels, we did not find much of an incidence of variation in the grain consumer prices. In general, they displayed the same trends as their respective free market prices. Their price levels have been traditionally higher than the reference prices pushed by the domestic support level and the marketing cost. This lack of incidence is also explained by the way that retail ceiling price is administered, because the fixed price just affects a specific quality of grain which by the most part is just found on the government retail outlets.

The sugar market presented two relevant price policies. The first one is directed to the domestic market by the imposition of a price ceiling policy at the wholesale market. This policy kept the domestic price above its international market price for most of the 1960s, but this relationship was reversed during the last decade. Representing this characteristic of the sugar market, an average level of 12 percent below its opportunity cost was chosen. This level took place during 1979-80.
There are no concrete figures about the percentage share of the domestic consumption of sugar, which is demanded by the industrial sector. According to the most recent figures from the LAICA, an estimated 25 percent is consumed by that sector. This immediately implies a factor subsidy to those industries that use sugar as an input of production because there is no price differentiation between sugar as a final good and sugar as an intermediate product. The quantity of sugar exported has been about 50 percent of the domestic production which recently has showed a decreasing tendency. Like any other export crop, this product has some export taxes. The export right tax was established in 1961 followed by the ad valorem export tax implemented in 1974. The level of both taxes together added up to 6 percent of the average f.o.b. price (1974-80).

The most significant market policy for the last two export products, coffee and beef, has been the tax on exports. The coffee industry faces the highest rate of taxation. The domestic production has been taxed since 1952 by the ad valorem tax based on the f.o.b. price. The tax rate has been 10 percent of the average f.o.b. price during 1976-80. The exported quantity also is taxed by an ad valorem tax established in 1974 at a level of 8 percent of the f.o.b. price. Lastly, the beef cattle industry faced an export tax of 1 percent of the average f.o.b. price during 1974-79. This product is also included in the consumer protection law which controls and fixes the retail prices. The important question is how well this law is enforced and how deep is its effect on the market price mechanism. According to the price series gathered by
Estadísticas y Censos for a beef cut similar in quality to the exported beef which is the second cut in popularity, the domestic retail price level displays the same trends as the export price but at a higher level. This characteristic reflects the lack of efficiency in the domestic marketing system, particularly when comparing the wholesale price and the retail price that in some instances has shown a price differential of about 90 percent.

This set of government policies needs to be analyzed under a sound and logical theoretical framework, which would enable us to perform the primary goal of this study. The main core of the model building process was to get a theoretical model capable of incorporating the cross-commodity relationships not just in the estimation procedure but also in obeying the behavioral relations among the set of key parameters. This was done with the idea that farmers and consumers do not just look at market signals from a specific commodity, rather they base their decision on all the information available in all related markets. This basic idea led us to a multicmodity approach to the problem.

The set of demand functions was obtained under the assumption that the consumers maximize a utility function subject to a budget constraint. The set of behavioral assumptions or constraints was also obtained under this framework. This set is constituted by the standard theoretical restriction of Engel Aggregation, Cournot Aggregation, homogeneity, and symmetry, which have to be satisfied by any form of utility functions.

The system of demand equations was specified as a function of all prices and income. By following the Goldbergen methodology, each demand
equation was explicitly described in terms of elasticities. This system of demand equation was estimated by the restricted ordinary least square procedure, because the set of independent variables (prices and income) was the same for each equation. Basically, two sets of independent variables were fitted under the linear in variables and the double logarithmic functional forms. The first set was defined as real prices (deflected by CPI) and the real per capita personal income, in the second group the price variables were defined as relative prices (the price of corn as anumeraire), and the income variable was defined as the sum of the personal expenditures on each of the commodities involved, of course, it was also specified in relative terms.

The sets of behavioral restrictions applied to this system were the homogeneity and symmetry constraints. They were applied specifically to the slopes of the demand equations rather to the elasticities with the idea of having more flexibility on the estimation of the changes of areas (welfare measurements) and to have the specific conditions for testing the stability of the model.

The best results obtained were given by the second set of independent variables and fitted with the linear in variables functional form, where the statistical results were rather encouraging in terms of statistical significance and the expected signs: The only exception was the direct price response of the demand for coffee, which resulted with a positive sign. In view of the time constraint, and in order to have the right sign for stability purposes, the direct price coefficient of coffee was restricted to be negative. This additional restriction brought about
significant changes basically in the magnitude of the direct price slopes of the basic grains and at the same time improved the significant level of the beef price slope. Also, this constraint made some changes on the signs of the cross effects, particularly the corn-beef, rice-coffee, and coffee-rice, which became positives and the beef-rice effect to be negative.

To conform with the welfare theory, the estimated demand coefficients were transformed to compensated demand slopes by applying the Slusky equation. Interestingly, the model assigned the lowest direct price coefficients to the two major export commodities (coffee and beef) and the highest ones to the basic grain coefficients. This result was not expected and should be analyzed in more detail because rice and corn, particularly the latter, occupy an important place in the national diet.

The sets of restriction, homogeneity, symmetric and negativeness of the slope of the demand of coffee were tested against an F statistical test: They were submitted as singly as well as jointly and in either case they did not pass the test at 5 percent of significance; implying that the restricted model is significantly different from the model without restrictions.

Turning to the supply side of the model, the systems of supply functions were obtained under the assumption of total revenue maximization by the country subject to the constraint imposed by the jointly product transformation surface. The implicit production function was assumed to be linear homogeneous. This was assumed to avoid the estimation of the factor demand, which by its nature and the lack of
information make this function so difficult to estimate. Under this linear assumption the factor demand is taken as perfectly elastic. With the same kind of constraints on the estimation process, the factor supply was assumed to be perfectly inelastic. These constraints on the model will have an effect on the estimated slopes and constitute an area where the model can be improved.

The system of supply equations were specified as a function of the set of real lagged prices, the respective quantity produced lagged one period, and the factor supply constraint represented by the sum of the value-added of each product at constant monetary units.

The homogeneity and symmetry conditions were imposed on the estimation procedure. The functional forms were again the linear and double logarithmic, where the latter gave the best results. The estimated coefficients displayed the expected signs with statistical significance levels that were good for corn, rice, and beef, but not for sugar and coffee, which showed a level well above the 5 percent significance level. The positive sign for the sugar supply coefficient was obtained by deleting two periods the producer price. This may reflect the fact that this crop takes between 14 to 16 months to be harvested.

The model assigned the highest values to the estimated direct price slopes of corn and rice, which may reflect the cash-flow nature of these crops. The sugarcane coefficients follow in magnitude, which is not a surprise because of the increasing share of the domestic consumption of

---

1 The deflected factor used was the wholesale price index in view of the lack of producer price index.
the country's supply. The lowest values were assigned to coffee and beef. This reflects the perennial nature of coffee, the rigidities associated with the stock of animals on the farm, and the structure of the international markets for those products.

The constraints imposed on the supply system were also tested which in this case has to be taken as an approximation. The results indicated that the homogeneity and symmetry restrictions imposed a significant difference.

The general equilibrium system was developed by pulling together the demand and supply systems under the equilibrium assumption of excess supplies equal to zero in each product market. Thus, a matrix of six excess supply equations and six endogeneous variables (product prices and the factor shadow price) was obtained, where the level of factor supplied is taken as given. The stability conditions applied to this system of excess supply equations are those conditions required by the Walrasian dynamic model. These conditions have to be taken as a good approximation because the model developed is not a close system. The key condition for stability is that all the characteristic roots of the excess supply matrix have to be positive. This condition was fulfilled partially, even by forcing the coefficient of the demand of coffee to be negative. Significant improvements, though, were obtained on the stability conditions of the model. By submitting this matrix of excess supplies to different policy shocks, the general equilibrium slopes or those that consider the price adjustments on the related markets, generated coefficients that are crucial for the welfare analysis.
The model so developed is not just capable of generating the direct effect (change in the quantity demanded or supplied) of a single policy on the target market by assuming as given the market demand or supply equations but also is capable of estimating that effect when some other markets are out of equilibrium, a relevant characteristic for the more than one price intervention welfare analysis.

A theoretical background for the general equilibrium welfare analysis was developed and explicitly demonstrated the relation between areas by means of using the dual properties of the demand and supply models. Thus, we demonstrated that all the private welfare effects are captured in the target market, but the net social effects (Just et al., 44) have to be adjusted through the government income (losses) when there are policies that generate that kind of income in some other inter-related markets. Also, by Just, we know that the private effects have to be adjusted when pricing control mechanisms (ceiling or floor price) exist in those related markets.

The estimation of the changes on the welfare areas caused by the market intervention is based on the general equilibrium or total elasticities of demand and supply. In order to have the same set of market policies combination for each market, the estimated slopes for both function were evaluated at the respective 1979 international prices and quantities, because the reference point is the assumed free market situation: In that specific year, all the relevant price interventions were in place. For comparison purposes, the set of demand and supply equations also were estimated following the simplest method of partial
equilibrium, where the demand elasticities were compensated by the income effect. Significant differences were found between the partial equilibrium estimated areas and those of the multicommodity equilibrium-single policy case. This discrepancy just showed up for the basic grains price support analysis. For example, the areas estimated by using the partial equilibrium results for corn were in general 30 to 40 percent higher than the ones obtained by using the single policy-total elasticity measures.

Talking about the basic grain price support as a market intervention, it is also the only one that presented great dissimilarities between the welfare results from the different policy combination, which indicates that the transfer of resources between the relevant private and public groups would depend finally on the existing set of price distortions. As a result of the changes in government revenues on the related markets and the changes caused on the private effects of the wholesale ceiling sugar price, the adjustment process was demonstrated to have a significant effect on the estimation of the final net welfare measures on the target market.

Based on the welfare results after the adjustments, the best set of policies from the point of view of consumers, which is the group most hurt by the corn pricing policy, is given by the combination of price support on rice, ceiling price on sugar, and taxes on the exports of sugar and beef. This set would not just eliminate the consumers' losses but rather will produce a net gain of about 58 percent of the initial consumer expenditure on corn. The rest of policy combinations also found
that the government can compensate the domestic consumers and still accruing some revenue.

The other basic grain policy analyzed was the support price on rice, which by the policy levels had made the country a rice exporter, implying a subsidy to the foreign consumers. The best set of policies was found to be the corn, rice, coffee, and beef market distortions, because it presented the lowest figures for the consumers and net efficiency losses.

As previously stated, the results obtained for the sugar ceiling price were very similar between all the combinations of policies studied. If we take any reduction on the government revenues as gain to society, then the set of corn, coffee, beef and sugar policies will be the one to be chosen. The similarities of the welfare results were also present on the export tax analysis for sugar, coffee, and beef, but the adjustment effects made the difference among the different sets of policies. Because the major goal of this kind of distortion is to produce a government income, then the best results on the sugar market are obtained by the set corn, rice, coffee, and sugar. For the coffee market the best results were given by corn, coffee, beef, and sugar. Finally, for the beef market, the best choice is the rice, coffee, beef, and sugarcane, because it is the one that minimizes the losses on the government revenues.

It is our hope that this research effort would accomplish at least two objectives. The need of recognizing that the presence of market inter-relations, as well as the presence of a set of price distortions,
would mean different conclusions about the welfare effects of a proposed change or new price intervention. We also recognize that the model, as it is presented, has several shortcomings. We believe that it is worthwhile to put more research efforts to improve the performance of the model, particularly in the areas of factor demand and supply specification, since the factor demand was assumed to be perfectly elastic and factor supply perfectly inelastic. One possible avenue would be to investigate the possibilities of endogenizing factor supply and demand. Another area of improvement would be on the stability of the model. We think that more attention has to be put on the estimation procedure, so the system itself would give the proper expected signs. Another possibility is to estimate the model for more homogeneous groups of commodities, homogeneous in the sense of being more market related. This has to be done for each side of the economy. A limitation of this method is that it is more difficult to evaluate two-price policies. It can be done with this model but it requires a step by step procedure.

The economic theory and the econometric tools were put to work together under this model, resulting in a less complex estimation procedure whose estimated coefficients have a sound and tractable economic background we hope this research effort will serve as a base for further improvements in the policy analysis field.
LITERATURE CITED


In doing this research I have received ideas, help, and support from many people. I want to express my sincere thanks to all of them.

Dr. Ike Van de Wetering, my major professor and friend, I want to thank him for all his support which helped get me through all the work involved with this dissertation.

My thanks to Dr. J. T. Scott of International Agricultural Programs, and Dr. Charlotte Roderick of the World Food Institute for their financial support, without which would have made it impossible to have achieved this degree.

My gratitude goes to the other members of my committee for taking the time to review and discuss with me the present work: William A. Meyers, Lehman Fletcher, J. T. Scott, and Stephen Schmidt.

The culmination of this degree represents an achievement for my whole family. Ana L., my wife, Victor J., Maria L., and Alejandro, my children. They have lovingly made many sacrifices to enable me to complete this degree. To my father, Victor M. who God called two years ago, to my mother, Elvia, and to my parents-in-law, Oldemar and Marielos, thanks and love.

A word of recognition goes to Carolyn Millage for her typing and her effort in helping meet the several deadlines.
Derivation of the Welfare Measurements

Price support on corn

\[ \Delta cs = \frac{a+b+c+d+2e}{WP \times Q_1} - \frac{e}{P \times Q_1} \]

\[ \frac{\Delta cs}{WP \times Q_1} = \frac{\Delta P}{WP} \left( 1 - \frac{1}{2} ED \times \frac{\Delta P}{WP} \right) \]
The change in producer surplus in terms of the initial revenue:

\[
\frac{\Delta PS}{WPxQ_0} = \frac{a+b}{WPxQ_0} = \frac{\Delta P}{WP} \left( 1 + \frac{1}{2} E^S \frac{\Delta P}{WP} \right)
\]

The net efficiency loss in terms of the initial consumer expenditure:

\[
\frac{w}{WPxQ_1} = \frac{c+e}{WPxQ_1} = 1/2 \left( \frac{\Delta P}{WP} \right)^2 \left( E^S \frac{Q_0}{Q_1} + E^D \right).
\]

Government import revenue in terms of the consumer expenditure:

\[
\frac{d}{WPxQ_1} = \frac{\Delta cs}{WPxQ_1} - \frac{(a+b)}{WPxQ_1} - \frac{c+e}{WPxQ_1}
\]

\[
\frac{d}{WPxQ_1} = \left( \frac{\Delta P}{WP} \right)^2 \left( 1 - E^D \frac{\Delta P}{WP} - E^S \frac{\Delta P}{WP} \cdot \frac{Q_0}{Q_1} - \frac{Q_0}{Q_1} \right).
\]
Support price on rice

The change in consumer welfare

\[ \frac{\Delta cs}{WPxQ_0} = \frac{b+c}{WPxQ_0} = \frac{\Delta P}{WP} (1 - 1/2 E^D). \]

The change in producer welfare

\[ \frac{\Delta Ps}{WPxQ_0} = \frac{b+c+d+e}{WPxQ_0} = \frac{\Delta P}{WP} (1 + 1/2 E^S). \]
Government revenue losses

\[ \frac{g.R}{WPxQ_0} = \frac{c+d+e}{WPxQ_0} = \frac{\Delta P.S}{WPxQ_0} - \frac{b}{WPxQ_0} \frac{\Delta P}{WPxQ_0} \left( E^S + E^D \right). \]

The net efficiency loss

\[ \frac{w}{WPxQ_0} = \frac{c+e}{WPxQ_0} = \frac{1}{2} \frac{\Delta P}{WP} \left( E^S + E^D \right). \]

Wholesale ceiling price on sugar

---

Consumer gain: \( b+c \)
Producer loss: \( b+c+f \)
Efficiency loss: \( f \)
The change in consumer surplus:

$$\frac{\Delta c_s}{WP \times Q_1} = \frac{b+c}{WP \times Q_1} = \frac{\Delta P}{WP} \left( 1 + \frac{1}{2} \frac{E^D \Delta P}{WP} \right).$$

The change in producer surplus:

$$\frac{\Delta P_s}{WP \times Q_1} = \frac{b+c+f}{WP \times Q_1} = \frac{\Delta P}{WP} \left( 1 + \frac{E^D \Delta P}{WP} \right).$$

The net efficiency loss:

$$\frac{\omega}{WP \times Q_1} = \frac{f}{WP \times Q_1} = \frac{1}{2} \left( \frac{\Delta P}{WP} \right)^2 E^D.$$